Nos. 18-1076, 18-1103

IN THE

United States Court of Appeals

FOR THE FEDERAL CIRCUIT

CONTINENTAL CIRCUITS LLC,

Plaintiff-Appellant,

v.

INTEL CORP., IBIDEN U.S.A. CORP.,
IBIDEN CO. LTD.,

Defendants-Cross-Appellants.

On Appeal from the United States District Court
for the District of Arizona, in No. 2:16-cv-02026-DGC

NON-CONFIDENTIAL BRIEF FOR
PLAINTIFF-APPELLANT CONTINENTAL CIRCUITS LLC

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FORM 9. Certificate of Interest

Form 9
Rev. 10/17

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

Continental Circuits LLC v. Intel Corporation, et al.

Case No. 18-1076, 18-1103

CERTIFICATE OF INTEREST

Counsel for the:
☐ (petitioner) ■ (appellant) ☐ (respondent) ☐ (appellee) ☐ (amicus) ☐ (name of party)

certifies the following (use "None" if applicable; use extra sheets if necessary):

1. Full Name of Party Represented by me	2. Name of Real Party in interest (Please only include any real party in interest NOT identified in Question 3) represented by me is:	3. Parent corporations and publicly held companies that own 10% or more of stock in the party
Continental Circuits LLC	Continental Circuits LLC	None

4. The names of all law firms and the partners or associates that appeared for the party or amicus now represented by me in the trial court or agency or are expected to appear in this court **(and who have not or will not enter an appearance in this case)** are:

Please see attached.

FORM 9. Certificate of Interest **Form 9**
Rev. 10/17

5. The title and number of any case known to counsel to be pending in this or any other court or agency that will directly affect or be directly affected by this court's decision in the pending appeal. *See* Fed. Cir. R. 47. 4(a)(5) and 47.5(b). (The parties should attach continuation pages as necessary).

None.

1/31/2018
Date

/s/ Jeffrey A. Lamken
Signature of counsel

Please Note: All questions must be answered

Jeffrey A. Lamken
Printed name of counsel

cc: All counsel by ECF

Reset Fields

CERTIFICATE OF INTEREST

Appellant Continental Circuits LLC states that the following partners or associates have appeared on their behalf before the trial court or are expected to appear in this court:

From **Caldwell Cassady Curry P.C.**: Bradley W. Caldwell, Jason D. Cassady, J. Austin Curry, Justin T. Nemunaitis, and Warren J. McCarty.

From **Aiken Schenk Hawkins & Ricciardi P.C.**: Joseph A. Schenk.

From **MoloLamken LLP**: Jeffrey A. Lamken, Michael G. Pattillo, and Benjamin T. Sirolly.

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CONFIDENTIAL MATERIAL OMITTED

Material has been redacted in the Nonconfidential Brief for Plaintiff-Appellant Continental Circuits LLC. This material is confidential technical information pursuant to the Protective Order entered by the U.S. District Court for the District of Arizona on December 2, 2016. Appx0802-0825. Redacted material on pages 18, 20, and 64 contains confidential information regarding manufacturing processes.

TABLE OF AUTHORITIES

Page(s)

CASES

STATUTES

STATEMENT OF RELATED CASES

Pursuant to Federal Circuit Rule 47.5, Plaintiff-Appellant Continental Circuits LLC notes that:

(a) there have been no other appeals in this case; and

(b) there are no other cases pending in this or any other court that will directly affect or be directly affected by this Court's decision in No. 18-1076 or No. 18-1103.

JURISDICTIONAL STATEMENT

The district court had jurisdiction under 28 U.S.C. §§ 1331 and 1338(a). On September 13, 2017, the district court entered a stipulated final judgment of non-infringement and non-indefiniteness, Appx0001-0002, based on its prior construction of certain claim terms, Appx0003-0032. On October 10, 2017, Continental Circuits LLC timely filed a notice of appeal. Appx6323-6325. This Court has jurisdiction under 28 U.S.C. § 1295(a)(1).

STATEMENT OF THE ISSUES

This case concerns the meaning of claim terms that include "surface of a dielectric material," "removal of a portion of the dielectric material," and "etching of the epoxy." There is no dispute that, from the perspective of a person skilled in the art, "the plain and ordinary meaning" of those phrases "does not include" a requirement that the claimed surfaces be created, or the claimed processes be performed, through "a repeated desmear process." Appx0006. The question presented is:

Whether those claim terms nonetheless "must be construed as limited to processes occurring 'in a repeated desmear process' or surfaces 'produced by a repeated desmear process.'" Appx1880; *see* Appx0005-0006.

STATEMENT OF THE CASE

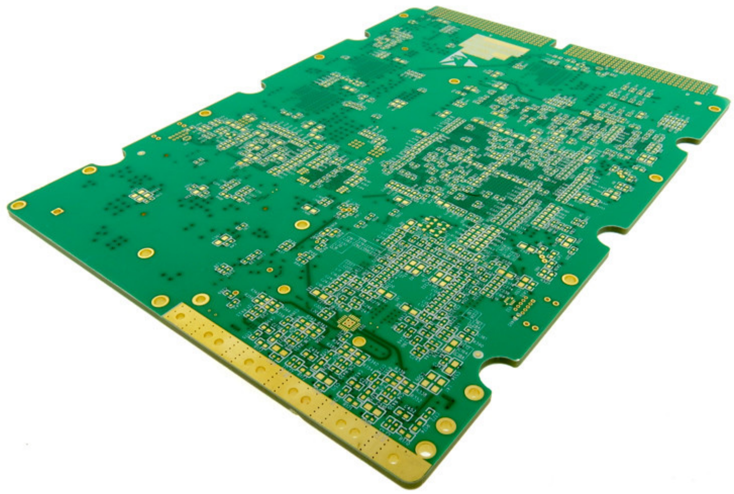
This case concerns the design and manufacture of circuit boards and other "multilayer electrical devices."

I. THE DELAMINATION PROBLEM FACED BY MULTILAYER ELECTRICAL DEVICE MANUFACTURERS

For years, circuit boards and other multilayer electrical devices suffered reliability problems because they would delaminate—the layers would separate—over time. The inventors had first-hand experience with those problems from their work at Continental Circuits, Inc. Formed in the 1970s, Continental Circuits was once in the top 10% of all U.S. circuit-board suppliers, manufacturing for companies like Intel and Motorola. Appx1365. In the 1990s, the inventors discovered how to resolve the delamination problem by binding the layers of multilayer devices together using microscopic "teeth." Teeth in one layer "bite" into the next, forming an interlocking, mechanical grip with unprecedented resistance to separation. This case concerns the proper construction of patent claims covering that invention.

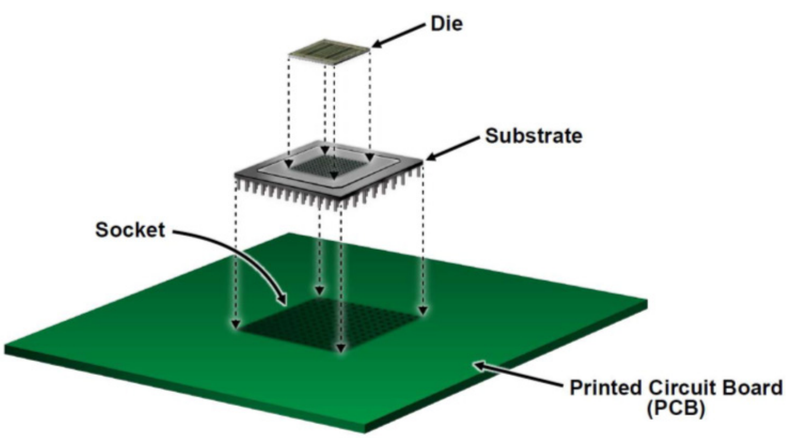
A. Multilayer Electrical Devices

Multilayer electrical devices like circuit boards provide pathways for electrical signals and allow different electronic components to communicate with each other. *See* Appx2026. A familiar example is the "printed circuit board," Appx0100, which is in virtually any computer, calculator, or radio:



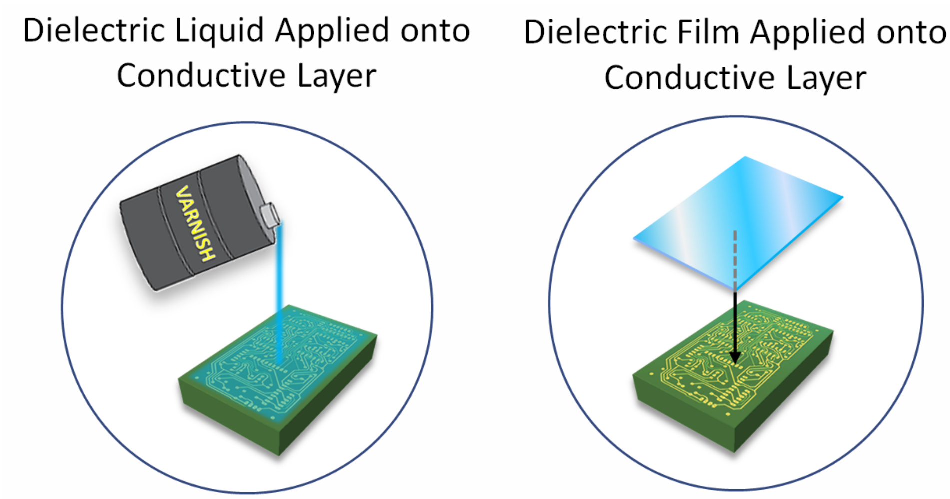
Appx2436.

Multilayer electrical devices are also used as "substrates" in microprocessors. Appx2025-2026. A substrate connects the microprocessor's "die"—the element containing microcircuitry—to a circuit board in a computing device.



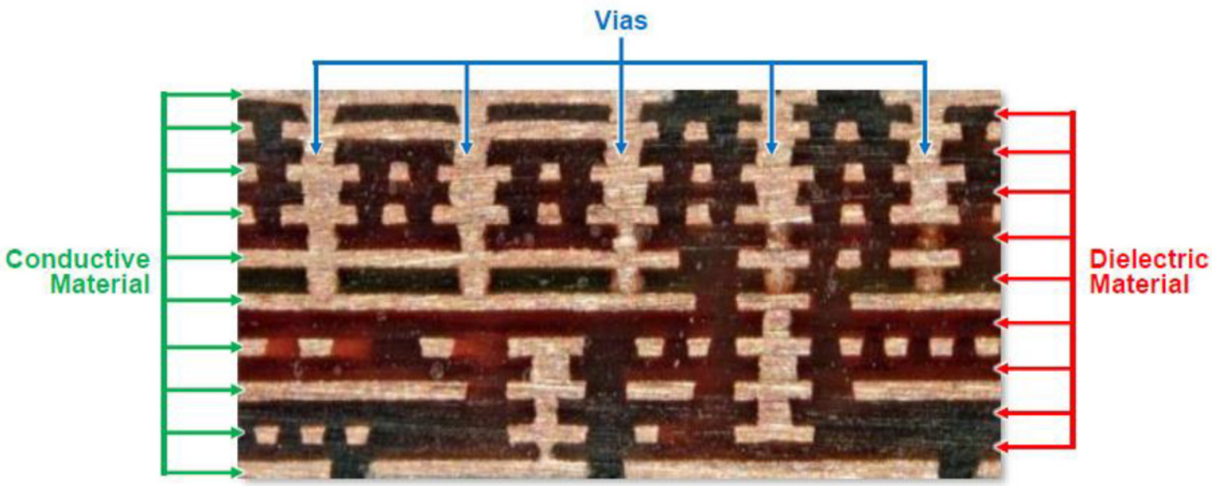
Appx2026.

Multilayer electrical devices alternate circuitry layers (made of conductive materials, typically copper) with layers of non-conductive insulating or "dielectric" materials (like epoxy). *See* Appx0104, 4:13-18. The layering can be achieved in various ways. The manufacturer may begin with a core of dielectric material, and then layer conductive materials on the top and bottom of that core. *Id.*, 4:46-52. The manufacturer then adds another layer of dielectric material. *See* Appx0105, 5:18-21.



Appx4299. Once the dielectric material is in place, another conductive layer is applied, and the process is repeated until the desired number of layers is achieved. Appx2027.

To increase the circuit density, manufacturers create "interconnects" between different layers of conductive material. Appx0105, 6:51-59. In particular, manufacturers drill or punch "micro vias" in the dielectric layer. When conductive material is applied, it fills the vias and creates a connection to the layer of conductive material beneath. *Id.*, 6:26-36; Appx2030. The illustration below shows a cross-section of a multilayer electrical device:

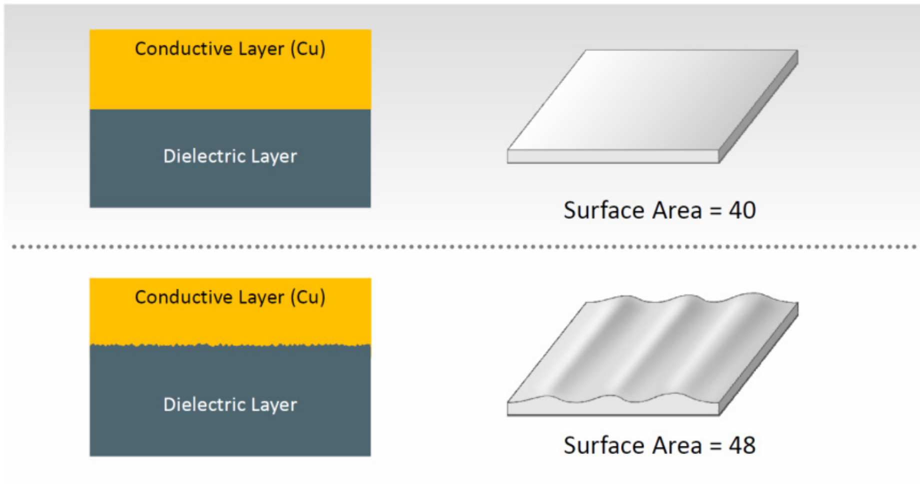


Appx2030.

B. The Delamination Problem and Prior-Art "Roughening" Techniques

Multilayer electrical devices present significant challenges. For instance, they are subjected to repeated heating and cooling, both in manufacturing and as they operate within electronic devices. Appx2031. Because the metal conductive layers and epoxy dielectric layers expand and contract at different rates in response to temperature changes, that heating and cooling may cause them to peel apart. Appx2030-2031. At the time of the inventions at issue, it was recognized that "thermal stress" caused "delamination, blistering, and other reliability problems" in multilayer electrical devices. Appx0103, 1:28-32.

To combat delamination, manufacturers sought to increase adhesion between conductive and dielectric layers. Prior-art "attempts to solve these problems" involved "roughening" the conductive or dielectric layer before adding the next layer. Appx0103, 1:33-35. Roughening increases the area of surface contact between layers, which in turn increases adhesion. *See id.*, 1:39-40; Appx2031.



Appx4289.

Manufacturers would roughen a surface by "etching" it—that is, removing some of the layer's surface material. Appx2471. Etching can be performed by "physical" methods, like sandblasting, or "chemical" methods, like applying acids. Appx0103, 1:33-35; Appx2032.

"[R]oughening approaches . . . improved adherence" in multilayer electrical devices. Appx0103, 1:39-40. But "roughening has its limits." *Id.*, 1:45-46. "[D]espite a long standing recognition of delamination, blistering, and reliability problems," and notwithstanding "attempts to find a solution, these problems" remained "persistent" at the time the patents-in-suit were filed. *Id.*, 1:42-46.

II. The Inventors Overcome The Delamination Problem With A Unique Surface Structure

A. Layers That Mechanically Grip Each Other Using "Teeth"

Inventors Brian McDermott, Daniel McGowan, Ralph Leo Spotts, Jr., and Sid Tryzbiak had a combined 40 years' experience in the circuit-board industry—and first-hand experience with the delamination problem—from their work at Continental Circuits. Appx1365-1366. Together, they found a solution—"a unique surface structure" for "joining the dielectric material to the . . . conductive layer." Appx0103, 1:50-54. That structure is "comprised of teeth that are preferably angled or hooked like fangs." *Id.*, 1:54-56. The teeth achieve a sort of bite in which the conductive layer "is actually burrowed in and under the dielectric material and vice versa." *Id.*, 1:66-2:3. The conductive layer's teeth "hook under the surface of the applied dielectric material to mechanically grip the applied dielectric material." Appx0104, 3:42-46. That "mechanical grip" "functions in a different manner" than the prior art's "adherence by means of increased surface area." Appx0103, 1:61-63. Because "one layer" is able to "mechanically grip a second layer," grip strength is much higher: The only way to separate the layers is to rip them apart, "destroying the integrity of at least one of the layers." *Id.*, 1:54-57, 2:5.

Figure 1 of U.S. Patent No. 7,501,582 illustrates the invention's "tooth structure," which contrasts with the merely "roughen[ed]" layers of the prior-art device depicted in Figure 2:

FIG. 1

FIG. 2 PRIOR ART

Appx0101 (annotations added); Appx0104, 3:8-12.

The Summary of the Invention explains that the "best methods for producing the teeth" can be implemented by using a "non-homogenous" dielectric, and performing a "slowed and/or repeated etch[ ]," Appx0103, 2:25-30, to produce deep "cavities, veins, openings, or gaps in the applied dielectric material," Appx0105, 5:37-40. Those cavities differ from the "uniform etch" of the prior art. Appx0103, 2:29-30. When the conductive material is layered on top of the dielectric, the metal fills the cavities and forms the invention's "teeth." Appx0104, 3:32-35.

On August 4, 1997, the inventors filed U.S. Patent Application No. 08/905,619, the parent of the patents at issue here. The patents-in-suit are U.S. Patent Nos. 7,501,582 ('582 patent), Appx0100; 8,278,560 ('560 patent), Appx0119; 8,581,105 ('105 patent), Appx0130; and 9,374,912 ('912 patent), Appx0142. All share a specification. As the patents' titles imply, they include both ***device*** claims directed at multilayer devices "with teeth" that "join[]" the layers, and ***process*** claims directed at techniques for making such devices. *See*, *e.g.*, '560 Patent, Appx0119 ("Electrical Device with Teeth Joining Layers and Method for Making the Same").

B. Device Claims and Related Disclosures

The patents-in-suit claim physical devices having "teeth" with specified characteristics.

1. For example, claim 100 of the '582 patent recites:

An electrical device including:

> ***a conductive layer*** built up so as to fill undercuttings with respect to ***a surface of a dielectric material*** so as to form ***teeth*** in cavities, a plurality of the undercuttings being ***obtuse to the surface***, wherein
>
> **. . .** a plurality of ***the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep***, and
>
> wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of ***the teeth engages a portion of the dielectric material at the slope***.

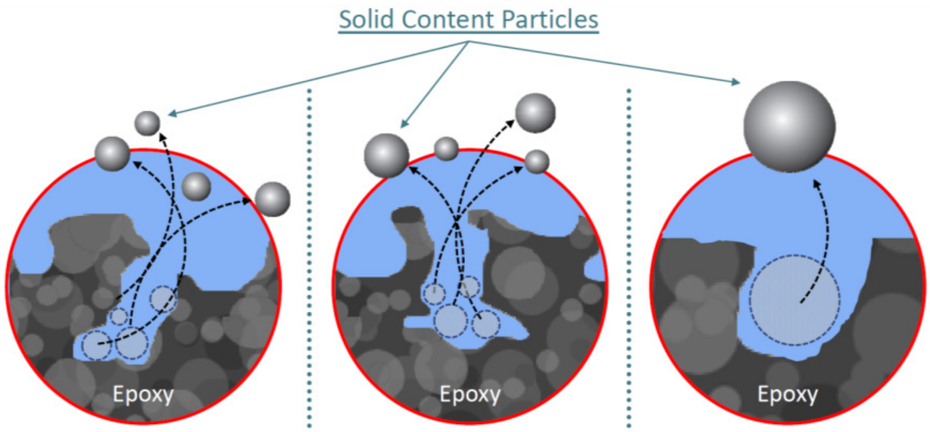
Appx0111, 18:49-60 (emphasis added). Claim 100 thus requires "undercuttings" (or "cavities") on the "surface of a dielectric material"; conductive material that fills the undercuttings in the form of "teeth" in specified sizes; and engagement between at least one tooth and cavity at an upgrade slope. Dependent claim 122 further requires "at least 5,000 said teeth per linear inch." Appx0113, 21:47-50.

The specification explains the rationale for those limitations—the shape, size, and frequency of the teeth—and discloses the "correct balance of these critically important factors" to achieve "a greatly improved . . . electrical device." Appx0103, 2:22-23. Regarding size, the inventors explained that teeth that are "too small, wide, straight, and shallow" would fail to achieve the desired grip. *Id.*, 2:9-13. Conversely, teeth that are "too large, deep, and fanged or hook-shaped" would cut too deeply into the dielectric, weakening the surface. *Id.*, 2:14-17. "The optimal [tooth] size" must be large enough to "maximize[e] surface area and mechanical grip," but not so large that it "undercut[s]" the dielectric so "as to weaken it." Appx0104, 3:53-57. Acceptable sizes range from "1 tenth of a mil deep" to "2 tenths of a mil" deep, with "1.5 tenths of a mil deep" being optimal. *Id.*, 3:58-61.

As for shape, the inventors explained that the teeth should be "obtuse, canine, or fang-shaped." Appx0104, 3:43. That helps them "hook under the exterior surface" to "mechanically grip" the dielectric. *Id.*, 3:43-46. The hooking is "in contrast to the shallower, more rounded surface typically produced by known roughening techniques." *Id.*, 3:47-48. While prior-art layers may have shown "occasional gouging," such gouges were not "on the order of the present invention." *Id.*, 3:49-51. And addressing the frequency required to achieve a strong grip, the inventors explained that the minimum number of teeth per linear inch is 5,000, but preferably there would be 15,000 teeth per linear inch. *Id.*, 3:62-65.

The inventors explained that the shapes and numbers of teeth disclosed must be understood as ranges, not precise targets. In a "representative sample" of the device, at least 20% of the teeth should be in the aforementioned ranges, while a 50% success rate will achieve "a preferred balance of mechanical grip without a weakening of the layering." Appx0104, 4:6-11.

Other device claims reflect the inventors' discoveries regarding the role of non-homogenous dielectric material. For example, claim 14 of the '560 patent recites an "article of manufacture" utilizing "an epoxy dielectric material delivered with solid content . . . sufficient that ***the etching of the epoxy uses non-homogeneity with the solid content*** to bring about formation of the non-uniformly roughened surface." Appx0127, 10:8-25 (emphasis added). The specification explains that dielectric materials with "a non-homogenous composition" will exhibit "an uneven chemical resistance"—so that, when etched, some portions of the dielectric will be eaten away more than others. Appx0103, 2:25-30.



Appx4310 (solid-content particles being removed from a non-homogenous dielectric). As a result, "slowed and/or repeated etching" of such a dielectric will form the desired cavities for teeth. Appx0103, 2:29-30.

While the independent claims of the '560 patent impose no limitations on how the etching is performed, certain dependent claims do. For example, claim 19 recites "[t]he article of claim 14, wherein the etching includes a first etching and a second etching." Appx0128, 11:1-2.

C. Method Claims and Related Disclosures

The patents-in-suit also disclose and claim ***processes*** for making the improved multilayer electrical device.

1. For example, claim 13 of the '105 patent recites a process using non-homogenous dielectric material to form the teeth:

> A ***process*** of making an article of manufacture, the process comprising:
>
> > implementing a circuit design for an electrical device by ***coupling an epoxy dielectric material delivered with solid***

> ***content sufficient that etching the epoxy*** forms a non-uniformly roughened surface comprising cavities located in, and underneath a surface of, the dielectric material, and sufficient that the ***etching of the epoxy uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface . . . , with a conductive material, whereby the etching of the epoxy forms the cavities***, and a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the non-homogeneous composition forms the cavities, in circuitry of the electrical device.

Appx0138, 10:15-31 (emphasis added).

Claim 13 does not require the "etching" step, or any other part of the claimed process, to be performed more than once. By contrast, dependent claim 53 does. It recites the "process of claim 13, wherein the etching includes a first etching and a second etching." Appx0139, 12:62-63.

2. The specification discusses the significance of the process limitations. While the specification addresses general manufacturing principles, it focuses specifically on "the process for forming the teeth and the cavities for the teeth." Appx0105, 6:41-42. As discussed above (at 11-12), the specification explains that "the best method[] for producing the teeth is to use non-homogenous materials . . . such that slowed and/or repeated etching will form teeth." Appx0103, 2:25-30.

The specification also discloses a preferred embodiment for that process, explaining that "the present invention ***can be*** carried out" using certain products—Shipley's desmear conditioner, Appx0105, 5:60 (emphasis added), and Probelec

XB 7081 dielectric material ("Probelec"), *id.*, 6:42-44. Probelec has a non-homogenous composition—it is "delivered with a solid content of 58%" suspended within dielectric material—making it ideal for the invention. Appx0106, 7:29-31.

The embodiment also discloses that etching the dielectric, to create the invention's teeth, can be performed within the context of what is known as the "desmear" process. *See* Appx0106-0107, 8:43-9:9. As explained above, manufacturers punch or drill holes in the dielectric to create "vias." *See* pp. 4-5, *supra*. The desmear process was used to remove residue—called "smear"—that remains after that punching or drilling. *See* Appx0106, 7:3-6; Appx2033. The desmear process—also called a "swell and etch"—incorporates etching as one step of a larger, six-step process:

1) <u>Swell</u>. A solvent is applied to cause the dielectric to swell, which prepares it for the etch.

2) <u>Rinse</u>. The dielectric is rinsed to remove swell chemicals.

3) <u>Etch</u>. A chemical, usually an acid, is applied to remove some of the dielectric material, creating an "etch."

4) <u>Rinse</u>. The dielectric is rinsed to remove chemicals remaining from the etch step.

5) <u>Neutralize</u>. Chemicals are applied to neutralize (stop) the etching.

6) <u>Rinse</u>. The dielectric is finally rinsed to remove any remaining chemicals from the neutralize step.

Appx2033-2034; *see* Appx0106, 8:43-67. As the patent explains, it was known in the art that the desmear process does more than remove smear. Rather, the "etching" step performed during a desmear on traditional materials can also roughen the dielectric layer—thereby increasing surface area—to increase adhesion. Appx2033-2035; *see* pp. 5-6, *supra*. The typical etch in a desmear lasts approximately 6 to 10 minutes. Appx0106, 8:57-60.

The specification discloses that "***[o]ne technique*** for forming the teeth" when using Shipley and the Probelec dielectric "is somewhat similar to . . . the swell and etch or desmear process." Appx0105, 5:40-44 (emphasis added). The difference is that, "contrary to all known teachings in the prior art . . . a 'double desmear process' is utilized." *Id.* That is, the desmear process is performed "a first time," then performed again "a second time." *Id.*, 5:46-47; *see also* Appx0106, 8:48-49; Appx0107, 9:1-9. The method "make[s] use of non-homogeneities in bringing about a formation" of cavities in the Probelec by achieving a deeper etch necessary for the "formation of the teeth." Appx0107, 9:3-9.

After the cavities are formed, a conductive layer is applied to the dielectric; the metal fills the cavities, and the interlocking "tooth structure" is created. Appx0105, 5:52-6:1; *see also* Appx0107, 9:10-14. That method can "significantly increase[]" the peel strength of a multilayer electrical device (*i.e.*, the force required to peel two layers apart), Appx0106, 7:1-3, from "6 lb/in peel strength," *id.*, 7:1, to "10 lb/in or more," *id.*, 7:6-9.

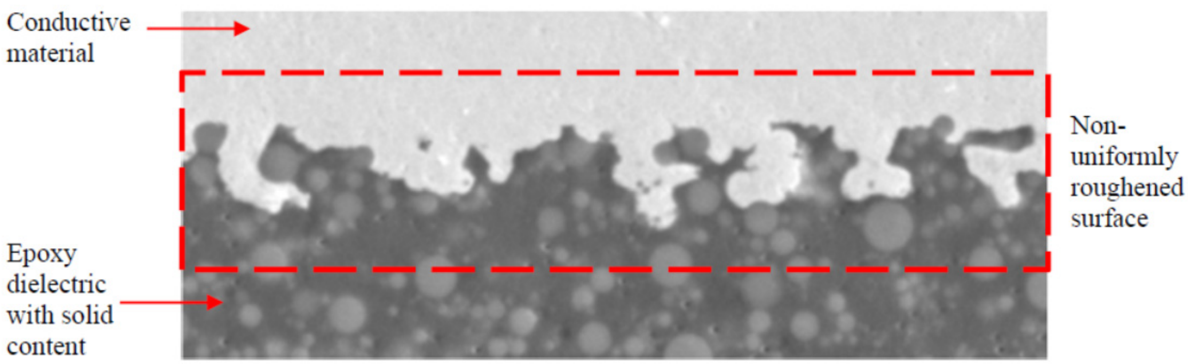
The specification explains that the described method, using Probelec and Shipley, is simply a preferred embodiment. "While a particular embodiment of the present invention has been disclosed, it is to be understood that various different modifications are possible and are within the true spirit of the invention, the scope of which is to be determined with reference to the claims set forth below." Appx0107, 9:18-22. The embodiment is expressly claimed in certain patents in the same family as the asserted patents. For example, Claim 1 of parent patent 6,700,069 ('069 patent) requires teeth set in the dielectric material, and dependent claim 18 further requires that "the teeth are formed by a double desmear process." '069 patent, 9:24-34, 10:40-41, *available at* http://patft1.uspto.gov/netacgi/nph-Parser?patentnumber=6700069. But no claim of the asserted patents recites the full "double desmear process" described in the Probelec/Shipley embodiment. Appx0105, 5:41-44.

III. Proceedings Below

A. Ibiden and Intel Use Continental Circuits' Patented Technology

From 1996 through 1998, Continental Circuits collaborated with Intel to improve circuit boards. The companies had several meetings to discuss design rules and manufacturing reliability. Appx1149. During that collaborative period, the inventors developed the tooth structure that is the subject of the patents-in-suit, applied for patents, and utilized the invention in their own Photolink product. *Id.*

Ibiden—a competing manufacturer of multilayer electrical devices—incorporated Continental Circuits' technology into its own products. Appx1244. Ibiden began drawing business away from Continental Circuits. *Id.*[1] Ibiden is now Intel's largest package substrate supplier. Appx1246. Before filing suit, Continental Circuits examined cross-sections of Intel processors to confirm infringement. Those cross-sections showed that they employ teeth that are indistinguishable from those pictured in the patent:



Cross-section of Intel Itanium series processor at >2000x magnification

Appx1382; *compare* Appx0101 (Fig. 1).

Intel and Ibiden have since provided information regarding the process they use to make the accused products. The inventors had explained that "the best method[] for producing the teeth" was to use a non-homogeneous dielectric, so that "***slowed and/or repeated*** etching will form teeth." Appx0103, 2:25-30

[1] Continental Circuits, Inc. went bankrupt in 1998. Nevertheless, the inventors continued to pursue patent protection. In 2016, they formed Continental Circuits LLC, the owner of the patents-in-suit.

(emphasis added). Intel and Ibiden's etching process is clearly [redacted]: It takes between [redacted], depending on product line, Appx4909; Appx4930, which is [redacted] the duration of the 6-10 minute prior-art etch during a desmear. *See* Appx0106, 8:59-60.

B. The District Court Action and *Markman* Hearing

On June 22, 2016, Continental Circuits LLC sued Intel Corporation, Ibiden U.S.A. Corporation, and Ibiden Co., Ltd. (collectively, "defendants") for patent infringement under 35 U.S.C. § 271. Appx0074. It asserted claims 85, 87, 89, 92, 94, 95, 100, 109, 114, and 122 of the '582 patent; claims 14 and 19 of the '560 patent; claims 13, 53, 71, 80, 82, 86, 88, 91, 95, 97, 101, and 103 of the '105 patent; and claims 2, 3, 18, 19, 20, 26, 27, and 28 of the '912 patent. Appx4880. After the suit's scope was narrowed in certain respects, *see* Appx1086-1106, the parties briefed claim construction, *see* Appx0054-0069.

While the claim-construction disputes were divided into four categories, Appx1880, only the "Category 1" terms are at issue in Continental Circuits' appeal.[2] The district court identified seven "Category 1" terms:

> <u>surface</u>: "a surface of a dielectric material," "a surface of a layer of a dielectric material," "a dielectric material comprising a surface";

[2] The district court ruled in Continental Circuits' favor with respect to the claim terms in Categories 2-4. Appx0015-0032. Defendants have indicated that their cross-appeal, No. 18-1103, may involve Categories 2-4. *See* Dkt. 16. Continental Circuits will discuss those terms as appropriate in its response to defendants' cross-appeal brief.

> removal: "removal of a portion of the dielectric material," "removal of some of the dielectric material";
>
> etching: "etching [of] the epoxy," and "etching [of] the dielectric material."

Appx0005; *see also* Appx1882-1888. Some of those terms describe physical things (*e.g.*, "surface of a dielectric material" from claim 100 of the '582 patent). Others describe process steps (*e.g.*, "etching of the epoxy" from claim 13 of the '105 patent and "removal of a portion of the dielectric material" in claim 114 of the '582 patent). Some are found in device claims (*e.g.*, claims 100 and 114 of the '582 patent). Others are in process claims (*e.g.*, claim 13 of the '105 patent).

Defendants nevertheless contended that ***all*** of those terms "must be construed as limited to ***processes*** occurring '***in a repeated desmear process***' or ***surfaces*** 'produced by ***a repeated desmear process***.'" Appx1880 (emphasis added). Defendants made clear that their construction requires a full repeated desmear, not just a repeated etch: "[A] desmear process would comprise six steps (1. swelling, 2. rinsing, 3. etching, 4. rinsing, 5. neutralizing, 6. rinsing)," and "a repeated desmear process would comprise repeating those six steps." Appx4881; *see* Appx4105. Continental Circuits urged that the terms have a plain and ordinary meaning that requires no construction—and that plainly does not require a double-desmear process. *See* Appx1882-1888.

One week before the *Markman* hearing, the district court ordered briefing "explaining the effect that [the parties'] proposed constructions . . . would have on the merits of this case." Appx3604. Defendants urged their construction—that all Category 1 terms include a "repeated desmear process" limitation, Appx1880—would provide them "a case-dispositive noninfringement defense" because "the accused Intel and Ibiden products are manufactured using a [redacted]," Appx3981. Defendants did not at that time disclose that their etching takes [redacted] the etching in the prior-art desmear process. *See* p. 18, *supra*. After briefing and a hearing, the court ruled for defendants, holding that each claim requires a "repeated desmear process." Appx0003-0032.

C. The District Court's Claim-Construction Decision

The district court admitted from the outset that the claims do not by their terms require the dielectric's surface to "be 'produced by a repeated desmear process.'" Appx0006. "As Plaintiff correctly notes," the court stated, "Defendants ***do not contend*** that the ***actual words of the claims*** provide this additional meaning." *Id.* (emphasis added). "Rather, Defendants seek to ***add a limitation*** to the claims." *Id.* (emphasis added). "[T]he plain and ordinary meaning of the phrases at issue does not include Defendants' proposed limitation." *Id.*

Perhaps because defendants did not contend that the "actual words of the claims" included the limitation they proposed, the district court never construed the claim terms to determine their meaning. It did not ask what a skilled artisan would understand the terms "surface," "removal," or "etch" to mean. Instead, the court acknowledged that the claims do not include a repeated desmear. But it then proceeded to render each disputed claim term as limited to use of a "repeated desmear process" nonetheless, because it read the specification to "disavow" any other process. *See* Appx0007-0010.

1. The district court identified nothing in the specification expressly disavowing all dielectric surfaces except those created through a repeated-desmear process, or all processes that do not employ a repeated desmear. The court instead characterized the specification as "repeatedly distinguish[ing] the process covered by the patent from the prior art and its use of a 'single desmear process.'" Appx0008. The court considered five passages from the specification "particularly relevant." *Id.* All of the passages were taken from the preferred embodiment disclosing a process utilizing the Shipley and Probelec products.

The first passage "explains that '***[o]ne technique*** for forming the teeth is somewhat similar to what has been known as the swell and etch [*i.e.*, desmear] process except that contrary to all known teachings in the prior art, in effect, a "double desmear process" is utilized.'" Appx0008 (quoting Appx0105, 5:41-44) (emphasis altered). Continuing that discussion, the second cited passage explains that while Shipley desmear conditioner is "suitable" for use in the process, "the desmear process as disclosed herein is contrary to the manufacturer's specifications, i.e., a 'double desmear process,' rather than the single desmear process of the known prior art." Appx0009 (quoting Appx0105, 5:59-63) (emphasis omitted).

The three remaining passages all relate to using Probelec dielectric:

- The first passage concerns Probelec's peel strength. "[T]he peel strength produced in accordance with the present invention is greater than the strength produced by the desmear process of the prior art, i.e., a single desmear process. For example, if a prior art desmear process is used to produce a 6 lb/in average peel strength, the present invention may produce an average peel strength on the order of 10 lb/in or more." Appx0009 (quoting Appx0106, 7:3-9) (emphasis omitted).

- The next passage states that, while "Probelec XB 7081 apparently was intended for use in the common desmear" process, it can be "used in carrying out the present invention. For example, the present invention differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth." *Id.* (quoting Appx0106, 8:45-52) (emphasis omitted).

- The final passage, again discussing the use of Probelec, declares: "In stark contrast with the etch and swell process of the known prior art, . . . a second pass through the process . . . is used." Appx0010 (quoting Appx0107, 9:1-3; *see* Appx0008-0010) (emphasis omitted).

Elsewhere in its opinion, the district court found it "clear" that the specification's description of "the use of [Probelec] XB 7081" is merely "a preferred embodiment, an illustration." Appx0017. The court acknowledged that "[i]t is improper to read limitations from a preferred embodiment described in the specification . . . into the claims absent a clear indication in the intrinsic record that the patentee intended the claims to be so limited." *Id.* (quotation marks omitted). Nonetheless, the court ruled that, because several passages referred to "the present invention," the discussion of a single- versus double-desmear process was "not just" referring to the "embodiment discussed in the specification as an example." Appx0011. The specification, it declared, "make[s] clear that the invention" must exclude "the prior art's single desmear process." Appx0010.

2. Continental Circuits urged that claim differentiation precluded reading in a "repeated desmear" limitation. Appx0013; Appx2444. For example, claim 14 of the '560 patent simply recites "etching the epoxy." Appx0127, 10:9. But dependent claim 19 recites: "The article of claim 14, ***wherein the etching includes a first etching and a second etching***." Appx0128, 11:1-2 (emphasis added). That dependent claim would be superfluous if the independent claims required a repeated-desmear process—which necessarily includes at least two etching steps—already. *See* pp. 14-15, *supra*. And the dependent claims of a parent patent (not asserted) specifically recite a "circuit board . . . wherein the teeth are formed by a double desmear process." Appx2445 (quoting '069 patent, 10:40-41). Under this Court's precedent, "the presence of a dependent claim that adds a particular limitation gives rise to a presumption that the limitation in question is not present in the independent claim." Appx2444-2445 (quoting *Phillips v. AWH Corp.*, 415 F.3d 1303, 1315 (Fed. Cir. 2005) (en banc)). The district court rejected that argument,

ruling that the specification language it invoked was sufficient to "overcome[] any presumption raised by claim differentiation." Appx0013.

The court was unpersuaded by language in the specification clarifying that references to a single-pass desmear process were not a disavowal of claim scope, such as language describing a double desmear as "one technique" or introducing it with the phrase "for example." Appx0013-0014. In the court's view, use of the phrase "for example" in parts of the specification "does not suggest that the double desmear process is only an illustration of one embodiment." Appx0014.

Finally, the court rejected Continental Circuits' contention that, even if the specification suggested departure from a ***standard*** prior-art single "desmear," it did not disavow all embodiments ***except*** a ***repeated*** desmear. For example, the "Summary of the Invention" explains that the "best methods for producing the teeth" include not just "repeated etching," but also "***slowed***" etching, or "slowed" etching combined with "repeated etching." Appx0103, 2:25-30 (emphasis added); *see* Appx0014. But the district court declared that the specification's disclosure of "slowed" etching does not "constitute[] an alternative embodiment of the patented invention," Appx0015, because "the balance of the specification makes clear that the single desmear process of the prior art is not part of the invention," Appx0014.

3. The court also invoked extrinsic evidence—a statement by the inventors' expert during patent prosecution, and a memorandum describing the inven-

tors' findings regarding Probelec—to support adding a "repeated desmear" limitation. *See* Appx0012-0013. That evidence was "not sufficient on its own to find disavowal." Appx0012. But the court thought it "corroborate[d]" its decision to graft a double-desmear limitation onto the claims. Appx0012; *see* Appx0013.

D. The Stipulated Final Judgment

In light of the district court's claim-construction order, the parties stipulated to entry of final judgment of non-infringement and non-indefiniteness. Appx4879. Continental Circuits stipulated that, under the court's construction of the Category 1 terms—as requiring repetition of the six-step desmear process—it could not prove that defendants infringe. Appx4881-4882. Defendants stipulated that they had failed to prove the patents indefinite. Appx4883. The district court issued final judgment. Appx0001-0002. This appeal, Appx6323, and defendants' cross-appeal, Appx6327, followed.

STANDARD OF REVIEW

"The ultimate interpretation of a claim term, as well as interpretations of evidence intrinsic to the patent (the patent claims and specification, along with the patent's prosecution history), are legal conclusions, reviewed by this court de novo." *Mass. Inst. of Tech. v. Shire Pharms., Inc.*, 839 F.3d 1111, 1118 (Fed. Cir. 2016) (quotation marks omitted). "Subsidiary factual determinations based on extrinsic evidence are reviewed for clear error." *Id.* (quotation marks omitted).

SUMMARY OF ARGUMENT

I. A. The claims are not limited to surfaces treated with, or processes that utilize, a "repeated desmear process." Appx0006. It is undisputed that "the plain and ordinary meaning of the phrases at issue does not include" a repeated-desmear "limitation." *Id.* Certain claims are directed to the invention's unique surface structure, including the physical characteristics of the "teeth" that allow the dielectric layer to mechanically "grip" the conductive layer. Other claims focus on the discovery that, if a non-homogenous dielectric is used, etching (including slowed or repeat etching) can produce the cavities necessary to form the teeth. No asserted claim requires a "repeated desmear process."

B. Claim differentiation principles impose an especially strong presumption against reading a "repeated desmear process" into the claims. For example, the patents include dependent claims that require performing at least two "etching" steps. Those dependent claims would be superfluous if the independent claims already required at least two desmears—which necessarily includes at least two etching steps. Other patents in the same family as the asserted patents expressly recite a double-desmear limitation. That further shows that the repeated-desmear limitation is not present in claims that omit mention of it.

II. A. The district court's decision to read a repeated-desmear process limitation into each claim was based on a preferred embodiment, which the district court took to disavow other means of producing the invention, including a prior-art single-pass desmear. But the specification—which discloses a number of embodiments that do not involve a repeated-desmear process—forecloses that construction. It discloses the crux of the invention as the toothed surface structure, without regard to how the teeth are formed. And it separately discloses ways of making the teeth that do not require a repeated desmear. The Summary of the Invention describes the "best methods" for producing the teeth as involving "slowed and/or repeated etching" of a "non-homogenous" dielectric. It makes no mention of a repeated desmear.

B. The specification includes a preferred embodiment that discloses how, when using certain products, a double-desmear process can form the invention's teeth. That embodiment, however, merely purports to disclose "one technique." It describes the advantages of the double-desmear process over the prior art's single-pass desmear in the context of that specific embodiment. It does not contain any language manifesting an intent to limit the scope of all claims to that technique.

The fact that several passages in the preferred embodiment refer to "the present invention" does not limit the outer bounds of the claims to that embodiment. Indeed, the specification elsewhere describes numerous other aspects of the "present invention" having nothing to do with a repeated desmear, including the teeth themselves, and use of a non-homogenous dielectric.

C. The district court also invoked extrinsic evidence. It acknowledged that evidence was not sufficient to establish disavowal—at most, it "corroborated" the court's construction. But upon examination, it is clear that the cited evidence does not even corroborate. It certainly cannot justify contradicting the plain language of the claims.

III. Finally, even assuming disavowal of "the prior art's single desmear process," the district court's construction still could not stand. Excluding the prior art's single desmear from the claims' scope is not the same as requiring a repeated desmear. For example, the patents disclose a "slowed" etch that is a departure from the prior art's single desmear, but that need not be performed in a repeated desmear. It was also improper for the district court to import a repeated-desmear process limitation into claims that merely recite physical devices and articles of manufacture without regard to the means by which they are produced.

ARGUMENT

One thing is beyond dispute: None of the claim terms at issue—the actual words used—suggests to a skilled artisan that the claims are limited to surfaces treated with, or processes that utilize, "a repeated desmear process." Appx0006. Everyone agrees that "the plain and ordinary meaning of the phrases at issue does not include Defendants' proposed [repeated-desmear] limitation." *Id.* Indeed, other claim terms preclude any effort to insert such a limitation. For example, the patents include dependent claims that require, as an additional limitation, at least two "etching" steps. Those dependent claims would be inexplicable if the independent claims already required at least two complete desmears—which necessarily include at least two etching steps.

The claims do not recite a "repeated desmear process" for a reason: That is not the claimed invention. The core of the claimed advance is the unique toothed surface structure that allows the dielectric layer to "grip" the conductive layer in a multilayer electrical device. Those toothed surfaces—which function differently than prior-art adhesion efforts—increase resistance to delamination. Many claims are directed only to the physical characteristics of those teeth, and the cavities in the dielectric layer that receive the teeth. Other claims address the process for making the teeth. But even those claims focus on the discovery that, if a ***non-homogenous*** dielectric material is used, ***etching*** can produce the cavities necessary to form the teeth. None of the independent process claims impose any limitations regarding ***how*** the etching must be performed. Certain dependent claims do include limitations governing the etching. But they nowhere suggest that the etching must be performed as part of a "repeated desmear process," as the district court required. Had the court focused on what the claims ***actually say***, it could not have reached the construction that it did.

Rather than starting with a serious effort to construe the terms used in the claims, the district court jumped first to the tail of the specification. The court invoked the disclosure of a repeated-desmear process in a preferred embodiment to read a repeated-desmear limitation into each and every claim. But the specification as a whole contradicts that effort. Up front, the Summary of the Invention explains that one of the best modes for producing the "teeth" is to use a non-homogenous dielectric material together with a "***slowed and/or repeated etching***" process. Appx0103, 2:25-30 (emphasis added). It is impossible to read that as rejecting slowed etching as a means of producing the cavities—much less requiring, for every single claim, not just a repeated "etch" but repetition of a six-step desmear process (which includes an etch). The district court cited five passages that contrast the prior-art single-desmear process with an exemplary embodiment involving two desmears. But the language used in those passages—such as "one technique," or "for example"—shows that they are merely illustrative ways of practicing the invention.

The fact that several of those passages refer to "the present invention," moreover, does not limit the outer bounds of the invention to the preferred embodiment. That is clear from the numerous other places in which the specification describes other aspects of the "present invention," such as the teeth themselves, and the use of a non-homogenous dielectric. To the extent the specification can be read to disavow anything at all, that would only be the ***prior-art*** desmear process—not disclosed departures from the prior art such as using a slow-etch desmear (or a repeated etch outside the desmear process) on a non-homogeneous dielectric. The district court's construction cannot be sustained.

I. THE ASSERTED CLAIMS DO NOT REQUIRE A "REPEATED DESMEAR PROCESS"

A. The Plain Language of the Claims Does Not Require a "Repeated Desmear Process"

It is a fundamental principle of claim construction that claim terms should be given their "ordinary and customary meaning," as understood by "a person of ordinary skill in the art." *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312-13 (Fed. Cir. 2005) (en banc). "When claim language has" a plain meaning on an issue, "leaving no genuine uncertainties on interpretive questions relevant to the case, it is particularly difficult to conclude that the specification reasonably supports a different meaning." *Straight Path IP Grp., Inc. v. Sipnet EU S.R.O.*, 806 F.3d 1356, 1361 (Fed. Cir. 2015). That is the case here. Each claim term at issue has an "ordinary meaning." As a result, determining whether they require a repeated-desmear process should "involve[] little more than the application of the widely accepted meaning of commonly understood words." *Phillips*, 415 F.3d at 1314.

The claim terms fall into three groups:

Claim Terms	Patents / Claims
"surface"	
"surface of a dielectric material" "surface of a layer of a dielectric material" "a dielectric material comprising a surface"	'582 Patent: Claims 94, 95, 100, 109, 122
"removal"	
"removal of a portion of the dielectric material" "removal of some of the dielectric material"	'582 Patent: Claims 85, 87, 89, 92, 114, 122
"etching"	
"etching [of] the epoxy" "etching [of] the dielectric material"	'560 Patent: Claims 14, 19 '105 Patent: Claims 13, 53, 71, 80, 82, 86, 88, 91, 95, 97, 101, 103 '912 Patent: Claims 2, 3, 18, 19, 20, 26, 27, 28

Appx1879-1889. Because there is no meaningful distinction between the phrases within each group, Continental Circuits addresses a representative term for each group.

1. *"Surface of a Dielectric Material"*

The term "surface of a dielectric material" appears in asserted device claims in the '582 patent. For example, claim 100 recites:

> An electrical device including:
>
> > a conductive layer built up so as to fill undercuttings with respect to a ***surface of a dielectric material*** so as to form teeth in cavities, a plurality of the undercuttings being obtuse to the surface, wherein
> >
> > . . . a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and
> >
> > wherein at least one of the cavities includes an upgrade slope with respect to the ***surface of the dielectric material***, and one of the teeth engages a portion of the dielectric material at the slope.

Appx0111, 18:49-60 (emphasis added).

Claim 100 is addressed to a "device"—a thing, not a process. The term "surface of a dielectric material" likewise refers to a thing, not a process. As defendants' expert acknowledged, the term means what it says—"the 'surface' terms . . . refer to the surface of the dielectric that is roughened prior to addition of a conductive layer." Appx2041. There is no way to read "surface of a dielectric material" to mean only a "surface of a dielectric material that has been treated through a repeated desmear process."

Claim 100 requires the device to have certain characteristics, some of which relate to the "surface" of the dielectric material: There must be "undercuttings" below the surface in the form of "cavities," such that the conductive layer will form teeth when added to the dielectric; the cavities must be "obtuse" to the surface; the cavities must be within a range of depths below the surface; and the teeth must engage the surface at a slope. Appx0111, 18:49-60. But the claim contains no limitation dictating ***how*** the cavities in the surface are made. It certainly does not require that the cavities be formed by a "repeated desmear process."

2. *"Removal of a Portion of the Dielectric Material"*

The phrase "removal of a portion of the dielectric material" appears in other asserted device claims of the '582 patent. For example, claim 114 recites:

> An electrical device including:
>
> a dielectric material having a surface remaining from ***removal of a portion of the dielectric material***; and
>
> means for mechanically gripping a conductive layer to the surface of the dielectric material so that the ***conductive layer is burrowed in and under the top surface of the dielectric material***, . . . wherein the means for mechanically gripping is ***comprised of teeth***, and a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and
>
> wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

Appx0112, 20:30-44 (emphasis added).

As with claim 100 above, claim 114 is directed to a physical thing—a "device"—not a process. It claims a thing with certain characteristics—the full limitation is "a surface remaining from removal of a portion of the dielectric material." Appx0112, 20:31-32. There is no meaning of that phrase suggesting that the removal must take place by particular means.

Other limitations require that the removal of dielectric material leave a surface with particular characteristics—it must leave cavities that allow for teeth in certain depths and at certain angles relative to the surface. *See* Appx0112, 20:33-44. But the claim is not directed to the removal process itself. It imposes no requirements as to ***how*** the "removal of a portion of the dielectric material" is achieved—by etch, desmear, or otherwise.

3. *"Etching the Epoxy"*

Finally, the phrase "etching the epoxy" appears in various claims, including "article of manufacture" claims of the '560 patent; "device," "product," and "process" claims of the '105 patent; and "process" claims of the '912 patent. Those claims, however, focus on using a non-homogenous epoxy dielectric material, and the ***result*** obtained by etching such a non-homogenous dielectric. None of the independent claims requires any particular ***method*** of etching. Some ***dependent*** claims require a repeated etching. But nothing in them suggests that must be performed in conjunction with repeating all six steps of the desmear process.

Independent Article of Manufacture/Device/Product Claims. Claim 14 of the '560 patent is representative of the "article of manufacture," "device," and "product" claims that include the "etching" term. It recites:

An article of manufacture, the article comprising:

> an epoxy dielectric material delivered with ***solid content sufficient that etching the epoxy forms*** a non-uniformly roughened surface comprising cavities located in and underneath a surface of the dielectric material, and sufficient that the ***etching of the epoxy uses non-homogeneity*** with the solid content to bring about formation of the non-uniformly roughened surface with at least some of the cavities having a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface,
>
> and a conductive material, whereby the ***etching of the epoxy forms the cavities***, and a portion of the conductive material in the cavities ***thereby forming teeth in the cavities***, wherein the ***etching of the non-homogeneous composition*** forms the cavities . . . .

Appx0127, 10:7-25 (emphasis and paragraph break added).

Once again, the claim is directed to an "article"—a thing, not a process. The claim requires that the dielectric material be "delivered with solid content," and thus have a "non-homogenous composition." Appx0127, 10:8, 10:22-23. The claim also requires that the "non-homogeneity" be "sufficient" that "etching of the epoxy" will "bring about formation" of "cavities," and that those cavities allow for formation of teeth when conductive material is applied to the "non-uniformly roughened [dielectric] surface." *Id.*, 10:11-16, 10:19-22. The claim also requires that the teeth have specified physical characteristics. *Id.*, 10:16-18.

Claim 14 thus recites the ***result*** of etching a non-homogenous dielectric material such that it produces the claimed teeth. But it nowhere requires any particular ***method*** of etching, much less a full six-step desmear process performed twice.

<u>*Independent Process Claims*</u>. The claim term "etching the epoxy" also appears in process claims. For example, claim 13 of the '105 patent recites:

> A process of making an article of manufacture, the process comprising:
>
> > implementing a circuit design for an electrical device by coupling an epoxy dielectric material delivered ***with solid content sufficient that etching the epoxy*** forms a non-uniformly roughened surface comprising ***cavities*** located in, and underneath a surface of, the dielectric material, and sufficient that the ***etching of the epoxy uses non-homogeneity with the solid content*** in bringing about formation of the non-uniformly roughened surface . . ., with a conductive material,
> >
> > whereby the ***etching of the epoxy*** forms the cavities, and a portion of the ***conductive material in the cavities thereby forming teeth in the cavities***, wherein the ***etching of the non-homogeneous composition forms the cavities*** . . . .

Appx0138, 10:15-31 (emphasis and paragraph break added).

While the claim is directed to a "process," that process consists of "coupling" a layer of "epoxy dielectric material delivered with solid content" with "a conductive material." The coupling is achieved through the use of "teeth" of conductive material that bite into "cavities" in dielectric material. The process requires "etching the epoxy," which creates the cavities as a result of the dielectric's "non-homogenous composition." But the claim is not concerned with

how the etching is performed; it nowhere suggests the etching must be carried out in a "repeated desmear process."

Dependent Claims. The dependent claims make that conclusion clearer still. Some dependent claims contain a limitation regarding "etching." For example, claim 19 of the '560 patent recites, "[t]he article of claim 14, wherein the etching includes a first etching and a second etching." Appx0128, 11:1-2. Likewise, other dependent process claims recite an independent process claim wherein the "etching" step "includes a first etching and a second etching." Appx0139, 12:62-63 ('105 patent claim 53, depending from claim 13).

Those dependent claims—which require two etchings—do not themselves encompass a double-desmear limitation. ***Etching*** twice is not the same as performing a ***desmear process*** twice. "[E]tching" is but one of several "sub-steps" in the "sequence for a desmear process." Appx0106, 8:43-44, 8:57-60 ('582 patent). Defendants' expert conceded that "etching" means the "appli[cation] [of] a chemical etchant to remove portions of the dielectric material." Appx2033 (defendants' expert); *see also* Appx2471-2472 (Continental Circuits' expert) ("removal of material" through "a chemical etching process"). By contrast, defendants' expert acknowledged, "the desmear process involve[s]" more—"swell, etch, and neutralization steps (each separated by a rinsing step)." Appx2033. Defendants thus agree that a repeated etch would not "suffice to be a repeated desmear."

Appx4105. They confirmed that a repeated desmear requires ***all six*** of the desmear "substeps" to be "done a second time." *Id.*; *see also* Appx4882. As a result, defendants' construction requires repeating "a desmear process [that would] compris[e] six steps (1. swelling, 2. rinsing, 3. etching, 4. rinsing, 5. neutralizing, 6. rinsing)." Appx4882.

The plain language of dependent claim 19 requires ***only*** that the etching step be performed twice. It does not require that the entire six-step "desmear process" be performed at all, much less "repeated." Indeed, as explained below, dependent claim 19's recitation of a repeated etch forecloses the effort to read a repeated-desmear requirement into the independent claims. If the independent claims already required at least two full desmears—which would include at least two etches—a dependent claim requiring two etches would be superfluous.

B. Claim Differentiation Precludes Reading a "Repeated Desmear Process" into the Asserted Claims

The "ordinary and customary meaning" of the disputed claim terms, *Phillips*, 415 F.3d at 1313, alone should foreclose reading a separate "repeated desmear process" limitation into them. But the unambiguous terms of other claims—along with the doctrine of claim differentiation—make that clearer still. "Other claims of the patent in question, both asserted and unasserted, can . . . be valuable sources of enlightenment as to the meaning of a claim term." *Id.* at 1314. Here, those other claims are not just enlightening; they are dispositive.

1. Under the doctrine of claim differentiation, "the presence of a dependent claim that adds a particular limitation gives rise to a presumption that the limitation in question is not present in the independent claim." *Phillips*, 415 F.3d at 1314-15; *see also Curtiss-Wright Flow Control Corp. v. Velan, Inc.*, 438 F.3d 1374, 1380 (Fed. Cir. 2006). That "presumption is especially strong" where the additional limitation "is the only meaningful difference between [the] independent and dependent claim." *Hill-Rom Servs., Inc. v. Stryker Corp.*, 755 F.3d 1367, 1374 (Fed. Cir. 2014). That is the situation here.

For example, independent claim 14 of the '560 patent includes the disputed term "etching the epoxy," without specifying how the etching must be performed. Appx0127, 10:9; *see* p. 36, *supra*. Dependent claim 19 recites the "article of claim 14, wherein ***the etching includes a first etching and a second etching***." Appx0128, 11:1-2 (emphasis added). The district court's construction would improperly render dependent claim 19 "superfluous." *Curtiss-Wright*, 438 F.3d at 1381; *see Saunders Grp., Inc. v. Comfortrac, Inc.*, 492 F.3d 1326, 1331 (Fed. Cir. 2007). As explained above, a desmear process includes etching as a sub-step. *See* pp. 14-15, *supra*. Consequently, a repeated-desmear process necessarily includes at least a first etching (part of the first desmear) and a second etching (part of the second desmear). It would have made no sense for the inventors to include dependent claim 19 to require at least two etching steps if independent claim 14, by requiring two desmears, already required that. Claim differentiation forecloses that interpretation of the claims.

It is a "cardinal principle" of construction—whether for statutes, contracts, or patent claims—that no word or phrase should be read so as to render others "wholly superfluous." *Duncan v. Walker*, 533 U.S. 167, 174 (2001); *see also Nat'l Ass'n of Mfrs. v. Dep't of Def.*, No. 16-299, slip op. 17 (U.S. Jan. 22, 2018) (rejecting statutory interpretation "that would render an entire subparagraph meaningless"). "[T]his [C]ourt has denounced" claim constructions that render terms "superfluous." *Stumbo v. Eastman Outdoors, Inc.*, 508 F.3d 1358, 1362 (Fed. Cir. 2007); *see also Glover v. West*, 185 F.3d 1328, 1332 (Fed. Cir. 1999). The district court's construction violates that rule.

Nor is that effect limited to claim 19. It renders many dependent claims—each adding only a repeated etch limitation—superfluous as well. *E.g.*, '560 patent, claims 6, 19, 20, and 21 (Appx0127-0128, 9:53-54, 11:1-12:2); '105 patent, claims 41-79 (Appx0139-0140, 12:38-13:48), and claims 90-99 (Appx0140, 14:35-14:54); '582 patent, claim 163 (Appx0116); '912 patent, claims 9-16 (Appx0150-0151, 10:64-11:12). The district court's construction improperly excises claim after claim out of patent after patent.

2. A comparison between the device and process claims likewise belies the district court's construction. For example, independent device claims 100 and

114 do not contain ***any*** limitation regarding ***how*** "cavities" (or "undercuttings") in the surface of dielectric material are formed. They do not recite "etching" at all. *See* pp. 32-35, *supra*. The terms the district court purported to construe do not even mention the cavities or undercuttings. They are simply "surface of a dielectric material," "a dielectric material comprising a surface," and "surface of a dielectric material." Appx0005; pp. 32-34, *supra*. They are directed to a ***surface***. They impose ***no*** limitation regarding how cavities in those surfaces are formed.

That omission was deliberate: Where the claims were meant to impose a limitation regarding the process for forming the cavities, they did so expressly. For example, certain independent process claims recite "removing a portion of a dielectric material in producing cavities." Appx0107, 9:29-30. And dependent claim 163 recites that process, "further including subjecting the dielectric material to a first etching of the dielectric material and a second etching of the dielectric material." Appx0116. That, too, shows that it is improper to read process limitations into device claims that do not mention process. *See Curtiss-Wright*, 438 F.3d at 1380 (claim-differentiation principles apply "more generally" across claims in a patent). Simply put, if claims 100 and 114 were limited to a particular process involving repeated desmears, they would have included that limitation expressly.

3. Patents in the same family ***do*** include the particular limitation the district court read into the claims here. Claim 1 of the '069 patent, in the same

family as the patents-in-suit, requires teeth set in the dielectric material. ’069 patent, *supra*, 9:24-34. Dependent claim 18 further recites: “The circuit board of claim 1, wherein the teeth are formed by a ***double desmear process***.” *Id.*, 10:40-41 (emphasis added). That limitation is absent from the claims here.

U.S. Patent No. 6,141,870—the ultimate parent of the patents-in-suit—likewise incorporates a double-desmear process in a dependent claim. Its claim 1 requires a step of “forming cavities in the applied dielectric material.” ’870 patent, 9:21, *available at* http://patft1.uspto.gov/netacgi/nph-Parser?patentnumber=6141870. Dependent claim 2 recites the six steps of a desmear, and requires they be repeated:

> The method of claim 1, wherein the step of forming cavities includes ***more than one set of sub-steps including***:
>
> > swelling the dielectric material;
> >
> > rinsing the dielectric material;
> >
> > etching the dielectric material;
> >
> > rinsing the dielectric material;
> >
> > neutralizing the dielectric material; and
> >
> > rinsing the dielectric material.

Id., 10:4-13 (emphasis added).

The contrast between that claim of the parent patent, and the claims asserted here, is telling. Where “predecessor . . . patents were drawn to narrow claims,” and the claims in the successor patents appear broader because they omit certain limitations, that "change in claim language" is a "powerful indicator as to the proper construction of the [subsequent] claims." *Saunders*, 492 F.3d at 1335-36. The earlier patents here included claims requiring a double-desmear process; these claims do not. The district court erred in importing a "repeated desmear process" limitation the inventors deliberately chose to omit.

II. The District Court Erred In Holding That The Specification Requires Reading A "Repeated Desmear Process" Limitation Into The Claims

The district court agreed that "the plain and ordinary meaning" of the claim terms "does not include" a "repeated desmear process" limitation. Appx0006. For that reason alone, anyone seeking to engraft that limitation onto the claims had a "heavy burden." *Id.* The court also understood that claim-differentiation principles imposed a further presumption against reading that limitation into the claims. *See* Appx0013. Indeed, that presumption was "especially strong" here, because adding defendants' proposed limitation would render myriad dependent claims superfluous. *Hill-Rom Servs.*, 755 F.3d at 1374. And the court nowhere denied that the original parent, and related patents, weighed against that effort to re-write the text of the claims.

Nonetheless, the district court held that the repeated-desmear-process "limitation" should be "add[ed]" to the claims, Appx0006, citing a preferred embodiment in the specification, *see* Appx0007-0011. "[I]mporting [a] limitation[] from the written description into the claims," of course, is the "'cardinal sin' of claim construction." *Teleflex, Inc. v. Ficosa N. Am. Corp.*, 299 F.3d 1313, 1324 (Fed. Cir. 2002). The district court nonetheless read the specification to "disavow" dielectric "surfaces" except those created through a repeated-desmear process, and all processes that do not employ a repeated desmear. *See* Appx0007-0010. But the specification does not remotely provide the "***clear disavowal*** of claim scope," using "words or expressions of ***manifest exclusion or restriction***," that is required. *Teleflex*, 299 F.3d at 1327 (emphasis added). And it does not meet the even more exacting standard that applies where, as here, the proposed construction also defies the "especially strong" presumption against rendering myriad claims superfluous—and defies the history of a series of related patents. *Hill-Rom Servs.*, 755 F.3d at 1374.

Nowhere does the specification limit the invention to repeated desmears. Language addressing a preferred embodiment—using products like the non-homogeneous Probelec dielectric and Shipley desmear conditioner—does reference a "double desmear process." But as the court acknowledged elsewhere in its opinion, "the use of [Probelec]" is merely "a preferred embodiment, an illustration." Appx0017. The reference to a double-desmear process is simply one convenient way the necessary etch step can be incorporated into existing manufacturing processes with those materials. The use of introductory phrases like "one technique" or "for example" makes that clearer still. And references to "the present invention" do not limit the invention to a repeated desmear. The "Summary of the Invention" nowhere mentions a repeated desmear. It highlights "***slowed*** and/or repeated etching" of a "non-homogenous" dielectric as the "best methods for producing the teeth." Appx0103, 2:29-30 (emphasis added). In the context of the specification, the scattered references to a repeated-desmear process in a single embodiment simply do not evince the clear intent to disavow claim scope this Court requires to "add a limitation" that has no basis in "the actual words of the claims." Appx0006.[3]

A. The Specification Defies a Mandatory Repeated-Desmear Process

Far from "clear[ly] and unmistakabl[y]" requiring a repeated-desmear-process limitation for all claims, *Thorner v. Sony Comput. Entm't Am. LLC*, 669 F.3d 1362, 1367 (Fed. Cir. 2012), the specification discloses multiple embodiments that ***do not*** require such a process.

1. The specification describes the crux of the invention: A "unique surface structure, which is particularly suitable for joining the dielectric material to

[3] The district court observed that, aside from disavowal, the only other "exception[] to the rule that claims are given their plain and ordinary meaning" is "'when a patentee sets out a definition and acts as his own lexicographer.'" Appx0006 (quoting *Thorner*, 669 F.3d at 1365). But the court did not base its construction on a lexicography theory: Nowhere did it purport to find that the patentees defined any disputed claim term as requiring a repeated-desmear process. Indeed, the court acknowledged that, far from construing the "actual words of the claims," it chose "to ***add a limitation*** to the claims." *Id.* (emphasis added).

the . . . conductive layer" of a multilayer electrical device. Appx0103, 1:52-54. It explains that "[t]he surface structure is comprised of teeth" that "enable one layer to mechanically grip a second layer." *Id.*, 1:54-57. That structure "functions in a different manner" than prior-art "adherence by means of increased surface area." *Id.*, 1:59-63. And it dramatically increases grip, as "separating" layers requires "ripping" them apart, "destroying the integrity of at least one of the layers." *Id.*, 2:3-6.

The specification details a preferred embodiment of that "desirable tooth structure." Appx0104, 3:9-10. The teeth may be made of the conductive material, and are preferably "obtuse, canine, or fang-shaped" so they "hook under the exterior surface" of the dielectric material. *Id.*, 3:43-46. The specification further discloses that "it is preferable that the teeth be within a certain size range," ideally between 1 and 1.75 tenths of a mil deep. *Id.*, 3:52-53, 3:58-61. And it discloses that the teeth "should be quite frequent in number"—ideally, 200,000 teeth per square inch—to ensure good grip. *Id.*, 4:1-2. That preferred embodiment describes a physical invention—a multilayer electrical device in which the layers are joined by a "unique surface structure" having certain physical characteristics. That embodiment—and the claims that cover it—stand without regard to ***how*** the teeth are formed.

2. The specification discloses ways of producing the teeth that do not require a repeated desmear. The Summary of the Invention explains that one of the "best methods for producing the teeth" is to use dielectric material with "a non-homogenous composition." Appx0103, 2:24-28. A "non-homogenous composition," it explains, will exhibit "an uneven chemical resistance, such that ***slowed and/or repeated etching*** will form [the] teeth." *Id.*, 2:25-30 (emphasis added); *see* Appx0105, 5:37-40 (uneven chemical resistance key to "the etching of cavities . . . in the applied dielectric material . . . to accommodate the teeth").

Those embodiments defy the district court's construction. The device and claimed teeth can be formed by "***slowed***" etching. That is not a repeated desmear. The "slowed" method does not require repetition of anything.[4] The device also can be formed by "***repeated etching***." But that is not a repeated desmear either: Etching is just one sub-step of the six-step desmear "***process***." Appx0105, 5:47 (emphasis added); pp. 14-15, 38-39, *supra*. Teeth can also be formed by a combination of slowed and repeated etching. But combining those isn't necessarily a

[4] The court suggested that "slowed" etching cannot be "an alternative embodiment of the patented invention" because the specification "suggests that varying the times of a single desmear process does not produce the teeth." Appx0015. The cited provision says no such thing. It says that "[o]ne technique"—a "double desmear process"—does not involve "merely increasing the times and temperatures" for the "desmear process," but rather "completing the [desmear] process a second time." Appx0105, 5:40-47. It never says increasing the etch time, when using non-homogenous dielectric, will fail to produce the teeth. *See* pp. 63, *infra*. The Summary of the Invention says the opposite.

double-desmear, either. The inventors' disclosure of processes not requiring a double desmear cannot possibly be reconciled with a "manifest exclusion or restriction" of all claims to a repeated desmear. *Thorner*, 669 F.3d at 1366.

3. That conclusion is further bolstered by the claims of the original patent application, which are deemed "part of the specification." *ScriptPro LLC v. Innovation Assocs., Inc.*, 833 F.3d 1336, 1341 (Fed. Cir. 2016) (quotation marks omitted). "When a specification is ambiguous about which of several features are stand-alone inventions, the original claims can help resolve the ambiguity . . . ." *ScriptPro, LLC v. Innovation Assocs., Inc.*, 762 F.3d 1355, 1361 (Fed. Cir. 2014). ***None*** of the original independent claims requires a repeated-desmear process. For example, original claim 1 recited a physical thing, not a process:

> An electrical device including:
>
> a base;
>
> a conductive layer adjacent to the base;
>
> a dielectric material adjacent to conductive layer; and
>
> a tooth structure including a metal layer set in the dielectric material to join the dielectric material to the metal layer.

File Wrapper for '870 patent, Application No. 08/905,619, at 13, filed Aug. 4, 1997, *available at* http://outlierdevhq.com/hosted-documents/continental-circuits/.[5]

[5] This Court may take judicial notice of prosecution history files. *See Standard Havens Prods., Inc. v. Gencor Indus., Inc.*, 897 F.2d 511, 514 n.3 (Fed. Cir. 1990).

And while original independent method claim 19 required "forming cavities in the applied dielectric material," it made no mention of a double-desmear. *Id.* at 15. The fact that the "original [independent] claims omit a [repeated-desmear] requirement" bolsters the conclusion that the inventors intended a repeated-desmear process "to be merely optional." *ScriptPro*, 762 F.3d at 1361.

Once again, claim differentiation strengthens that presumption. Original claim 21 depended from method claim 19, adding the limitation that "the step of forming cavities includes more than one set" of the six desmear sub-steps. Application No. 08/905,619, at 15. That claim would be superfluous if the independent claim already required a repeated desmear. *See* pp. 40-42, *supra*. Thus, from the original application onward, it has been clear that the inventors did not intend to limit the claims to a repeated desmear—except when specifically stated.

B. The Preferred Probelec/Shipley Embodiment Does Not Limit the Scope of the Claims to a Repeated-Desmear Process

The district court focused on a single preferred embodiment: a process for making the teeth using certain products—Probelec non-homogenous dielectric, and Shipley's desmear conditioner. *See* Appx0105-0107, 5:40-9:9. The embodiment involves a "'double desmear process,'" *i.e.*, "completing [the desmear] process a first time, and then completing the process a second time." Appx0105, 5:53-47. While the court took that as a disclaimer of all other methods, Appx0006-0007, it is merely an example. Fundamental claim-construction principles and the text of the specification alike preclude "read[ing] limitations from" that "preferred embodiment . . . into the claims." *Liebel-Flarsheim Co. v. Medrad, Inc.*, 358 F.3d 898, 913 (Fed. Cir. 2004).

1. *The Probelec/Shipley Embodiment Is Not—and Disclaims Any Intent To Be—Limiting*

It is long settled that one "cannot overcome the 'heavy presumption' that a claim term takes its ordinary meaning simply by pointing to the preferred embodiment." *Teleflex*, 299 F.3d at 1327; *see also Gemstar-TV Guide Int'l, Inc. v. Int'l Trade Comm'n*, 383 F.3d 1352, 1366 (Fed. Cir. 2004). Doing so is insufficient even where the defendant points to the "***only*** . . . embodiment" in the specification. *Teleflex*, 299 F.3d at 1327 (emphasis added). *A fortiori*, it is insufficient where, as here, claim-differentiation principles and multiple other embodiments belie the proposed limitation.

Instead, a "characteriz[ation] [of] the invention" in the specification can limit claim scope ***only*** if accompanied by unequivocal "words or expressions" manifesting intended "exclusion or restriction." *Teleflex*, 299 F.3d at 1327. But far from "clear[ly] and unmistakabl[y]" requiring a repeated-desmear-process limitation in all claims, *Thorner*, 669 F.3d at 1367, the language the district court invoked (Appx0008-0011) says the opposite: It describes a double desmear as "***[o]ne technique*** for forming" the invention's "teeth." Appx0105, 5:40-41 (emphasis added). It does not describe that as the sole claimed technique. And while the specification details the "double desmear process" used in the Probelec/Shipley embodiment, *see* Appx0106-0107, 8:43-9:9; pp. 13-16, *supra*, the district court recognized that "the use of [Probelec]" is merely "a preferred embodiment, an illustration," Appx0017. That is not less true when describing the use of Probelec with a double desmear.

Indeed, the inventors took pains to stress that the embodiment does not represent the invention's full scope: "While a particular embodiment of the present invention has been disclosed," the specification warns "***[t]here is no intention . . . to limit the invention*** to the exact disclosure presented herein as a teaching of one embodiment." Appx0107, 9:18-25 (emphasis added). Instead, "the scope" of the claimed invention "is to be determined with reference to the claims" themselves. *Id.*, 9:20-22. That is the opposite of "a clear disavowal of claim scope." *Thorner*, 669 F.3d at 1366. While the district court dismissed that language as "boilerplate," Appx0015, it never explained why an express statement in the specification—that the embodiments were not meant to limit the scope of the claims—should be disregarded when considering whether the specification manifested a clear intent to limit the claims to a particular embodiment.

2. *The Probelec/Shipley Embodiment's References to the Prior Art Do Not Limit the Claims to a Repeated-Desmear Process*

The district court thought the Probelec/Shipley embodiment important because it "repeatedly distinguishes the process covered by the patent from the prior art and its use of a 'single desmear process.'" Appx0008. But the district court overlooked this Court's warning that, "[t]o avoid importing limitations into the claims, it is important to keep in mind that the purposes of the specification are to teach and enable those of skill in the art to make and use the invention and to provide a best mode of doing so." *Phillips*, 415 F.3d at 1323. The specification's purpose is ***not*** to define the scope of the claims. Here, each of the "[f]ive portions of the specification" the court invoked appears in the context of the Probelec/Shipley embodiment. Appx0008. Far from purporting to limit the invention to a double-desmear process, that embodiment merely "provide[s] an example of how to practice the invention in a particular case" using certain products. *Phillips*, 415 F.3d at 1323.

The first statement the district court cited introduces the Probelec/Shipley embodiment as disclosing "[o]ne technique for forming the teeth" that, "contrary to all known teachings in the prior art," utilizes a "double desmear process." Appx0105, 5:40-44. And the statements that follow are specific to using a double-desmear process with the particular Probelec and Shipley products discussed in that embodiment. For example, the second statement the district court invoked is that "the desmear process as disclosed herein is contrary to the manufacturer's specification" for the "Crimson product of Shipley"; "i.e., a 'double desmear process,' rather than the single desmear process of the known art." Appx0009 (quoting Appx0105, 5:59-63). The third statement similarly provides that, "[a]lthough Probelec XB7081 was apparently intended for use in the common desmear (swell and etch) process," it "can alternatively be used in carrying out the present invention" if the "sub-steps in the desmear process are repeated." *Id.* (quoting Appx0106, 8:45-53). The fourth statement explains that, while a "prior art," "single pass desmear process" will "produce a 6 lb/in average peel strength" when using Probelec, "the present invention may produce an average peel strength on the order of 10 lb/in or more" using that same dielectric. *Id.* (quoting Appx0105-0106, 6:57-7:9). And the fifth states that, "[i]n stark contrast with the etch and swell process of the known prior art, . . . a second pass through the process . . . is used," which "make[s] use of non-homogeneities [in the Probelec] in bringing about a formation of the teeth." Appx0010 (quoting Appx0107, 9:1-5).

"Properly read in this context, the statement[s] merely convey the advantages of" a double-desmear process "over [the] prior art conventional" single-pass desmear process "***[i]n the context of the . . . embodiment***." *Gemstar*, 383 F.3d at 1366 (emphasis added). They explain that, when using these particular products, the double-desmear process will create the invention's teeth in the non-homogenous dielectric. *See* Appx0107, 9:1-5.

The focus on a double-desmear process—as opposed to other possible methods—makes perfect sense in the context of that embodiment. The specification explains that "slowed and/or repeated ***etching***" of non-homogeneous dielectric, Appx0103, 2:25-30 (emphasis added), can produce the "cavities, veins, openings, or gaps in the applied dielectric material" necessary for formation of the invention's teeth, Appx0105, 5:37-40. Manufacturers' machines were already configured to perform an etch in conjunction with the broader, six-step desmear process in common use. *See* p. 14, *supra*; Appx3884-3907 (describing manufacturing process). Thus, it would require minimal change to existing manufacturing processes to perform "repeated" ***etching*** simply by running a second desmear program on the layers—as opposed to reprogramming machines entirely to alter the duration of a single etch.

That the inventors disclosed a straightforward way to perform the invention in the context of existing materials and processes does not suggest they meant to exclude all other methods. The statements are "not a disavowal or disclaimer indicating that ***the claims*** excluded all or part of the properties" when formed without a repeated-desmear process. *Gemstar*, 383 F.3d at 1366 (emphasis added). And they certainly cannot overcome every principle of claim construction pointing the other direction.

3. *References to "the Present Invention" Do Not Change the Result*

The district court also relied on the fact that several passages in the Probelec/Shipley embodiment draw a distinction between "'the present invention'" and "'the desmear process of the prior art, i.e., a single desmear process.'" Appx0011 (quoting Appx0106, 7:3-6); *see also* Appx0105, 5:59-63; Appx0106, 8:50-52. As this Court has explained, "use of the phrase 'present invention' or 'this invention' is not always . . . limiting, such as where the references to a certain limitation as being the 'invention' are not uniform, or where other portions of the intrinsic evidence do not support applying the limitation to the entire patent." *Absolute Software, Inc. v. Stealth Signal, Inc.*, 659 F.3d 1121, 1136-37 (Fed. Cir. 2011). That is the case here. The specification refutes any notion that scattered use of the phrase "the present invention" limits the claims to a repeated-desmear process.

The district court ignored the specification's most prominent statement describing the present invention—the section entitled "SUMMARY OF THE INVENTION." Appx0103, 1:48-2:29; *see C.R. Bard, Inc. v. U.S. Surgical Corp.*, 388 F.3d 858, 864 (Fed. Cir. 2004) ("Statements that describe the invention as a whole are more likely to be found in certain sections of the specification, such as the Summary of the Invention."). That section explains that the invention is a "unique surface structure, which is particularly suitable for joining the dielectric material to the . . . conductive layer" of a multilayer electrical device. Appx0103, 1:52-54. It explains that the "improvement" over the prior art is its "surface of the teeth," *id.*, 1:58-60, which "enable[s] one layer to mechanically grip a second layer," *id.*, 1:54-57. Five of the six paragraphs in the Summary of the Invention concern the size, shape, and frequency of the teeth. *See id.*, 1:50-2:24. In the sixth paragraph, the Summary introduces methods of making the teeth. It explains that "the best methods for producing the teeth [are] to use non-homogeneous materials" with "slowed and/or repeated etching." *Id.*, 2:25-30. It does not say the etching must be done in a desmear process, much less a double desmear—it omits any reference to "desmear" entirely. Pp. 48-49, *supra*.

The section titled "FIELD OF THE INVENTION" likewise repeatedly refers to "the present invention" without mentioning a double-desmear process. Appx0103, 1:11-24. It begins: "The ***present invention*** is directed to methods for making or manufacturing an electrical device, and the process, composition, and product thereof." *Id.*, 1:13-15 (emphasis added). It continues: "More particularly, the ***present invention*** involves such multilayer electrical devices as circuit boards constructed by joining a dielectric material to a subsequently applied conductive material." *Id.*, 1:15-18 (emphasis added). "Still more particularly," the "***present invention***" involves "an electrical device" with layers, "the conductive layer being joined to the applied dielectric material in an improved manner." *Id.*, 1:18-24 (emphasis added). The section does not define the field of invention in terms of an improved desmear process. And none of those references to the "present invention" mentions a double desmear.

The specification contains still more references to "the invention" or the "present invention" that have nothing to do with a repeated-desmear process. *See* Appx0104, 3:32-35 ("The ***invention*** can be carried out by forming cavities in the applied dielectric material 6 for receiving the teeth, and then forming the teeth from the conductive coating and metal layer formed thereon." (emphasis added)); *id.*, 4:19-20 ("FIG. 3 illustrates one of the ***many ways*** to begin the process of forming the teeth in accordance with the ***present invention***." (emphasis added)). In other places, the patent refers more broadly to steps of manufacturing the device as "the ***present invention***." Appx0105, 6:29-35 (emphasis added).

Finally, while the district court found that the specification "clearly asserts that 'the present invention'" is the double-desmear process—"not just" the "embodiment discussed in the specification as an example," Appx0011—the specification says otherwise. It describes the Probelec/Shipley embodiment and its disclosure of a double-desmear process as "a particular ***embodiment*** of the ***present invention***." Appx0107, 9:18-22 (emphasis added).

The specification thus uses the phrase "present invention" to describe aspects of the invention having nothing to do with a repeated-desmear process. It makes no sense to ignore those disclosures and focus—as the district court did—on a few references to a repeated desmear in a preferred embodiment to define the invention's scope for all purposes. *See Voda v. Cordis Corp.*, 536 F.3d 1311, 1320-

22 (Fed. Cir. 2008) (while parts of the specification referred to one embodiment as the "present invention," specification did not uniformly refer to invention as so limited); *Praxair, Inc. v. ATMI, Inc.*, 543 F.3d 1306, 1326 (Fed. Cir. 2008) (references to specific embodiment as "the apparatus of this invention" and a "useful feature of this invention" in the specification "are contradicted by a number of express statements . . . clearly indicating that [the feature at issue] is a feature only of certain embodiments"). And that is doubly true when doing so violates virtually every other rule of claim construction.

C. The Prosecution History and Extrinsic Evidence Do Not Save the District Court's Construction

The district court's decision cannot be salvaged by reference to extrinsic evidence. That evidence—concededly insufficient to support disavowal itself, Appx0013—highlights the shortcomings in the court's approach.

1. The district court cited a declaration by Continental Circuits' expert, Professor C.P. Wong, Ph.D., entered to respond to a written-description rejection during prosecution of the '560 patent. *See* Appx0012. The examiner had rejected some claims as reciting new matter, namely, "etching of the epoxy us[ing] non-homogeneity ***with the solid content***" and "wherein some of the cavities comprise veins." Appx2067. Professor Wong had identified "Paragraph 66 of the . . . specification [as] describ[ing] how th[e] known Probelec XB7081 resin is used to form teeth to unexpectedly improve the adherence of a conductive material applied

to the prepared epoxy dielectric material." Appx2074. He explained that, "[a]s described in this paragraph, performing two separate swell and etch steps is a technique which forms the teeth." *Id.*

Nothing in that statement reflects the "clear and unmistakable" "disavowal" that is necessary "for prosecution disclaimer to attach." *3M Innovative Props. Co. v. Tredegar Corp.*, 725 F.3d 1315, 1325 (Fed. Cir. 2013). Professor Wong described the process disclosed in that paragraph ("two separate swell and etch steps") as "***a*** technique" for forming the cavities—not "***the only*** technique." And he explained that the technique was disclosed in the context of the Probelec embodiment. That section of the specification is, as the district court acknowledged, "an illustration." Appx0017. That the inventors relied on the patent's preferred embodiment to overcome a written-description rejection does nothing to disclaim other embodiments. *See Absolute Software*, 659 F.3d at 1137.

Indeed, when the issue was put to the inventors directly during prosecution, they made clear that the invention does not require a particular process to form the teeth. They told the examiner that "there ***is no requirement for any process*** for forming cavities in the independent claim 19 (Group I) or any of claims 20, 22, 24, or 25 (Group II): ***chemical, physical, etching, or whatever***." Appx2510 (emphasis added). The court's construction contradicts that clear statement.

2. The district court also cited two private documents the inventors wrote in connection with commercial production of circuit boards. Appx0012-0013. The first says that "we use a double pass desmear to achieve the tooth structure" in certain products. Appx3322-3324. That is no disclaimer at all—it merely reflects that the inventors were putting the specification's preferred embodiment into practice. *See Absolute Software*, 659 F.3d at 1137.

The second document compares the peel strength of two batches of circuit boards that had been manufactured by Continental Circuits. The first batch was prepared using "two passes through desmear." Appx3831. "Due to a program glitch," however, the second batch "only went through the desmear cycle once before the machine shut down." *Id.* The memo states that "it is still unknown for sure what the main factor in high Cu peel strength is." *Id.* But it remarks that "a two pass desmear cycle doubles the peel strength of a one pass desmear cycle," while "varying the times in the cycle do[es] not seem to have that great of an effect." *Id.*

The district court invoked that line as "helpful corroboration." Appx0013. But the statement is entitled to no weight at all. For one thing, it does not mention what variations in the times were at issue; nor does it address which parts of the cycle were varied—etch, rinse, neutralize, or swell. More fundamentally, such "extrinsic evidence . . . may be used only to help the court come to the proper understanding of the claims; it may not be used to ***vary*** or contradict the claim language." *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1584 (Fed. Cir. 1996) (emphasis added). The district court's analysis violates that rule, invoking the statement not as evidence of how to understand a claim term, but as support for "***add[ing]*** a limitation to the claims" that simply is not there. Appx0006 (emphasis added).

III. ANY DISAVOWAL WOULD HAVE LIMITED SCOPE AND EFFECT

Even if there were a disavowal—and there is none—it would be far more limited than the district court supposed. It would be limited to forming teeth through the prior-art process—not unconventional variations specifically identified in the specification. And it would be limited to process claims.

A. Any Disavowal Would Be Strictly Limited to Using a Single *Prior-Art* Desmear

The district court's decision appeared to be motivated by a concern that the claims should not be read to encompass the prior-art single desmear. It thus read the Probelec/Shipley embodiment as "mak[ing] clear that the invention" excludes "the ***prior art's*** single desmear process." Appx0010 (emphasis added). But the patents do not claim the prior-art single desmear process. *See* Appx0103, 1:58-60, 2:9-13.[6] More important, ***excluding*** the "prior art single desmear process" is not the same as ***requiring*** a "repeated desmear process." Appx0006.

One can depart from the "prior art" single desmear process in myriad ways, as the Summary of the Invention explains: It discloses a "slowed . . . etching" process that can form teeth in a single pass when used with "non-homogenous" materials. Appx0103, 2:29-30. That does not require the etch to be performed in conjunction with a desmear at all. And even if it were performed as part of that process, it plainly is not the same as the "single desmear process of the ***known prior art***." Appx0105, 5:62-63 (emphasis added). Among other things, the etching is "slowed" ***in comparison to*** the prior-art technique. The district court nowhere explained why the "***prior art's*** single-pass desmear process" would encompass a non-conventional "slowed" etch, much less combining that non-conventional, extended-duration etch together with non-homogenous materials, as the Summary of the Invention discloses. The district court's requirement of a "repeated desmear process" is too broad even under its own theory.

That difference may be critical here. The parties stipulated that judgment for defendants was appropriate only because "Continental Circuits cannot prove that any Accused Products are manufactured according to a desmear process comprising six steps (1. swelling, 2. rinsing, 3. etching, 4. rinsing, 5. neutralizing, 6.

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[6] To the extent there is any concern that the claims do claim the prior art, that is an issue of validity, not claim construction. *See Hill-Rom Servs.*, 755 F.3d at 1374.

rinsing), followed by a process comprising those six steps." Appx4882-4883. But judgment for defendants is not appropriate if they use the [redacted] etching method disclosed in the Summary of the Invention. The evidence defendants submitted suggests they are doing precisely that: The prior-art single-desmear etching sub-step lasted "6-10 minutes." Appx0106, 8:59-60. Defendants' etching sub-step is significantly [redacted] in comparison: For example, Ibiden's etching sub-step is [redacted] that, ranging between [redacted], depending on product line. Appx4909, 4930. If creating the teeth as described in the Summary of the Invention—with an unconventional [redacted] etch on a non-homogenous dielectric—is infringement, reversal must follow.

B. No Disavowal Can Be Imported into the Non-Process Claims

The district court's effort to "import[]" a repeated-desmear process limitation "from the written description" into the ***process*** claims of the patents-in-suit was itself a "cardinal sin" of claim construction. *Teleflex*, 299 F.3d at 1324. But its effort to import that repeated-desmear ***process*** limitation into claims that merely recite physical ***devices*** and articles of manufacture crossed the line to mortal sin.

This Court has warned that courts should not "blur[] [the] important difference[s] between" process and apparatus claims. *Baldwin Graphic Sys., Inc. v. Siebert, Inc.*, 512 F.3d 1338, 1344 (Fed. Cir. 2008). Courts must "take care to avoid reading process limitations into an apparatus claim . . . because the process by which a product is made is irrelevant to the question of whether that product infringes a pure apparatus claim." *Id.* Indeed, "[t]he method of manufacture, even when cited as advantageous, does not of itself convert product claims into claims limited to a particular process." *Vanguard Prods. Corp. v. Parker Hannifin Corp.*, 234 F.3d 1370, 1372 (Fed. Cir. 2000). Thus, even where a court may be justified in reading a certain process limitation into a process claim, it is still improper to read that process limitation into an apparatus claim, even if they use "similar terms." *Baldwin*, 512 F.3d at 1344.

The district court ignored those principles. When the patents-in-suit intended to claim "[a] product produced by [a] process," the claims said so expressly. *See, e.g.*, Appx0140, 14:56-59 ('105 patent claims 100-103); Appx0111, 17:9-10 ('582 patent claim 82). But none of the asserted apparatus claims (*e.g.*, '582 patent claims 85, 87, 89, 92, 94, 95, 114, 100, 109, and 122; '560 patent claim 14; and '105 patent claims 80, 82, 86, and 88) purports to be limited "to the manufacturing process set forth in the specification." *Vanguard*, 234 F.3d at 1372. The terms used, such as "surface," nowhere suggest a particular process. At a bare minimum, the district court's construction requiring that the claimed apparatuses be "produced by a repeated desmear process," Appx0006, should be reversed.

CONCLUSION

The district court's judgment should be reversed.

January 31, 2018

Respectfully submitted,

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ADDENDUM

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IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF ARIZONA

Continental Circuits LLC, Plaintiff, v. Intel Corporation, et al., Defendants.	No. CV16-2026 PHX DGC **FINAL JUDGMENT**

Pursuant to and for the reasons set forth in Continental Circuits LLC's ("Continental Circuits") and Defendants Intel Corporation, Ibiden U.S.A. Corporation, and Ibiden Co., Ltd.'s ("Defendants") September 7, 2017 Stipulation And Joint Motion For Entry Of Final Judgment Of Non-Infringement And Non-Indefiniteness ("Stipulation") (Doc. 266).

THE COURT ENTERS FINAL JUDGMENT of:

1. non-infringement of all asserted claims of U.S. Patent No. 7,501,582 ("the '582 patent"), U.S. Patent No. 8,278,560 ("the '560 patent"), U.S. Patent No. 8,581,105 ("the '105 patent"), and U.S. Patent No. 9,374,912 ("the '912 patent") (collectively the "Patents-in-Suit") in view of the Court's construction of the Category 1 terms in the Claim Construction Order (ECF No. 243); and

2. non-indefiniteness under 35 U.S.C. §112, ¶ 2 with respect to the terms "a sample of the circuitry" (claims 94, 95, and 122 of the '582 patent); "upgrade slope" (claims 85, 87, 89, 92, 94, 95, 100, 109, 114, and 122 of the '582 patent); "peel strength

greater than a peel strength that would be produced by a single desmear process" (claims 87 and 92 of the '582 patent); and "substantially greater cross-sectional distance distant from the [initial] surface" (claims 14 and 19 of the '560 patent; and claims 13, 53, 71, 80, 82, 86, 88, 91, 95, 97, 101, and 103 of the '105 patent).

The Court also **dismisses without prejudice** Defendants' defenses and counterclaims, except for those concerning indefiniteness under §112, ¶ 2 with respect to the terms listed in the preceding paragraph. Defendants may revive any defenses and counterclaims dismissed without prejudice in the event of a remand.

This is a final, appealable judgment.

Dated this 12th day of September, 2017.

David G. Campbell
United States District Judge

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IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF ARIZONA

Continental Circuits LLC, Plaintiff, v. Intel Corporation, et al., Defendants.	No. CV16-2026 PHX DGC **ORDER**

Plaintiff Continental Circuits LLC asserts claims for patent infringement against Defendants Ibiden U.S.A. Corp., Ibiden Co. Ltd., and Intel Corp. The Court held a *Markman* hearing on August 4, 2017. This order will set forth the Court's ruling on the issues addressed during the hearing and in the parties' briefs.

I. Background.

Defendant Ibiden produces layered electronic devices at its facilities overseas. *See* Doc. 133, ¶¶ 51, 110.[1] These layered devices are used in computer electronics, including computer processors manufactured by Defendant Intel. *See id.*, ¶¶ 49-51.

The devices are made of alternating layers of conductive and non-conductive materials. *See id.*, ¶ 29. When adhesion between the layers is poor, the layers can separate, creating problems for or failure of the electronic product in which they are

[1] Page citations are to numbers placed at the top of each page by the Court's CM/ECF system rather than the document's original page numbers.

incorporated. *See id.* In the 1990s, four employees of Continental Circuits, Inc., a now-defunct circuit-board manufacturer, invented a "novel surface roughening technique" using etching to create a "non-uniformly roughened surface" that allows for stronger adhesion between layers. *Id.*, ¶¶ 28-29, 120. The four co-inventors applied to patent the surface-roughening technology in 1997, and two patents were issued in 2000 and 2004. *Id.*, ¶¶ 12-13. Those patents are not at issue in this case. A continuation application was filed by early 2005, and eventually resulted in the issuance of the four patents that are at issue here: U.S. Patent Nos. 7,501,582 (2009), 8,278,560 (2012), 8,581,105 (2013), and 9,374,912 (2016) (collectively, the "patents-in-suit"). *See id.*, ¶¶ 14-17, 35-36. Copies of these patents can be found at Doc. 188-3, Exs. 1-4.

Plaintiff Continental Circuits LLC is a non-operating entity that was formed in 2016 and owns the patents-in-suit. Doc. 49, at 11 n.8; Doc. 133, ¶ 19. The day after the last of the patents-in-suit was issued, Plaintiff filed this action. *See* Doc. 1. Plaintiff alleges that Defendants have infringed the patents-in-suit.

The parties have filed a joint claim construction statement that identifies the patent terms to be addressed in this order. Doc. 177. The statement identifies three categories of claims to be construed, each of which includes a number of closely related claims found in the patents. *Id.* It also identifies four terms that Defendants claim are indefinite and therefore invalid. *Id.* The parties have filed briefs on claim construction. Docs. 188, 189, 199, 200. At the Court's request, the parties filed additional memoranda regarding the ramifications of their claim construction positions. Docs. 225, 230.[2]

II. Legal Standard.

A patent includes two basic components: (1) a written description of the invention, referred to as the "specification" of the patent, and (2) the patent claims. The claims define the scope of the invention covered by the patent. *Phillips v. AWH Corp.*, 415 F.3d

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[2] Some of the parties' filings are redacted to remove trade secrets. Unredacted versions have been filed under seal at Docs. 234-238.

1303, 1312 (Fed. Cir. 2005) (en banc). Claim construction is a matter of law to be decided by the Court. *Markman v. Westview Instruments, Inc.*, 517 U.S. 370, 372 (1996).

Words of a claim are generally given the ordinary and customary meaning the words would have for a person of ordinary skill in the art at the time of the invention. *Phillips*, 415 F.3d at 1313. "[T]he person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification." *Id.* The specification is also highly relevant. The Federal Circuit has characterized it as "the single best guide to the meaning of a disputed term." *Id.* at 1315 (quotation marks and citation omitted). A court may also consider the patent's prosecution history. *Id.* at 1317. "Like the specification, the prosecution history provides evidence of how the PTO and the inventor understood the patent." *Id.* The claims, specification, and prosecution history are commonly referred to as "intrinsic evidence."

Extrinsic evidence may also be used in claim construction. Extrinsic evidence consists of all evidence external to the patent and prosecution history, including expert and inventor testimony, dictionaries, learned treatises, and other patents. *Id.* Extrinsic evidence is viewed as less reliable than the patent and its prosecution history in determining how to read claim terms. *Id.* at 1318.

III. Category 1 Terms.

Category 1 in the parties' joint claim construction statement concerns a number of claims in the patents-in-suit that address the etching of the dielectric or epoxy layer of an electronic circuit board or comparable device. Doc. 177 at 4-9. Some of the claims simply refer to "etching the epoxy," while others refer to "etching the dielectric material," "removal of a portion of the dielectric material," "removal of some of the dielectric material," "a surface of a layer of a dielectric material," "a surface of a dielectric material," and "a dielectric material comprising a surface." *Id*. Plaintiff contends that these phrases require no construction. Defendants contend that each phrase should be construed to include a requirement that the etching, removal, or modification of the dielectric material be "produced by a repeated desmear process." *Id*.

As Plaintiff correctly notes, Defendants do not contend that the actual words of the claims provide this additional meaning. Rather, Defendants seek to add a limitation to the claims – namely, that the etching or alteration of the dielectric material occur through a repeated desmear process. Because the plain and ordinary meaning of the phrases at issue does not include Defendants' proposed limitation, Defendants carry a heavy burden. The Federal Circuit has explained that there are only two exceptions to the rule that claims are given their plain and ordinary meaning: "1) when a patentee sets out a definition and acts as his own lexicographer, or 2) when the patentee disavows the full scope of a claim term either in the specification or during prosecution." *Thorner v. Sony Computer Entm't Am. LLC*, 669 F.3d 1362, 1365 (Fed. Cir. 2012). The standard Defendants must meet for either of these exceptions is "exacting." *Id.* at 1366.

"To act as its own lexicographer, a patentee must 'clearly set forth a definition of the disputed claim term' other than its plain and ordinary meaning." *Id.* at 1365 (quoting *CCS Fitness, Inc. v. Brunswick Corp.*, 288 F.3d 1359, 1366 (Fed. Cir. 2002)). "It is not enough for a patentee to simply disclose a single embodiment or use a word in the same manner in all embodiments, the patentee must 'clearly express an intent' to redefine the term." *Id.* (quoting *Helmsderfer v. Bobrick Washroom Equip., Inc.*, 527 F.3d 1379, 1381 (Fed. Cir. 2008)).

A disavowal also must be "clear and unmistakable." *Id.* at 1367. "'Where the specification makes clear that the invention does not include a particular feature, that feature is deemed to be outside the reach of the claims of the patent, even though the language of the claims, read without reference to the specification, might be considered broad enough to encompass the feature in question.'" *Id.* at 1366 (quoting *SciMed Life Sys., Inc. v. Advanced Cardiovascular Sys., Inc.*, 242 F.3d 1337, 1341 (Fed. Cir. 2001)). "'The patentee may demonstrate intent to deviate from the ordinary and accustomed meaning of a claim term by including in the specification expressions of manifest exclusion or restriction, representing a clear disavowal of claim scope.'" *Id.* (quoting *Teleflex, Inc. v. Ficosa N. Am. Corp.*, 299 F.3d 1313, 1325 (Fed. Cir. 2002)).

After careful review of the patents-in-suit, the Court concludes that Defendants have met the exacting standard required to adopt their proposed limitation.

A. The Patents' Disavowal of Prior Art.

The Federal Circuit has found disavowal when a patent "repeatedly disparaged an embodiment as 'antiquated,' having 'inherent inadequacies,' and then detailed the 'deficiencies [that] make it difficult' to use." *See GE Lighting Solutions, LLC v. AgiLight, Inc.*, 750 F.3d 1304, 1309 (Fed. Cir. 2014) (quoting *Chi. Bd. Options Exch., Inc. v. Int'l Sec. Exch., LLC*, 677 F.3d 1361, 1372 (Fed. Cir. 2012)). For example, in *Inpro II Licensing, S.A.R.L. v. T-Mobile USA, Inc.*, 450 F.3d 1350, 1354-55 (Fed. Cir. 2006), the Federal Circuit affirmed the construction of "host interface" as a "direct parallel bus interface." The court noted that the only embodiment disclosed was a direct parallel bus interface and that "the specification emphasizes the importance of a parallel connection in solving the problems of the previously used serial connection." *Id.* This discussion demonstrated "what the inventor has described as the invention." *Id.* at 1355; *see also OpenWave Sys., Inc. v. Apple Inc.*, 808 F.3d 509, 513-17 (Fed. Cir. 2015) (narrowly construing claim term "mobile device" to exclude communication devices containing a "computer module" based on limiting statements in specification that disparaged prior art communication devices containing such "computer modules"); *Fed. Retractable Techs., Inc. v. Becton, Dickinson & Co.*, 653 F.3d 1296, 1305 (Fed. Cir. 2011) (limiting scope of syringe "body" to a one-piece body based in part on distinction of prior art syringes composed of multiple pieces); *SciMed*, 242 F.3d at 1341 (finding disavowal based on disparagement of a particular embodiment and statements that the "present invention" does not include the embodiment).

The specification, which is common to all the patents-in-suit, provides this introduction: "The present invention is directed to methods for making or manufacturing an electrical device, and the process, composition, and product thereof. More particularly, the present invention involves such multi-layer electrical devices as circuit boards constructed by joining a dielectric material to a subsequently applied conductive material." '582 Patent at 1:13-18.[3] The purpose of the invention is to improve on multi-layer electrical devices that "suffer from delamination, blistering, and other reliability problems. This is particularly true when the laminates are subject to thermal stress." *Id.* at 1:30-32.

The specification explains that the patented invention produces a stronger bond between the dielectric layer and the conductive layer by forming teeth in each layer that interlock with each other. "The surface structure is comprised of teeth that are preferably angled or hooked like fangs or canine teeth to enable one layer to mechanically grip a second layer." *Id*. at 1:54-57.

The specification then proceeds to explain the process by which these teeth are formed in the manufacturing of a multi-layer electrical device. Step 6 is the relevant step for purposes of Category 1 claims. Step 6 "involves the etching [of] cavities, veins, openings, or gaps in the applied dielectric material, or more particularly an outermost surface thereof, to accommodate the teeth." *Id.* at 5:37-40. The process by which layers of dielectric material are prepared for boding to a conductive layer is known as a "desmear" process. The '582 Patent repeatedly distinguishes the process covered by the patent from the prior art and its use of a "single desmear process." Five portions of the specification are particularly relevant.

First, the specification explains that "[o]ne technique for forming the teeth is somewhat similar to what has been known as the swell and etch or desmear process, except that ***contrary to all known teachings in the prior art, in effect, a 'double desmear process' is utilized.***" *Id.* at 5:41-44.[4] The description then becomes even more specific: "That is, not merely increasing the times and temperatures and other parameters for the

[3] The parties' Category 1 arguments all focus on the '582 Patent. The Court will focus on that patent as well. The Court's citations to portions of a patent throughout this order will include a column number and line numbers, separated by a colon.

[4] All bolded and italicized emphases in this order have been added by the Court.

desmear process, ***but instead completing the process a first time, and then completing the process a second time***." *Id.* at 5:44-48.[5]

Second, the patent explains that "the desmear process ***as disclosed herein*** is contrary to the manufacturer's specification, ***i.e., a 'double desmear process,' rather than the single desmear process of the known prior art***." *Id.* at 5:60-63. This statement not only equates the prior art with a "single desmear process," but specifically states that "the desmear process as disclosed herein" is "contrary" to that prior art.

Third, the specification explains:

> the peel strength produced in accordance with ***the present invention*** is greater than the [peel] strength produced by ***the desmear process of the prior art, i.e., a single pass desmear process***. For example, if a ***prior art desmear process*** is used to produce a 6 lb/in average peel strength, ***the present invention*** may produce an average peel strength on the order of 10 lb/in or more.

Id. at 7:3-9. This statement again equates the prior art with "a single pass desmear process," and states that "the present invention" produces a greater strength than that prior art.

Fourth, the patent recommends the use of Probelec XB 7081 for creation of the dielectric layer. The specification contains this explanation:

> Although Probelec XB 7081 apparently was intended for use in the common desmear (swell and etch) process as used in conventional plated through hole plating lines, Probelec XB 7081 ***can alternatively be used in carrying out the present invention***. For example, ***the present invention differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth***.

Id. at 8:45-52. This language explains that although Probelec XB 7081 was intended for the prior art process of single desmear, it "can alternatively be used in carrying out the present invention." In other words, the prior art single desmear process is not "the

[5] Plaintiff emphasizes that this description applies to "[o]ne technique for forming the teeth," arguing that this is only an illustration. The Court will address this argument below.

present invention." It also explains precisely how "the present invention" differs from the prior art: "sub-steps in the desmear process are repeated as a way of forming the teeth."

Fifth, the specification contains this strong statement: "In ***stark contrast*** with the etch and swell process of the ***known prior art***, however, a second pass through the process (sub-steps A through F) is used. The second pass seems to make use of non-homogeneities in bringing about a formation of the teeth." *Id.* at 9:1-9. This language draws a "stark contrast" between the "known prior art" and the current invention's "second pass through the process."

In summary, these statements identify the "swell and etch" or "single desmear" process as the "prior art," the "known prior art," the "common desmear process," and "the desmear process of the prior art," and expressly distinguish that prior art from the patented invention. The specification states that the invention is "contrary to all known teachings in the prior art" (*id.* at 5:43-48), is "contrary" to "the single desmear process of the known prior art" (*id.* at 5:61-63), "differs from the common desmear process" (*id.* at 8:50-52), and stands in "stark contrast" with the "known prior art" (*id.* at 9:1-3). These statements are clear and strong. They do not merely point out deficiencies in the prior art, they state with emphasis that this invention is different from the prior art. They make clear that the invention does not include the prior art's single desmear process.

B. "The Present Invention."

When an inventor describes "the present invention" as including particular elements, it can be viewed as a disavowal of a broader scope that might otherwise apply. *See Hill-Rom Servs., Inc. v. Stryker Corp.*, 755 F.3d 1367, 1372 (Fed. Cir. 2014) ("[W]e have held that disclaimer applies when the patentee makes statements such as 'the present invention requires . . .' or 'the present invention is . . .' or 'all embodiments of the present invention are . . .'"); *see also Pacing Technologies, LLC v. GarminIntern., Inc.*, 778 F.3d 1021, 1025 (Fed. Cir. 2015).

In *Honeywell Int'l, Inc. v. ITT Indus., Inc.*, 452 F.3d 1312, 1318 (Fed. Cir. 2006), the court addressed a "fuel injection system component." Although the ordinary meaning of a "fuel injection system component" is not limited to a fuel filter, the Federal Circuit found that the proper construction was narrower than the customary meaning and was limited to a filter. The court noted that the specification repeatedly described the fuel filter as "this invention" and "the present invention," and held that "[t]he public is entitled to take the patentee at his word and the word was that the invention is a fuel filter." *Id.*; *see also Edwards Lifesciences LLC v. Cook Inc.*, 582 F.3d 1322, 1327 (Fed. Cir. 2009) (limiting the claim term "graft" to mean "intraluminal graft" when "the specification frequently describes an 'intraluminal graft' as 'the present invention' or 'this invention'").

As shown in the quotations above, the specification states that "the peel strength produced in accordance with ***the present invention*** is greater than the [peel] strength produced by the desmear process of the prior art, i.e., a single desmear process." '582 Patent at 7:3-6. This statement suggests "the present invention" produces results different from the single desmear process. The specification also states that "***the present invention*** differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth." *Id.* at 8:50-52. This statement clearly asserts that "the present invention" – not just the embodiment discussed in the specification as an example – differs from the prior art because it involves a repeat of the desmear process. The specification further states that "***the desmear process as disclosed herein*** is contrary to the manufacturer's specifications, i.e., a 'double desmear process,' rather than the single desmear process of the known prior art." *Id.* at 5:59-63. Although this statement is addressing the specifications of the XB 7081, it also states that "the desmear process as disclosed" in the patent is a "double desmear process." These statements unmistakably affirm that "the present invention" differs from the single desmear process of the prior art.

C. Prosecution History and Other Portions of the Patents.

As Defendants note, the examiner rejected all pending claims during prosecution of the '560 Patent. Doc. 188-3 at 155. In response, the applicants submitted a declaration from Professor C.P. Wong, Ph.D, which included this explanation:

> As described in this paragraph, performing two separate swell and etch steps is a technique which forms the teeth. Although how this occurs within the dielectric material is not recited with in-depth detail, I understand the specification as informing that the teeth formation results from the release of some solid content in the first etching pass, forming irregular recesses and volume displacement. By forming the irregular releases in the first etching pass, an opening within the dielectric material would then be enlarged in the second etch pass, making the structure shown in Figure 1 and recited in the claims[.]

Doc. 188-3 at 109.

This statement clearly describes the patented method as involving two etching processes. Although Plaintiff correctly notes that Dr. Wong refers only to "a technique" as opposed to "the technique," Dr. Wong explains that the patented teeth are created by the second etching pass. This part of the prosecution history corroborates the conclusions reached above, even if not sufficient on its own to find disavowal.

Other portions of the patents also support the conclusions reach above. For example, the '582 Patent includes claims which assert that the products produced by the patented process are superior to products created by "a single roughening process," "a single pass roughening," or "a single desmear process." *See, e.g.*, '582 Patent at 10:25, 10:33-34, 11:4, 11:11, 11:48, 11:55, 12:2, 12:15, 12:42-43, 12:59, 14:7, 17:34, 17:38-39, 18:1, 18:6, 18:36-37, 18:41-42, 19:10-11, 19:14-15, 19:26. 19:40, 19:66-67, 20:15-16. These claims are not at issue in this case, but both sides agreed during the *Markman* hearing that the Court can consider them in this order. Their wording confirms that the present invention is different from a single desmear process.

Defendants also point to extrinsic evidence that supports the Court's conclusion. Documents produced by the inventors state that "a two pass desmear cycle doubles the peel strength of a one pass desmear cycle, but varying the times in the cycle do not seem to have that great of an effect." Doc. 235-2, Ex. 26. The primary inventor of the patented product, Brian McDermott, wrote in a 1998 letter that "we use a double pass desmear to achieve the tooth structure." Doc. 235-3, Ex. 30. This extrinsic evidence, although not reliable enough to be dispositive, provides helpful corroboration of the Court's conclusion. *Phillips*, 415 F.3d at 1319 (explaining that extrinsic evidence "may be useful to the court").

D. Plaintiff's Arguments.

Plaintiff relies on the principle of claim differentiation and argues that references to a repeat desmear process are found in several independent claims, but not in dependent claims. Doc. 189 at 16. Plaintiff notes that "the presence of a dependent claim that adds a particular limitation gives rise to a presumption that the limitation in question is not present in the independent claim." *Phillips*, 415 F.3d at 1315.

The claim differentiation presumption can be overcome by clear indicia in the specification and prosecution history. As the Federal Circuit has explained, "claim differentiation is a rule of thumb that does not trump the clear import of the specification." *Edwards*, 582 F.3d at 1332; *see also Seechange Int'l, Inc. v. C-COR, Inc.*, 413 F.3d 1361, 1369 (Fed. Cir. 2005) (noting that claim differentiation is "not a hard and fast rule and will be overcome by a contrary construction dictated by the written description or prosecution history.").

The Court finds, for reasons explained above, that the specification clearly distinguishes between the current invention and the prior art of a single desmear process. The clear and unequivocal rejection of that prior art overcomes any presumption raised by claim differentiation.

Plaintiff also notes that the specification begins its discussion of the double desmear process by describing it as "[o]ne technique for forming the teeth[.]" '582 Patent at 5:40-41. Although this is true, the patent then proceeds to explain at length the difference between the current invention and the prior art single desmear process. As already noted, in two places the specification distinguishes this prior art from "the present invention." Thus, although the specification does include a reference to "one technique," the subsequent, detailed explanation makes clear that the patented invention is different from the single desmear process.

Similarly, the words "for example" in one portion of the specification do not suggest that the double desmear process is only an illustration of one embodiment of the patented invention. *Id.* at 8:49-50. Rather, the language is used to explain why XB 7081, which is normally made for a single desmear process, "can alternatively be used in carrying out the present invention." *Id*. at 8:48-49. The specification states: "For example, the present invention differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth." *Id*. at 8:49-52. Thus, the example is not one means by which the invention may be embodied, but an explanation of why XB 7081 can be used with the patented product – by repeating the desmear process for which XB 7081 was designed.

Plaintiff notes that an early statement in the specification refers to methods of production other than repeated desmearing: "For example, a dielectric material can have a non-homogeneous composition or thickness to bring about an uneven chemical resistance, such that ***slowed and/or repeated etching*** will form teeth instead of the uniform etch." *Id*. at 2:27-30. Plaintiff argues that this sentence identifies "slowed" etching as an additional method for making the patented invention, in contrast to repeated etching. The word "slowed" does appear once in the specification, but the Court cannot conclude that this single word justifies a finding that the patents include the single desmear process.

As explained above, the balance of the specification makes clear that the single desmear process of the prior art is not part of the invention. In fact, it is part of the problem the invention was designed to overcome. Defendants' expert, Dr. Srini Raghavan, also credibly explains in his declaration that a person of ordinary skill in the art would not read the word "slowed" in the context of the patents to mean that the patents embrace single-pass desmearing. Doc. 199-3, ¶¶ 15-17. Finally, language in the specification and in the extrinsic evidence suggests that varying the times of a single desmear process does not produce the teeth that are key to the invention. *See* ’582 Patent at 5:43-47; Doc. 235-2, Ex. 26. For these reasons, the Court cannot accept Plaintiff’s argument that the single word “slowed” constitutes an alternative embodiment of the patented invention. *See Trustees of Columbia University in City of New York v. Symantec Corp.*, 811 F.3d 1359, 1366 (Fed. Cir. 2016) (explaining that “[t]his single sentence in the specification cannot overcome the overwhelming evidence in other parts of the specification”).

Finally, the Court notes that the boilerplate disclaimer of lexicography and disavowal at the end of the specification does not alter its conclusion. ’582 Patent at 9:18-25. The Court finds the detailed and repeated explanation of the specification, not this disclaimer, to be controlling.

IV. Category 2 Terms.

The parties’ second category of disputed claims includes the following phrases from the ’560, ’105, and ’912 Patents: “Epoxy dielectric material delivered with solid content,” “epoxy dielectric material . . . the dielectric material delivered with solid content,” “dielectric material delivered with solid content,” “dielectric material that is delivered with solid content,” and “dielectric material delivered with . . . solid content.” Doc. 177 at 12-13. Defendants contend that each of these phrases should be construed to mean dielectric material “delivered with solid particles suspended in a liquid.” *Id.* Plaintiff contends that no construction is necessary. Alternatively, Plaintiff contends that the phrases should be interpreted to include “dielectric material having solid particles suspended in the dielectric material.” *Id.* The dispute is whether the patents require the use of liquid dielectric material in manufacturing the multi-layer electronic devices they cover. For several reasons, the Court concludes that Plaintiff is correct – the patents do not require use of a liquid dielectric material.

A. Plain and Ordinary Meaning.

As noted above, words of a claim are generally given the ordinary and customary meaning the words would have to a person of ordinary skill in the art at the time of the invention. *Phillips*, 415 F.3d at 1313. The Court concludes that the plain and ordinary meaning of the words in Category 2 does not require use of a liquid dielectric material.

The parties agree that dielectric material can be applied either in solid or liquid form. Neither side argues that the simple phrase "dielectric material" necessarily specifies one or the other. Given this fact, the Court concludes that the plain and ordinary meaning of "epoxy dielectric material delivered with solid content" or "dielectric material delivered with solid content" is delivery of a dielectric material the content of which is solid. Were it not for other portions of the patents, the Court would be inclined to conclude that the form of dielectric material specified in the claims is solid. This is precisely opposite the argument made by Defendants – that the ***only form*** of dielectric material permitted under the claims is liquid. The plain meaning does not support Defendants' position.

B. Specification.

The specification provides clarification. Dielectric material is applied to the multi-layer electronic device in Step 3 of the process described in the patents. The specification gives this description of Step 3:

> Step 3 includes applying the dielectric material to the outermost surface of the conductive layer (and the base if appropriate for the circuitry or electrical device at issue) prepared in accordance with step 2. ***The dielectric material can be applied by as [sic] a (dry film), a (liquid) curtain coating, a (liquid) roller coating, or an analogous application or bonding technique.***

'582 Patent at 5:15-21.[6] This language explains that the patented invention can use either dry or liquid dielectric material. The explanation is unambiguous.

[6] Some sentences in the specification include numbers that refer to specific components of the figures shown at the beginning of the specification. Quotations throughout this order omit those numbers.

The specification goes on to provide a preferred embodiment for the invention. It includes this explanation:

> Turning now particularly to the process for forming the teeth and the cavities for the teeth, the present invention ***can be carried out*** by a new use of a CIBA-GEIGY product known as Probelec XB 7081 as a photoimagable dielectric material. Generally, and in accordance with its specifications sheet, Probelec XB 7081 is a single component, 100% epoxy photodielectric material especially developed for . . . multi-layer boards.

Id. at 6:41-48.

As is clear from this language, the use of XB 7081 is a preferred embodiment, an illustration. The specification says only that the patent "can be carried out" by using this product, which is a liquid, not that it must be carried out in this manner. Later portions of the specification continue discussion of this preferred embodiment. When the specification describes the method for applying the dielectric material, it again uses XB 7081 as an illustration. *Id*. at 7:15-37.

"[I]t is improper to read limitations from a preferred embodiment described in the specification – even if it is the only embodiment – into the claims absent a clear indication in the intrinsic record that the patentee intended the claims to be so limited." *Liebel-Flarsheim Co. v. Medrad, Inc.*, 358 F.3d 898, 913 (Fed. Cir. 2004). Unlike the Category 1 phrases discussed above, where the specification clearly distinguishes the invention from the prior art single desmear process, the specification and other intrinsic evidence contain no clear indication that the dielectric material to be used in the patented process must be liquid. Nor does the specification describe "the present invention" as not including solid forms of dielectric material. For a court to find that a specification has disclaimed a particular possible interpretation of the claims, "there must be a clear and unmistakable disclaimer." *Thorner*, 669 F.3d at 1366-67; *see also Pacing Techs.*, 778 F.3d at 1024. The patents' preferred embodiment of XB 7081 does not constitute a clear and unmistakable disclaimer of a solid dielectric material.

C. Prosecution History.

Defendants look to the prosecution history to support their argument that the dielectric material must be applied in liquid form. Doc. 188 at 14-15. But the legal standard for finding a prosecution history disclaimer requires "a clear and unmistakable disavowal of scope during prosecution." *Purdue Pharma L.P. v. Endo Pharm. Inc.*, 438 F.3d 1123, 1136 (Fed. Cir. 2006). Ambiguous statements in the prosecution history will not support a finding of disclaimer. *SanDisk Corp. v. Memorex Prods., Inc.*, 415 F.3d 1278, 1287 (Fed. Cir. 2005) ("There is no 'clear and unmistakable' disclaimer if a prosecution argument is subject to more than one reasonable interpretation, one of which is consistent with a proffered meaning of the disputed term."); *see also LG Elecs., Inc. v. Bizcom Elecs., Inc.*, 453 F.3d 1364, 1373-74 (Fed. Cir. 2006) (finding that prosecution history statements were not sufficiently clear to justify limiting claims), *reversed on other grounds by Quanta v. LG Elecs.*, 128 S. Ct. 2109 (2008).

Defendants note that the examiner for the '560 Patent rejected a number of claims because "[i]t is not clear as to what is meant by a dielectric material being delivered with solid content and it is also unclear as to how epoxy uses non-homogeneity with the solid content." Doc. 183 at 158. The applicants responded with a document submitted on June 25, 2012. Doc. 188-3 at 96-109. The document attached a declaration by Dr. Wong. *Id.* at 107-109. The relevant portions of the document provide this explanation:

> Dr. Wong testifies that, from the identified passages of the specification of the subject application, one of ordinary skill would understand that the specification disclosed the use of a generally liquid epoxy non-homogeneous dielectric, specifically as noted by the Examiner in the Action Sentence bridging [pages] 3 and 4. As noted by Dr. Wong, by describing the epoxy as having a solid content of 58%, one skilled in the art would understand that Probelec XB 7081 includes solid particles suspended in a generally liquid epoxy.
>
> * * *
>
> As discussed above, the specification describes the use of a "dielectric material" with "non-homogeneous composition . . . to bring out uneven chemical resistance, such that slowed and/or repeated etching will form teeth instead of a uniform etch." The operation of this aspect of the process of the present application is explained in the Declaration, Paragraph 7. In addition, the Specification describes the use of an epoxy, e.g., Probelec

> XB 7081, having "a solid content of 58%." By describing the epoxy as having a solid content of 58%, one skilled in the art would understand that Probelec XB 7081 includes solid particles in a percentage of 58% suspended in a generally liquid epoxy and that utilization of an epoxy "delivered with solid content" similar to Probelec as the applied dielectric material.

Id. at 103-104. Defendants also emphasize this paragraph from Dr. Wong's attached declaration:

> I have been asked to comment on the question of disclosure in the original specification for the claim language requiring an epoxy dielectric material delivered with solid content . . . . A particular example of this epoxy having solid content is disclosed as Probelec XB 7081 as described in paragraphs (0051-0065). Paragraphs (0051 to 0060) describe the various properties of this epoxy material. In paragraph (0056), McDermott discloses a "solid content of 58%." By describing this epoxy as having a solid content of 58%, I understand that Probelec XB 7081 includes solid particles suspended in a generally liquid epoxy.

Id. at 108.

Defendants contend that this language amounts to a disclaimer of solid dielectric material for the patented process. The Court does not agree.

Portions of the quoted language simply describe XB 7081, the product used in the specification's preferred embodiment. These portions state that XB 7081 includes solid particles suspended in a generally liquid epoxy. Such a description of a product used in a preferred embodiment does not constitute a disclaimer of all other possible forms of dielectric material.

Other portions of the quoted language refer to epoxy "having a solid content of 58%," and state that one skilled in the art would understand this to mean a liquid containing solid particles. But the reference to 58% does not appear in any of the Category 2 claims to be construed – they all refer to dielectric material "delivered with solid content." The fact that dielectric material "having a solid content of 58%" suggests a liquid with 58% solid particles, as the statements from the prosecution history say, does not mean that the phrase "delivered with solid content," standing alone, also means a liquid. At most, the statements are ambiguous.

The prosecution history does not clearly and unmistakably disavow use of solid dielectric materials. *Purdue*, 438 F.3d at 1136. As a result, the Court cannot rely on the prosecution history as a basis for concluding that solid dielectric materials are excluded from the patent. To the contrary, the specification expressly states that a dry film dielectric material may be used.

V. Category 3.

The parties' third category of claim terms are "means-plus-function limitations." Doc. 177 at 2-3. The relevant statute provides that "[a]n element in a claim for a combination may be expressed as a means or a step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim ***shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.***" 35 U.S.C. § 112(f). When this statute applies to a claim, the claim is construed by identifying the "function" associated with the plain language, and then identifying the corresponding "structure" in the specification that is associated with that function.

The parties have identified three claim terms requiring construction, and agree that each of these terms constitutes a means-plus-function limitation. The parties also agree on the function for each term. The Court's task, therefore, is to find the corresponding "structure" in the specification for each function.

The first limitation, found in the '582 Patent, is "means for joining the conductive layer to the dielectric material." Doc. 177 at 15. The parties agree that this claim has the following function: "joining the conductive layer to the dielectric material." *Id*.

The second claim also comes from the '582 Patent and reads: "means for mechanically gripping a conductive layer to the surface of the dielectric material so that the conductive layer is burrowed in and under the top surface of the dielectric material." *Id*. The parties agree on the following function for this claim: "mechanically gripping a conductive layer to the surface of the dielectric material so that the conductive layer is burrowed in and under the top surface of the dielectric material." *Id.*

The third term comes from the ’105 Patent and reads: “means for interlocking a conductor part of the circuitry configured for filling cavities with an epoxy dielectric material disposed in combination with the circuitry and coupled with the conductor part.” *Id.* at 116. The parties agree on this function: “interlocking a conductor part of the circuitry configured for filling cavities with an epoxy dielectric material disposed in combination with the circuitry and coupled with the conductor part.” *Id.*

The parties disagree on the structure that should correspond to each claim. With respect to the first claim, Plaintiff asserts that the structure should be Figure 1 of the ’582 Patent, together with the following statement from the specification: “It could also be said that the layers joined in a saw-toothed manner, i.e., teeth made of both materials in an interlocking bite.” Defendants, on the other hand, contend that the structure should include seven paragraphs from the ’582 Patent specification – paragraphs that discuss the connection between the dielectric material and the conductive layer in considerable detail. These paragraphs include a discussion of teeth, a saw-toothed description of the teeth, a triangular shape description of the teeth, canine or fang-shaped teeth, and preferable sizes and frequencies for the teeth. ’582 Patent at 3:18 to 4:11.

With respect to the second claim term, Plaintiff contends that the corresponding structure consists of Figure 1 and the following statement:

> However, the preferred embodiment utilizes a surface of obtuse, canine, or fang-shaped teeth to help the conductive coating hook under the exterior surface of the applied dielectric material to mechanically grip the applied dielectric material. The obtuse, canine, or fang-shaped teeth are in contrast to the shallower, more rounded surface typically produced by known roughening techniques. Note in FIG. 2 that roughening techniques can produce some occasional gouging but nothing on the order of the present invention.

’582 Patent at 3:42-51. Defendants propose the same seven-paragraph structure that they advocate with respect to the first claim.

For the third claim, which is found in the ’105 Patent, Plaintiff proposes that the structure include Figure 1 and the following language from the specification:

> The invention can be carried by forming cavities in the applied dielectric material for receiving the teeth, and then forming the teeth from the conductive coating and metal layer formed thereon. Generally, the teeth can be of any triangular shape (e.g., equilateral, isosceles, scalene, right, obtuse, or any combination thereof). Preferably, though, the teeth are obtuse so as to hook or angle under the exterior surface of the applied dielectric material.

’105 Patent at 3:40-47. Defendants propose the same seven-paragraph structure that they propose for the other claims. *Id.* at 3:26-4:29.

The Federal Circuit has instructed “that corresponding structure must include all structure that actually performs the recited function.” *Cardiac Pacemakers, Inc. v. St. Jude Medical, Inc.*, 296 F.3d 1106, 1119 (Fed. Cir. 2002); *see also Callicrate v. Wadsworth Mfg., Inc.*, 427 F.3d 1361, 1369 (Fed. Cir. 2005) (holding that it was error for the district court to limit the corresponding structure to the preferred embodiment and not include “all structure in the specification corresponding to the claimed function”). In light of this guidance, the Court concludes that Plaintiff’s proposed structures are too narrow. Although they include some discussion of the means by which the conductive and dielectric layers adhere to each other, those discussions do not include “all structure” described in the specification “that actually performs the recited function.” *Cardiac Pacemakers*, 296 F.3d at 1119. The Court also disagrees with Plaintiff’s suggestion that the words “joining,” “mechanically gripping,” and “interlocking” have different meanings. These terms are not defined in the patents. Each is used to describe the means by which the layers adhere to each other. And, as Defendants note, these terms are used interchangeably in some parts of the specification. *See, e.g.*, ’582 Patent at 1:50-57, 3:21-23.

The seven paragraphs identified by Defendants describe the structure by which the dielectric material adheres to the conductive layer in more detail, but even they leave out some structure, and the Court has difficulty understanding how these technical and lengthy paragraphs could be used by a jury to determine whether the accused products infringe. Indeed, both sides acknowledged during the *Markman* hearing that it would be best to prepare for the jury a short and clear description of the structure that corresponds to the functions identified above.

The disagreement between the parties seems to be over which portions of the structure discussed in the specification must be present for a product to infringe. Plaintiff contends that the presence in the accused product of any part of the structure will be sufficient. Defendants argue that at least four different components of the structure must be present before infringement is found. Defendants identify these components by looking to parts of the specification that are not included in their seven paragraphs of proposed structure.

The Court concludes that the parties' *Markman* briefs do not provide a sufficient discussion of the law or the specification for the Court to resolve this disagreement. As a result, the Court will require the parties to do the following:

1. Develop an agreed-upon description of each element of structure found in the specification that relates to the adhering function of these claims. This can include separate paragraphs for each element (tooth shape, frequency, size, etc.) or a narrative description of the entire structure. It should be in language suitable for a jury instruction.
2. Brief two questions: (1) As a legal matter, how many elements of a structure must be present in an accused product for a finding of infringement? (2) How does that law apply to these patents – what elements of structure disclosed in the specification must be present for an accused product to infringe in this case?
3. The parties shall confer and, within 10 days of this order, propose a schedule for completing these tasks, including page limitations.

VI. Indefiniteness.

The relevant statute provides that "[t]he specification shall conclude with one or more claims ***particularly pointing out and distinctly claiming*** the subject matter which the applicant regards as his invention." 35 U.S.C. § 112(b). This requirement ensures that a patentee adequately notifies the public of the scope of his or her invention. "A patent is invalid for indefiniteness if its claims, read in light of the specification delineating the patent, and the prosecution history, fail to inform, with reasonable certainty, those skilled in the art about the scope of the invention." *Nautilus v. Biosig Instruments, Inc.*, 134 S.Ct. 2120, 2123 (2014). At the same time, however, "absolute precision is unattainable." *Id.* Courts therefore "must take into account the inherent limitations of language" and allow a "modicom of uncertainty" so as to provide appropriate incentives for innovation. *Id.* at 2128. Because an indefinite claim is an invalid claim, an accused infringer must prove indefiniteness clearly and convincingly. *Bancorp Servs., LLC v. Hartford Life Ins. Co.*, 359 F.3d 1367, 1371 (Fed. Cir. 2004).

A. "A Sample of the Circuitry."

Claims in the '582 Patent require that "a sample of the circuitry" have a frequency of teeth sufficient to provide at least 5,000 teeth per linear inch. '582 Patent, Claims 94, 95, 122. Defendant contends that the phrase "a sample of the circuitry" is indefinite because it does not provide enough precision for a person skilled in the art to determine the scope of the invention with reasonable certainty. *See Nautilus*, 134 S.Ct. at 2129. The Court does not agree.

The specification begins by identifying the location of the teeth that are critical to the patent. Figure 1 is a magnified photograph of the interface between a conductive layer and a dielectric layer in a device made according to the patent, and clearly illustrates the teeth of the two layers that interlock with each other. Figure 2 is a magnified photograph of the same interface in a device made by the prior art. The boundary between the two layers is much smoother and lacks the cavities and teeth illustrated in Figure 1. The specification then provides this explanation:

> FIG. 1 is an illustration of a conductive coating and metal layer on the applied dielectric material with a desirable tooth structure. In contrast, FIG. 2 is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes. . . . Compare FIG. 1 and FIG. 2, and note particularly the size, shape, frequency, and depth of the teeth in FIG. 1 with the surface produced by roughening in FIG. 2.

’582 Patent at 3:8-17.

The specification proceeds to explain the nature of the teeth called for by the patents:

> As to frequency, the teeth should be quite frequent in number; at least about 5,000 teeth per linear inch, and preferably about 10,000 per linear inch; and even better is at least about 15,000 teeth per linear inch.
>
> As to surface area, there should be at least about 25,000 teeth per square inch, better still is essentially at least about 100,000 per square inch, and preferably at least about 200,000 per square inch, or even greater.

Id. at 3:62 to 4:2

Having described this tooth frequency, the specification explains:

> It should be recognized that the teeth generally are not formed to a precise dimension. As shown in FIG. 1, some of the teeth are somewhat differently sized, angled, and proportioned. Thus, ***a representative sample*** of the electrical device should have teeth in about these ranges.
>
> Having at least about 20% of the teeth in one or more of these ranges, and preferably about 50% is a preferred balance of mechanical grip without a weakening [of] the integrity of the layer, particularly in combination.

Id. at 4:3-11.

Several points are apparent from this quoted language. First, the teeth are located at the interface between the dielectric material and the conductive layer. Second, the frequency of the teeth should be at least 5,000 per linear inch and 25,000 per square inch. Although Defendants protest that they don’t know where these teeth are located, Figure 1 and this language makes clear that they are located in the interface between the two layers. Third, the specification states that “a representative sample of the electrical device should have teeth in about these ranges.” *Id.* at 4:6-7.

In light of this specification, claims in the ’582 Patent are not indefinite. Claim 94 states that the patented device includes “a conductive layer of material built up on a surface on a layer of dielectric materials, the layers joined in a saw-tooth manner made of both materials in an interlocking bite.” *Id.* at 18:14-17. The claim then states: “[T]he conductive layer is a portion of circuitry of an electrical device, the conductive layer is comprised of teeth such that a sample of the circuitry has a frequency of the teeth sufficient to provide at least 5,000 of the teeth per linear inch." *Id.* at 18:18-22. According to this language, the conductive layer is a portion of the circuitry, and a sample of the circuitry – the conductive layer – should show a frequency of teeth sufficient to provide at least 5,000 teeth per linear inch. In light of the specification's suggestion that the samples should be "representative," and its unambiguous explanation that the location of the teeth and the area to be sampled is the interface between the dielectric and conductive layers, the Court concludes that a person reasonably skilled in the art could determine how to obtain such a sample.

Defendants argue that the size and location of the sample are not specified in the claim. True, but the size clearly must be large enough to show "a frequency of the teeth sufficient to provide at least 5,000 of the teeth per linear inch," and, according to the specification, should be a "representative sample." The parties may disagree on how big that sample ought to be, but the Court cannot conclude that such disagreement makes this claim indefinite. Persons of ordinary skill in the art would understand a sample size large enough to be representative of the interface as a whole.

The Court disagrees with Defendants' argument that the location of the sample is unknown, or that the sample might even be taken from locations in the electronic device other than the interface between the dielectric material and the conductive layer. Reading the specification leaves no doubt as to the meaning of the claim: the interface is the location of the teeth to be sampled, and the teeth in the interface must be shown by sampling to have a frequency of at least 5,000 per linear inch.

B. "Upgrade Slope."

Claims in the '582 Patent call for the formation of cavities in the dielectric material "wherein at least one of the cavities includes an upgrade slope with respect to the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope." '582 Patent at 17:58-61. Defendants claim that the phrase "upgrade slope" is indefinite because a person of ordinary skill could not distinguish when a slope is "upgrade" as opposed to "downgrade," or where the slope is located. Plaintiff responds that the slope, according to the language of each claim at issue, calls for "an upgrade slope ***with respect to the surface of the dielectric material***." *See, e.g.*, '582 Patent, Claims 89, 94. Plaintiff argues that this language shows that "upgrade slope" describes the orientation of cavity walls in relation to the surface of the dielectric material. Doc. 200 at 15.

The specification includes this explanation:

> A further way of articulating the "teeth" concept is to view each tooth as being substantially triangular in shape, with the base of the triangle being a plain of the dielectric material before it is etched, or more precisely by the exterior surface thereof. The invention can be carried out by forming cavities in the applied dielectric material for receiving the teeth, and then forming the teeth from the conductive coating and then a layer formed thereon. Generally, the teeth can be of any triangular shape, e.g., equilateral, isosceles, scalene, right, obtuse, or any combination thereof". Preferably, though, the teeth are obtuse so as to hook or angle under the exterior surface of the applied dielectric material.
>
> The use of any shape of teeth increases the surface area where the conductive coating is on the applied dielectric material. However, the preferred embodiment uses a surface of obtuse, canine, or fang-shaped teeth to help the conductive coating and metal layer hook under the exterior surface of the applied dielectric material.

'582 Patent at 3:28-46.

With this explanation from the specification, the Court concludes that a person of ordinary skill in the industry could understand with reasonable certainty the meaning of the claim at issue: A dielectric material comprising a surface with cavities "wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope." The cavities formed in the dielectric material must have sloped sides, relative to the flat surface of the dielectric material, and the teeth formed from the conductive layer must engage a portion of the dielectric material at the sloped side of the cavity.

As Plaintiff's counsel conceded at the *Markman* hearing, this terminology does not specify any specific slope or angle, and, as a result, every cavity, no matter how small or shallow, would have sides that are sloped relative to the surface of the dielectric material and therefore satisfy this claim requirement. Indeed, even the undulating surface of the prior art as illustrated in Plaintiff's opening brief (Doc. 189 at 9, lines 13-15) would appear to satisfy this description. As a result, the Court cannot see how this claim language distinguishes the patented invention from the prior art, but that is not a question of definiteness.

C. "Peel Strength Greater Than."

Defendants challenge the '582 Patent claims that call for "peel strength greater than a peel strength that would be produced by a single desmear process." Doc. 177 at 18. Defendants agree that "peel strength" is a term of art that generally refers to the adhesive strength that exists between two layers. Doc. 188 at 25. Defendants argue, however, that this claim language specifies no method for measuring peel strength and no criteria for determining the peel strength of a product produced by a single desmear process, and therefore leaves a person of ordinary skill in the art with no basis to determine what measurement is intended.

Plaintiff asserts with some persuasive force that IPC-TM-650, method 2.4.8, is the standardized method for measuring peel strength by one skilled in the art. Doc. 200-3 at ¶ 30. But Plaintiff also argues that any scientifically reasonable method for measuring peel strength could be used, the only requirement being that it show a peel strength in the product made under the patent that is greater than the peel strength of a product made by a single desmear process.

The Court agrees with Plaintiff. Defendants do not contend that the word "greater" is indefinite. And the fact that a particular method of measuring peel strength is not identified does not make the language indefinite. Those skilled in the art know the accepted means for measuring peel strength. Nor is the claim indefinite because the baseline peel strength of a product made with a single desmear process is not specified. No particular peel strength is required; it just must be lower, upon measurement, than the peel strength of the patented product measured by the same method. Persons skilled in the art know how to conduct such measurements and how to locate a product made by a single desmear process.

D. "Substantially Greater."

Claims 14 and 19 of the '560 Patent and several claims in the '105 Patent call for cavities in the dielectric layer having "a first cross-sectional distance proximate the [initial] surface" and a "substantially greater cross-sectional distance distant from the [initial] surface." Doc. 177 at 19. Defendants contend that the intrinsic record is devoid of any objective criteria for determining how much greater is "substantially greater" within the meaning of the claims, and that these limitations therefore are indefinite. Defendants note that the '912 Patent does not include the word "substantially," calling simply for a "greater cross-sectional distance." As a result, Defendants argue, "substantially" must have some meaning beyond "greater," a meaning not apparent from the intrinsic evidence.

Plaintiff notes that the Federal Circuit has "repeatedly confirmed that relative terms such as 'substantially' do not render patent claims so unclear as to prevent a person of skill in the art from ascertaining the scope of the claim." *Deere & Co. v. Bush Hog, LLC*, 703 F.3d 1349, 1359 (Fed. Cir. 2012). Plaintiff agrees, however, on the relevant test: "Such a term is not indefinite if the intrinsic evidence provides 'a general guideline and examples sufficient to enable a person of ordinary skill in the art to determine [the scope of the claims].'" *Enzo Biochem, Inc. v. Applera Corp.*, 599 F.3d 1325, 1335 (Fed. Cir. 2010) (citation omitted).

Plaintiff points to the following language from the specification as providing guidance on the meaning of "substantially":

> In comparison with the above-mentioned roughening techniques of the prior art, it is believed that a surface of the teeth is an improvement in that there is an increase in surface area. However, it is still better to use teeth that are fang-shaped to enable a mechanical grip that functions in a different manner than adherence by means of increased surface area. By using the fanged, angled, canine, or otherwise hooked teeth (in addition to increased surface area), there is a multidirectional, three dimensional interlacing and overlapping of layers.

’582 Patent at 1:58-66. Plaintiff also points to language in the specification stating that “the . . . metal layer is actually burrowed under the dielectric material and vice versa.” *Id.* at 1:66 to 2:3.

Plaintiff’s expert, Dr. Hoffman, provides this explanation of why this description is sufficient for one skilled in the art to understand the meaning of “substantially”:

> In light of the specification and the art, a person of ordinary skill would understand that the cross-sectional distance of the interior of a cavity must exceed a crosssectional distance nearer the opening of a cavity enough to create the “mechanical grip” described in the patents and allow the conductive material to burrow “in and under” the dielectric material. *See, e.g.*, ’582 Patent at 1:58-2:3.
>
> A person of ordinary skill in the art would recognize that if the cross-sectional distance of the interior of the cavity only exceeds the cross-sectional distance of the opening by a very slight amount, the mechanical grip disclosed in the patents would not be achieved.
>
> A person of ordinary skill in the art would further understand that the specific difference between comparative cross-sectional distances may vary based on particular application and material properties. For example, a person having ordinary skill in the art would understand that materials having high tensile strength will more readily grip copper, meaning that the degree of undercutting and burrowing (that is to say the amount which the cross-sectional distance distant the surface is greater than the distance proximate the surface) can be lesser than a material with lower tensile strength.

Doc. 200-3 at ¶¶ 35-37.

As noted above, the Supreme Court recently held that “a patent’s claims, viewed in light of the specification and prosecution history, [must] inform those skilled in the art about the scope of the invention with ***reasonable certainty***.” *Nautilus, Inc.*, 134 S. Ct. at 2129. After *Nautilis*, the Federal Circuit explained that “[t]he claims, when read in light of the specification and the prosecution history, ***must provide objective boundaries*** for those of skill in the art.” *Interval Licensing LLC v. AOL, Inc.*, 766 F.3d 1364, 1371 (Fed. Cir. 2014). The Federal Circuit also explained that “[w]hen a ‘word of degree’ is used, the court must determine whether the patent provides ‘***some standard for measuring that***

degree.'" *Biosig inst., Inc. v. Nautilis, Inc.*, 783 F.3d 1374, 1378 (Fed. Cir. 2015) (quoting *Enzo Biochem*, 599 F.3d at 1332).

Although it is a close question, the Court concludes that the patents satisfy this standard. Language from the specification quoted above explains that the cavities should extend under the surface of the dielectric material ("actually burrowed under the dielectric material") so that the teeth that fill the cavities "mechanical[ly] grip" the dielectric material. '582 Patent at 1:58 to 2:3. This suggests that the base of the cavity should not be perfectly aligned with the surface of cavity, the sides of the cavity forming a perpendicular wall, but instead should be sufficiently offset from the surface opening to permit the tooth to engage the dielectric material in a mechanical grip. The Court concludes that one skilled in the art could determine the extent to which the cavity must extend under the dielectric material to permit such a mechanical grip. The claims provide additional guidance by stating that the peel strength formed by these gripping teeth must exceed the peel strength of a layer created by a single-pass desmear process. And Figure 1 provides further explanation, illustrating the kinds of cavities and teeth intended by the patent.

Admittedly, this language requires some judgment by persons skilled in the art, but it is judgment informed by the intended function of the cavities (to create a mechanical grip), the result that should be realized (peel strength greater than single-pass desmearing creates), and the illustration in Figure 1. As the Federal Circuit explained after *Nautilis*, "absolute or mathematical precision is not required." *Interval Leasing*, 766 F.3d at 1370. The Federal Circuit also favorably cited its previous holding that the phrase "not interfering substantially" was not indefinite even though the construction "define[d] the term without reference to a precise numerical measurement." *Enzo Biochem*, 599 F.3d at 1335.

E. Indefiniteness Conclusion.

With respect to the claims in Category 4, the Court concludes that Defendants have not satisfied their "clear and convincing" burden of showing that the claims are indefinite.

Dated this 9th day of August, 2017.

David G. Campbell

David G. Campbell
United States District Judge

US007501582B2

(12) **United States Patent**
McDermott et al.

(10) **Patent No.: US 7,501,582 B2**
(45) **Date of Patent: Mar. 10, 2009**

(54) **ELECTRICAL DEVICE AND METHOD FOR MAKING SAME**

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(73) Assignee: **Peter K. Trzyna, Esq.**, Chicago, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 98 days.

(21) Appl. No.: **10/790,363**

(22) Filed: **Mar. 1, 2004**

(65) **Prior Publication Data**

US 2004/0163847 A1 Aug. 26, 2004

Related U.S. Application Data

(63) Continuation of application No. 09/694,099, filed on Oct. 20, 2000, now Pat. No. 6,700,069, and a continuation of application No. 08/905,619, filed on Aug. 4, 1997, now Pat. No. 6,141,870.

(51) **Int. Cl.**
H05K 1/03 (2006.01)

(52) **U.S. Cl.** **174/255**; 174/256; 174/257

(58) **Field of Classification Search** 174/255–262; 29/850–853; 216/15–16
See application file for complete search history.

(56) **References Cited**

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Primary Examiner—Tuan T. Dinh

(57) **ABSTRACT**

A multilayer electrical device, such as a printed circuit board, having a tooth structure including a metal layer set in a dielectric. The device includes a base; a conductive layer adjacent to the base; a dielectric material adjacent to conductive layer; a tooth structure including a metal layer set in the dielectric material to join the dielectric material to the metal layer; and wherein the metal layer forms a portion of circuitry in a circuit board having multiple layers of circuitry.

162 Claims, 2 Drawing Sheets
(1 of 2 Drawing Sheet(s) Filed in Color)

FIG. 1

FIG. 2 PRIOR ART

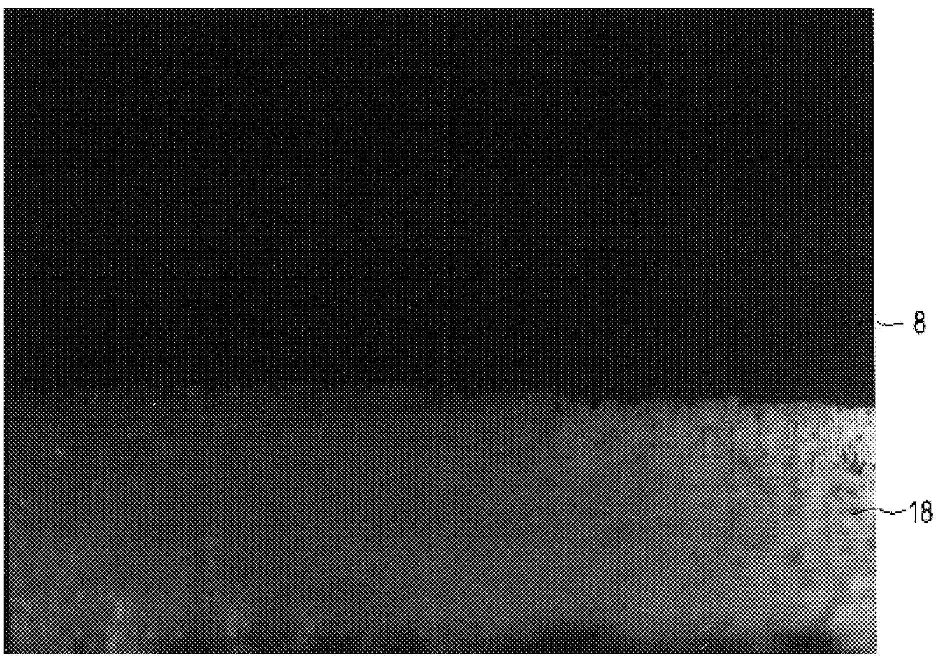


FIG. 3

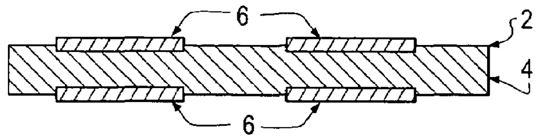


FIG. 4

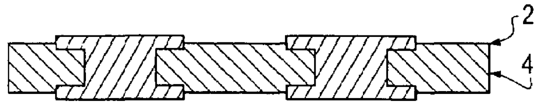


FIG. 5

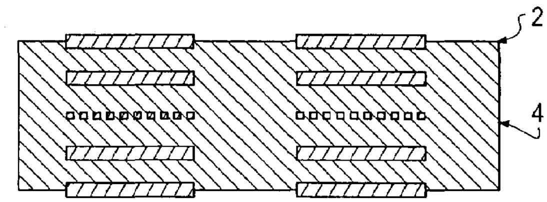


FIG. 6

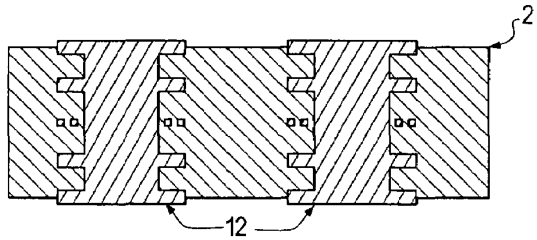


FIG. 7

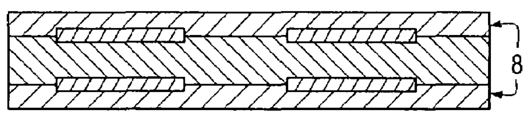


FIG. 8

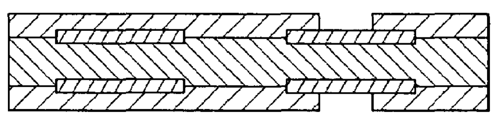


FIG. 9

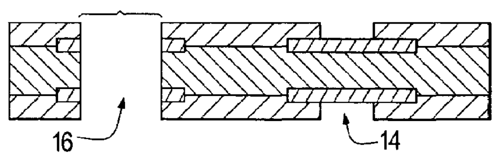


FIG. 10

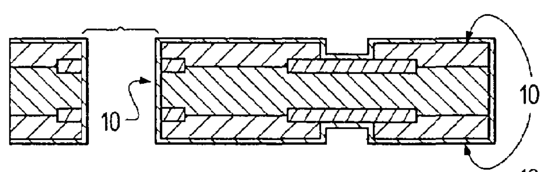
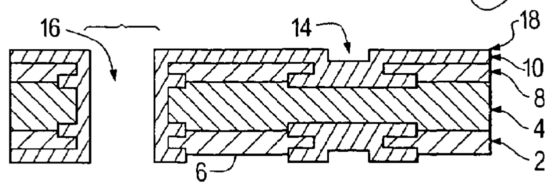


FIG. 11



ELECTRICAL DEVICE AND METHOD FOR MAKING SAME

This patent application is a continuation application that claims priority, and incorporates by reference, from U.S. patent application Ser. No. 08/905,619, now U.S. Pat. No. 6,141,870, filed Aug. 4, 1997, and U.S. patent application Ser. No. 09/604,099, filed Oct. 20, 2000, issuing Mar. 2, 2004, as U.S. Pat. No. 6,700,069.

I. FIELD OF THE INVENTION

The present invention is directed to methods for making or manufacturing an electrical device, and the process, composition, and product thereof. More particularly, the present invention involves such multilayer electrical devices as circuit boards constructed by joining a dielectric material to a subsequently applied conductive material. Still more particularly, the present invention involves an electrical device having a substrate or base, an applied dielectric material thereon, which in turn has a thin conductive coating thereon, and a conductive layer formed upon the conductive coating, the conductive layer being joined to the applied dielectric material in an improved manner.

II. BACKGROUND OF THE INVENTION

Multilayer electrical devices—those made from layering a dielectric material and a conductive material on a base—suffer from delamination, blistering, and other reliability problems. This is particularly true when the laminates are subjected to thermal stress.

Known attempts to solve these problems seem to have focused on physical or chemical roughening, particularly of the base or substrate. See for example, U.S. Pat. No. 4,948,707. Although oxide-related chemical roughening processes have been used, an emphasis on physical roughening may reflect the use of materials that are relatively chemically resistant. Both physical and chemical roughening approaches have improved adherence to the base.

However, the extent to which this adherence can be increased by roughening has its limits. And despite a long standing recognition of delamination, blistering, and reliability problems, and the attempts to find a solution, these problems have been persistent in electrical devices made of layered materials.

III. SUMMARY OF THE INVENTION

The inventors herein have observed that the general problem of poor adherence between the laminates or layers can be addressed by forming a unique surface structure, which is particularly suitable for joining the dielectric material to the conductive coating and conductive layer. The surface structure is comprised of teeth that are preferably angled or hooked like fangs or canine teeth to enable one layer to mechanically grip a second layer.

In comparison with the above-mentioned roughening techniques of the prior art, it is believed that a surface of the teeth is an improvement in that there is an increase in surface area. However, it is still better to use teeth that are fang-shaped to enable a mechanical grip that functions in a different manner than adherence by means of increased surface area. By using the fanged, angled, canine, or otherwise hooked teeth (in addition to increased surface area), there is a multidirectional, three dimensional interlacing or overlapping of layers. For example, in joining the dielectric material to the conductive coating and metal layer, the conductive coating and metal layer is actually burrowed in and under the dielectric material and vice versa. Thus, separating them not only involves breaking the surface area adherence, but also involves destroying the integrity of at least one of the layers by ripping the teeth, the layer pierced by them, or both.

Further, it has been found preferable to have numerous teeth sized and shaped so that they are not too large or too small. If the teeth are too small, wide, straight, and shallow, then the surface resembles the roughened surface of prior art techniques, vaguely analogous to a surface of molar teeth, and the adherence is not much better than that achieved by known prior art roughening techniques.

However, if the teeth are too large, deep, and fanged or hook-shaped, the teeth undercut the surface to such an extent that the strength of the dielectric material surface is weakened. As a result, adherence is decreased over the preferred embodiment.

Not too great and not too slight, the right sized and shaped teeth, set in a fanged orientation and with sufficient frequency, have been found to be the best structure. If the correct balance of these critically important factors is created, the result is a greatly improved circuit board or other such electrical device.

It is theorized by the inventors that the best methods for producing the teeth is to use non-homogeneous materials and/or techniques. For example, a dielectric material can have a non-homogeneous composition or thickness to bring about an uneven chemical resistance, such that slowed and/or repeated etching will form teeth instead of a uniform etch.

IV. BRIEF DESCRIPTION OF THE DRAWINGS

The file of this patent contains at least one drawing executed in color. Copies of this patent with the color drawing(s) will be provided by the Patent and Trademark Office upon request and payment of the necessary fee

FIG. **1** is an illustration of a conductive coating and metal layer applied dielectric material with a desirable tooth structure;

FIG. **2** is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes;

FIG. **3** is an illustration of a double sided printed circuit board without plated through holes;

FIG. **4** is an illustration of a multilayer printed circuit board with plated through holes, filled or unfilled with conductive or nonconductive material;

FIG. **5** is an illustration of a multilayer printed circuit board without plated through holes;

FIG. **6** is an illustration of a multilayer printed circuit board having more than two layers with plated through holes filled or unfilled with conductive or nonconductive material;

FIG. **7** is an illustration of any of the foregoing printed circuit boards after applying a dielectric material thereon;

FIG. **8** is an illustration of the multilayer printed circuit board of FIG. **7** after forming micro vias;

FIG. **9** is an illustration of the multilayer printed circuit board of FIG. **7** after opening the through holes and after etching the applied dielectric material to produce the teeth illustrated in FIG. **1**;

FIG. **10** is an illustration of the multilayer printed circuit board of FIG. **9** after application of a conductive coating to fill in around the teeth and connect micro via holes and the through holes; and

FIG. **11** is an illustration of the multilayer printed circuit board of FIG. **10** after plating the conductive coating to form a metal layer and complete forming circuitry.

V. DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a conductive coating and metal layer on the applied dielectric material with a desirable tooth structure. In contrast, FIG. **2** is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes. In both FIGS. **1** and **2**, show a dielectric material and a combination of a thin conductive coating and metal later. Compare FIG. **1** and FIG. **2**, and note particularly the size, shape, frequency, and depth of the teeth in FIG. **1** with the surface produced by roughening in FIG. **2**.

A way of articulating this "teeth" concept is to view each tooth as being made of one layer and set in a second layer. However, the perspective is arbitrary, and one could equally view each tooth as made of the second layer set in the first. It could also be said that the layers join in a saw-toothed manner, i.e., teeth made of both materials in an interlocking bite. In any case, however, there are teeth, and for the sake of consistency, this specification will adopt the convention of referring to the teeth as being made of the conductive coating and metal layer set in the dielectric material.

A further way of articulating the "teeth" concept is to view each tooth as being substantially triangular in shape, with the base of the triangle being defined by a plane of the applied dielectric material before it is etched, or more precisely by the exterior surface thereof. The invention can be carried by forming cavities in the applied dielectric material **6** for receiving the teeth, and then forming the teeth from the conductive coating and metal layer formed thereon. Generally, the teeth can be of any triangular shape (e.g., equilateral, isosceles, scalene, right, obtuse, or any combination thereof). Preferably, though, the teeth are obtuse so as to hook or angle under the exterior surface of the applied dielectric material.

The use of any shape of teeth increases the surface area where the conductive coating is on the applied dielectric material. However, the preferred embodiment utilizes a surface of obtuse, canine, or fang-shaped teeth to help the conductive coating and metal layer hook under the exterior surface of the applied dielectric material to mechanically grip the applied dielectric material. The obtuse, canine, or fang-shaped teeth are in contrast to the shallower, more rounded surface typically produced by known roughening techniques. Note in FIG. **2** that roughing techniques can produce some occasional gouging, but nothing on the order of the present invention.

As to size of the teeth, as mentioned above, it is preferable that the teeth be within a certain size range. The optimal size range for obtuse, canine, or hook-shaped teeth involves a balance between maximizing surface area and mechanical grip, but not undercutting the surface of the applied dielectric material **8** to such an extent as to weaken it. Accordingly, the teeth should be sized at least 1 tenth of a mil deep. Better is at least 1.25 tenths of a mil deep, and even better is at least 1.5 tenths of a mil deep. However, 1.75 tenths of a mil is acceptable, and about 2 tenths of a mil is reaching the limit.

As to frequency, the teeth should be quite frequent in number; at least about 5,000 teeth per linear inch, and preferably at least about 10,000 teeth per linear inch; and even better is at least about 15,000 teeth per linear inch.

As to surface area, there should be at least about 25,000 teeth per square inch, better still is essentially at least about

100,000 per square inch, and preferably at least about 200,000 per square inch, or even greater.

It should be recognized that the teeth generally are not formed to a precise dimension. As shown in FIG. **1**, some of the teeth are somewhat differently sized, angled, and proportioned. Thus, a representative sample of the electrical device should have teeth in about these ranges. Having at least about 20% of the teeth in one or more of these ranges, and preferably at least 50%, is a preferred balance of mechanical grip without a weakening the integrity of the layering, particularly in combination.

As illustrated in FIGS. **3-11**, there is an electrical device, such as a printed circuit board **2** having a base **4**. The base **4** has a conductive layer **6** thereon. A dielectric material **8** is applied on the conductive layer **6**, and a conductive coating **10** (such as a thin coating of palladium) is deposited on the dielectric material **8**. Metal layer **12** is formed on the conductive coating **10**.

FIG. **3** illustrates one of the many ways to begin the process of forming the teeth in accordance with the present invention. A first step (step **1**), includes providing a base **4** for constructing an electrical device, such as a printed circuit board **2**. FIG. **3** illustrates one such construction, namely a base **4** for constructing a multilayer printed circuit board **2**, the base **4** having any positive number of layers or laminates, for example the two layers shown in FIGS. **3** and **4**, or more than two layers as illustrated in FIGS. **5** and **6**, etc. One configuration or another is not significant, except that multiple layers provide a better medium for constructing circuitry of increased complexity or density. FIGS. **3-6** illustrate an embodiment in which the conductive layer **6** is on at least an upper side, and preferably also on a lower side of the base **4**.

As may be needed for a particular circuitry design, FIG. **4** illustrates that the electrical device can be further manipulated, for example, by forming through holes **12** by mechanical drilling, laser drilling, punching, or the like. The plated through holes **12** are shown in FIGS. **4** and **6** as filled or unfilled with a conductive or a nonconductive material.

FIG. **5** illustrates a configuration for the multilayer printed circuit board **2** with base **4** having more than two layers or laminates, the conductive layers **6** located there between.

FIG. **6** shows the multilayer printed circuit board **2** after forming, plating, and if needed, filling the through holes **12** in the manner of FIG. **4**.

To summarize, step **1** of the process includes providing a base **4** for forming an electrical device such as a printed circuit board **2**, wherein the base **4** can be formed to have one or more layers or laminates. At least one conductive layer **6** is on the base **4**. The base **4** can be double sided with the conductive layer **6** being located outside the base **4** and between the layers or laminates.

The printed circuit board **2** can be further prepared, as may be desirable for a particular circuitry design, by forming open through holes **12** and plating and if needed, filling the through holes **12** to electrically connect to that portion of the conductive layer **6** appropriate for whatever circuitry design is being constructed, e.g., each side of a double sided circuit board **2**. In other words, step **1** involves providing one of the configurations described in FIGS. **3-6**.

Step **2** includes preparing an outer-most surface of the conductive layer **6** for any of the above-mentioned configurations. The step of preparing is carried out to enable adherence, e.g., of the applied dielectric material **8** to the conductive layer **6**, preferably in a manner that utilizes a respective tooth structure. The step of preparing can be carried out, for example, by using an oxide or an oxide replacement process to treat the conductive layer **6** to such an extent that the teeth (or cavities for teeth) are formed.

As to using an oxide process, a copper oxide can be chemically deposited on a copper surface to produce a tooth-like structure on the surface of the copper. This process is carried out to prepare the copper surface prior to applying another layer of material, thereby providing increased bond strength between the two materials.

As to using an oxide replacement process to form a tooth structure, a micro etch on the surface of the copper is followed by a coating of an adhesion promoter to enhance a bond between copper and the dielectric material **8**. For example, Alpha Metals, Inc. offers a PC-7023 product which is suitable for an oxide replacement process.

Step **3** includes applying the dielectric material **8** to the outermost surface of the conductive layer **10** (and the base **4** if appropriate for the circuitry or electrical device at issue) prepared in accordance with the step **2**. The dielectric material **8** can be applied by as a (dry) film, a (liquid) curtain coating, a (liquid) roller coating, or an analogous application or bonding technique. FIG. **7**, in comparison with FIGS. **3**-**6**, illustrates the dielectric material **8** on the outermost surface(s) of the conductive layer **4** (and the base **2**).

Step **4** includes preparing the applied dielectric material **8** for receipt of a conductive coating **10**, which to exemplify, is detailed more particularly below. Generally, though, the preparing step **4** can include exposing, developing, and curing the applied dielectric material **8** to form patterns for further construction of the circuitry, including such features as constructing a via or photo via **14**, for optionally filling by conductive or non-conductive materials, e.g., screened, roller coated, etc. Compare FIGS. **6** and **7**.

Step **5** includes forming open through holes **16** as shown in FIG. **9**. As indicated above with regard to filled through holes **12**, the open through holes **16** can be formed by such methods as drilling, boring, punching, and the like.

Step **6**, as discussed subsequently in greater detail, involves the etching cavities, veins, openings, or gaps in the applied dielectric material **8**, or more particularly an outermost surface thereof, to accommodate the teeth. One technique for forming the teeth is somewhat similar to what has been known as the swell and etch or desmear process, except that contrary to all known teachings in the prior art, in effect, a "double desmear process" is utilized. That is, not merely increasing the times and temperatures and other parameters for the desmear process, but instead completing the process a first time, and then completing the process a second time. Consider using the following Shipley products for the double desmear process: CIRCUPOSIT MLB conditioner **211**, promoter **213**B, and neutralizer **216**. Non-homogeneous materials and/or processes seem to be determinative.

Step **7** includes applying a conductive coating **10** to the cavities in the applied dielectric material **8**. The conductive coating **10** is also applied to the photo-defined via holes **14** and the open through holes **16**. Techniques for applying the conductive coating **10** include a direct plate process or an electroless copper process. To carry out the present invention, it is preferable to use a palladium-based direct plate process or other non-electroless process. In this regard, a Crimson product of Shipley is suitable, though the desmear process as disclosed herein is contrary to the manufacturer's specifications, i.e., a "double desmear process," rather than the single desmear process of the known prior art. Compare FIGS. **1**, **2**, and **9**.

Step **8** includes forming a metal layer **18** on the conductive coating **10**, by such metal deposition techniques as electrolytic or non-electrolytic plating, to form the tooth structure and teeth as discussed above. The metal layer **18** and conductive coating **10** collectively form circuitry on the outermost surface of the applied dielectric material **8**, which can connect to whatever portion of conductive layer **6** as may be needed for a particular design, preferably by making at least one connection through a micro via. See FIG. **10**. A direct plate process, followed as needed by say a semi-additive or fully additive pattern plating process, is recommended.

A direct plate process is a replacement for traditional electroless copper plating of non-conductive surfaces. Direct plate processes apply a very thin conductive coating (e.g., using palladium or graphite) to the non-conductive surface, thus enabling electroplating of copper or other conductive material onto the previously non-conductive surface. Thus, "direct plate" is used to describe directly plating onto a non-conductive surface without first requiring a non electrolytic (electroless) plating process.

A semi-additive plating process involves first electroplating a thin conductive layer onto the total non-conductive surface, before applying a photoresist and subsequently pattern plating the required circuitry. For semi-additive plating, the thin conductive layer must be removed (etched) from the non-conductive surface. For fully additive plating, photoresist is applied directly on the non-conductive surface, followed by pattern plating the required circuitry (after applying the thin conductive coating in the direct plate process). That is, the fully additive plating forms only the required circuitry and requires no etching.

It should be recognized that the present invention can optionally be carried out by initially skipping step **5** (forming the open through holes **16**) during initial "sets" of the foregoing steps, i.e., completing steps **6** and **7**; then repeating steps **2** through **8**, again skipping step **5** each time until the last set of steps, as required to form the electrical device or circuitry of interest. This will produce an electrical device with a second tooth structure that is not set in the first layer of dielectric material **8**, and indeed the idea of using a toothed structure is not limited to any one layer and is best employed in holding multiple layers together. Step **5** can be carried out after the desired layers have been formed.

Turning now more particularly to the process for forming the teeth and the cavities for the teeth, the present invention can be carried out by a new use of a Ciba-Geigy product known as Probelec XB 7081 as a photoimagable dielectric material **8**. Generally, and in accordance with its specification sheet, Probelec XB 7081 is a single component, 100% epoxy photodielectric material specially developed for Sequential Build Up (SBU) of multilayer boards.

Probelec XB 7081 is a negative working, high resolution liquid photo-imageable (LPI) material which allows mass-forming of micro vias for fabrication of high-density interconnects (HDI). Compatible with conventional plating and circuitization techniques, Probelec XB 7081 also provides outstanding electrical and physical properties for most circuit board applications, and is compatible with most circuit board substrate materials.

Probelec XB 7081 is specially developed to act as a dielectric between circuit layers in fabrication of blind and buried micro via MLBS. The high resolution photo dielectric allows mass forming of micro vias for the construction of high density interconnects. Probelec XB 7081 has wide process latitudes, excellent handling characteristics, and is known as self-leveling and having an adjustable dry thickness of 1-3 mils. Probelec XB 7081 has a high resolution capability of 1-2 mil micro vias, and is known for chemical resistance, even for additive plating; there are excellent electrical and physical properties and a UL 94V-0 rating. Probelec is specified to demonstrate more than a 6 lb/in peel strength. By application of this invention this peel strength should be significantly increased due to the formation of the teeth. Accordingly the peel strength produced in accordance with the present invention is greater than the peal strength produced by the desmear process of the prior art, i.e., a single pass desmear process. For example, if a prior art desmear process is used to produce a 6 lb/in average peel strength, the present invention may produce an average peel strength on the order of 10 lb/in or more.

As to the general properties of Probelec XB 7081, there is a storage stability (1-component system) for more than 6 months at 25° C.; the pot life in a coater machine is more than 1 week; the hold time of the coating is more than 1 week (dark or exposed) and more than 1 day in yellow light.

When using Probelec XB 7081 to carry out the above-mentioned step **3** of applying a coating of the dielectric material, there is a pre-cleaning sub-step A. Pre-cleaning should be carried out in chemical, mechanical brushing, or pumice spray units. Extra precaution is needed to ensure that the pre-cleaning equipment and chemistry is not contaminated by materials from previous processing steps. Contrary to Ciba specifications, it is preferred to use an oxide or oxide replacement to prepare the surface prior to applying a coating of the dielectric. Hold times after pre-cleaning should be minimized to avoid oxidation of copper surfaces. In all coating applications, pre-cleaned substrates should be free of particles. Additional cleaning steps, e.g., with detergents, may be required to remove organic residues.

Next there is a coating sub-step B. Probelec XB7081 seems to have been primarily designed for curtain coating and is delivered with a solid content of 58%. Substrates should be heated to about 40° C. prior to coating to ensure all residual moisture is removed and to prepare substrate for curtain coating. For initial charging of a coater machine, Probelec XB 7081 needs to be premixed with about 15% of PMA (PMA is 1-methoxy-2-propyl acetate) to ensure proper viscosity. The additional PMA thins the coating down to about 50% solids.

The resin temperature should be 25±1° C., with a conveyor speed of 90 m/min. The viscosity is at 25° C., DIN AK4 cup at 60 sec. (400 cps), with a coater gap width of 500 mm. The wet weight is 7.5-10.0 gms/600 CM sq. and 11.6-15.5 gms/ft sq. The dry thickness is 45-60 mm.

Next is a flash dry sub-step C. Coated panels must be held in a horizontal position under dust-free conditions to air dry. At this stage, minimal air flow is recommended. The drying time is 12-18 min. at a drying temperature of 30-40° C.

Next is a final dry sub-step D. After flash air drying, final drying at an elevated temperature is needed to achieve better than 95% removal of solvents for tack-free handling. This can be accomplished in batch or conveyorized tunnel ovens, as follows:

	Tunnel Oven	Batch Oven
Drying Temperature:	130-140° C.	90° C.
Drying Time:	2-3 minutes	30 minutes

After cooling, the panels can have a second side coating (sub-steps A through D) if appropriate for the circuit design, and then for an exposure sub-step E.

In the exposure sub-step E, catalyst for cross linking of epoxy resin is generated. The main spectral sensitivity of Probelec XB 7081 is in the range of 350-420 nm. Conventional exposure units, collimated or non-collimated, with peak spectral emission of 365 nm are recommended. Both

diazo and silver halide films are suitable as working phototools. Good artwork to coating contact is essential for consistent micro via reproduction. The exposure energy is 1200-1600 mJ/cm sq. and the exposure time (7 kW) is 30-40 seconds. The Stouffer Step (21 scale) is 5-7.

Next is a thermal bump step F. Thermal bump provides the energy for crosslinking the catalyzed epoxy resin. This process can be done in convection batch or conveyorized tunnel ovens. For a batch oven, 110° C. for 60 min. is appropriate, and for a conveyorized tunnel oven, 130° C. for 10-20 min. is appropriate.

Next is a developing sub-step G. The unexposed areas of Probelec XB7081 are developed away in continuous spray developing machines. Various models with different processing capacities are available for this purpose. A Ciba-Geigy product DY 950 (Gamma-Butyrolactone (GBL)) developer is recommended for processing Probelec XB7081. This developer is a halogen-free, high-boiling organic solvent suitable for on-site distillation or recycling. Probimer 450/470 spray developing equipment is specially designed for use with this developer solution. The temperature is 20±2° C., and the spray pressure is 2-4 bar. The speed for Probimer 450 is 2-3 m/min; for Probimer 470, 3-4 m/min.

Next is a final cure sub-step H. Final thermal curing is needed to impart good mechanical, chemical, and electrical properties to the dielectric film. The thermal curing can take place in batch or conveyorized tunnel ovens. The thermal curing temperature is 150° C., with a thermal curing time of 60 minutes.

Next can come the step **5** of further preparing, for example, by forming through holes **16**. If plated through holes **16** (PTH's) are needed for interconnecting layers to the bottom or back side of the printed circuit board **2**, drilling should of course be done before plating. This allows the plating of the surface together with the through holes **16**. Plating and such post-processing of the photoimagable dielectric material **8** is dependent on particular process preferences. Probelec XB7081 is compatible with panel-plate, pattern-plate or additive plating.

The following process sub-steps of the above-mentioned step **6** describe a generic sequence for a desmear process to form cavities in the dielectric. Although Probelec XB7081 apparently was intended for use in the common desmear (swell and etch) process as used in conventional plated through hole plating lines, Probelec XB7081 can alternatively be used in carrying out the present invention. For example, the present invention differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth. Sub-step A, swelling the dielectric material **8**, can be carried out with butyl diglycol/sodium hydroxide/water 80° C. for 3-5 minutes. Sub-step B is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step C is etching the dielectric material **8**, which can be carried out using potassium permanganate/sodium hydroxide/water 80° C., 6-10 minutes. Sub-step D is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step D includes a further rinsing of the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step E is neutralizing the dielectric material **8** in sulfuric peroxide (1.5%) for 3 to 5 minutes. Finally step F is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes.

In stark contrast with the etch and swell process of the known prior art, however, a second pass through the process (sub-steps A through F) is used. The second pass seems to make use of non-homogenaities in bringing about a formation of the teeth. Thus, unlike the prior swell and etch chemical roughening process, which produces a surface characterized by a surface gloss measurement at an angle of 60° which is between 15 and 45%, the present invention has less gloss (<10%).

Turn now in greater detail to the step **7** of applying the conductive coating **10** for subsequent deposition of the metal layer **18** by, say, plating. Good results can be achieved with a flash plate of 0.7-1.0 mm (30-40 micro inches). The flash plate is followed by baking at 130-150° C., for 2 hours.

For pattern plating, plating resist can be applied after baking. Depositing the metal layer **18** by electroplating can be carried out such that there is 10-25 mm (0.4-1.0 mil.).

While a particular embodiment of the present invention has been disclosed, it is to be understood that various different modifications are possible and are within the true spirit of the invention, the scope of which is to be determined with reference to the claims set forth below. There is no intention, therefore, to limit the invention to the exact disclosure presented herein as a teaching of one embodiment of the invention.

We claim:

1. A process of making an electrical device, the process including:

removing a portion of a dielectric material in producing cavities in a surface of a remaining portion of the dielectric material; and

building up a conductive layer in the cavities in forming teeth set in and under the surface and in forming a portion of circuitry of an electrical device, wherein a plurality of the cavities are obtuse with respect to the top surface, and a plurality of the cavities are at least 1 tenth of a mil deep and less than 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the remaining portion of the dielectric material, and one of the teeth engages the remaining portion of the dielectric material at the slope.

2. The process of claim **1**, wherein the removing of the portion is sufficient to produce a surface gloss measurement at an angle of 60 degrees of less than 10%.

3. The process of claim **1**, wherein the producing cavities does not include physical roughening, and the building up the conductive layer includes building up the conductive layer in producing a dielectric surface contact area greater than a dielectric surface contact area that would be produced by a single pass roughening.

4. The process of claim **1**, wherein the producing cavities does not include physical roughening, and the building up the conductive layer includes building up the conductive layer in producing a peel strength greater than a peel strength that would be produced by a single desmear process, and the forming teeth includes forming a plurality of hooked teeth.

5. The process of claim **1**, wherein the producing cavities does not include physical roughening, and the building up the conductive layer includes filling the cavities sufficiently that separation of the conductive layer from the remaining portion of the dielectric material requires destroying integrity of at least one of the conductive layer and the remaining portion of the dielectric material.

6. The process of claim **2**, wherein the building up is sufficient to produce a peel strength greater than a peel strength of a single desmear process.

7. A process of making an electrical device, the process including:

producing, from a dielectric material, a surface including cavities remaining from removing a portion of the dielectric material; and

building up a conductive layer in the cavities in forming substantially angular teeth set in a remaining portion of the dielectric material and in forming a portion of circuitry of an electrical device, and wherein a sample of the circuitry has at least 20% of the teeth being at least 1 tenth of a mil deep and less than 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface and one of the teeth engages the remaining portion of the dielectric material at the slope.

8. The process of claim **7**, wherein the removing of the portion is sufficient to produce a surface gloss measurement at an angle of 60 degrees of less than 10%.

9. The process of claim **7**, wherein the removing is such that froming the cavities does not include physical roughening, and the building up the conductive layer includes building up the conductive layer in producing a dielectric surface contact area greater than a dielectric surface contact area that would be produced by a single pass roughening, and the forming substantially angular teeth includes forming a plurality of substantially angular teeth that mechanically grip the remaining portion of the dielectric material, more than by adherence.

10. The process of claim **7**, wherein the removing is such that forming the cavities does not include physical roughening, and the building up the conductive layer includes building up the conductive layer in producing a peel strength greater than a peel strength that would be produced by a single desmear process, and the forming substantially angular teeth includes forming a plurality of substantially angular hooked teeth.

11. The process of claim **7**, wherein the removing is such that forming the cavities does not include physical roughening, and the forming substantially angular teeth is such that separation of the conductive layer from the remaining portion of the dielectric material would destroy integrity of at least one of the conductive layer and the remaining portion of the dielectric material.

12. A process of making an electrical device, the process including:

building up a conductive layer of material on a surface of a layer of dielectric material, the layers joined in a saw-tooth manner made of both materials in an interlocking bite in forming a portion of circuitry of an electrical device, the conductive layer forming teeth such that a sample of the circuitry has a frequency of the teeth sufficient to provide at least 5,000 of the teeth per linear inch, the teeth set respectively in cavities of the bite, and the sample of the circuitry has at least 20% of the teeth being at least 1 tenth of a mil deep and less than 2 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface, and one of the teeth engages a portion of the dielectric material at the slope.

13. The process of claim **12**, further including providing a micro via interconnect for the circuitry.

14. The process of claim **12**, wherein, prior to the building up, the layer of the dielectric material has a surface gloss such that a surface gloss measurement at an angle of 60 degrees is less than 10%.

15. The process of claim **12**, wherein the removing is such that forming the cavities does not include physical roughening, and the building up the conductive layer includes building up the conductive layer in producing a dielectric surface contact area greater than a dielectric surface contact area that would be produced by a single pass roughening, such that a plurality of the teeth mechanically grip the layer of dielectric material, more than by adherence, at the surface contact area.

16. The process of claim **12**, wherein the producing the interlocking bite does not include physical roughening, and the building up the conductive layer includes building up the conductive layer in producing a peel strength greater than a peel strength that would be produced by a single desmear process, such that the forming teeth includes forming a plurality of hooked teeth.

17. The process of claim **12**, wherein the forming teeth is such that separation of the layers would destroy integrity of at least one of the conductive layer and the dielectric material.

18. A process of making an electrical device, the process including:

building up a conductive layer in filling undercuttings with respect to a surface of a dielectric material so as to form a plurality of teeth in cavities, some of the teeth being obtuse to the surface and in the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, in forming a portion of circuitry of an electrical device,

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

19. A process of making an electrical device, the process including:

producing a surface with cavities remaining after removing portion of a dielectric material sufficient to produce a surface with a surface gloss measurement at an angle of 60 degrees of less than 10%; and

building up a conductive layer in the cavities in forming electrical device circuitry, wherein the cavities are obtusoly angled and the building up the conductive layer includes forming teeth in the cavities and in the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface, and one of the teeth engages a portion of the dielectric material at the slope.

20. The process of claim **19**, wherein producing the cavities does not include physical roughening, and the building up the conductive layer includes building up the conductive layer in producing a dielectric surface contact area greater than a dielectric surface contact area that would be produced by a single pass roughening, and the forming teeth includes forming a plurality of teeth that mechanically grip, more than by adherence, the surface contact area.

21. The process of claim **19**, wherein the producing cavities does not include physical roughening, and the building up the conductive layer fills the cavities sufficiently to produce a peel strength greater than a peel strength that would be produced by a single desmear process, and the forming teeth includes forming a plurality of hooked teeth.

22. The process of claim **19**, wherein the producing cavities does not include physical roughening, and the building up the conductive layer includes building up the conductive layer sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of at least one of the conductive layer and the dielectric material.

23. A process of making an electrical device, the process including:

forming electrical device circuitry with teeth produced by building up a conductive layer in cavities of a dielectric material that has an exterior surface and a dielectric surface area greater than a dielectric surface area that would be produced by a single pass roughening, wherein a sample of the circuitry has at least 20% of the teeth that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the exterior surface, and one of the teeth engages a portion of the dielectric material at the slope.

24. The process of claim **23**, further including providing a micro via interconnect for the circuitry.

25. The process of claim **23**, further including producing the cavities without physical roughening and sufficiently to produce a peel strength greater than a peel strength that would be produced by a single desmear process, and such that a plurality of the teeth are hooked teeth.

26. The process of claim **23**, wherein the conductive layer is built up sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of at least one of the conductive layer and the dielectric material.

27. A process of making an electrical device, the process including:

combining a dielectric material with a conductive layer in forming a portion of circuitry of an electrical device, said combining being carried out with means for joining the conductive layer to the dielectric material,

the means including teeth built up on the dielectric material and angled sufficiently to mechanically grip the dielectric material in three dimensions, wherein a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the teeth is in one of a plurality of cavities that includes an upgrade slope with respect to an etched surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

28. A process of making an electrical device, the process including:

combining a dielectric material with means for joining a conductive layer built up on the dielectric material sufficient to produce a peel strength greater than a peel strength that would be produced by a single desmear process, the conductive layer forming a portion of circuitry, wherein

the combining is carried out with the means for joining comprised of teeth, a plurality of the teeth being obtuse to a top surface of the dielectric material and within cavities in the range of at least 1 tenth of a mil deep to 1.75 of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

29. A process of making an electrical device, the process including:

forming electrical device circuitry by building up a conductive layer on a surface of dielectric material so as to produce a peel strength greater than a peel strength that would be produced by a single desmear process, wherein

a sample of the circuitry includes at least 20% of teeth that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of a plurality of cavities, respectively adjacent to the teeth, includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

30. The process of claim **29**, wherein the electrical device comprises a circuit board.

31. The process of claim **29**, wherein the building up the conductive layer includes building up the conductive layer sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of at least one of the conductive layer and the dielectric material.

32. A process of making an electrical device, the process including:

producing a surface remaining from removing a portion of a dielectric material; and

applying means for mechanically gripping a conductive layer to the surface so that a conductive layer is burrowed in and under the surface, wherein

the conductive layer forms a portion of circuitry of an electrical device, wherein the applying is carried out with the means for mechanically gripping comprising teeth, and a plurality of the teeth are within the range of 1 tenth of a mil deep to 2 tenths of a mil deep, and

wherein at least one of a plurality of cavities, respectively adjacent to the teeth, includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

33. A process of making an electrical device, the process including:

forming electrical device circuitry by building up a conductive layer on a dielectric material sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of the conductive layer and of the dielectric material, wherein

the building up the conductive layer includes forming teeth that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of a plurality of cavities, respectively adjacent to the teeth, includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

34. A process of making an electrical device, the process including:

building up a conductive layer on a dielectric material sufficient to produce a surface gloss measurement at an angle of 60 degrees of less than 10%, in forming circuitry of an electrical device, wherein

the building up the conductive layer includes producing teeth within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of a plurality of cavities, respectively adjacent to the teeth, includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

35. The process of claim **34**, wherein building up the conductive layer includes building up the conductive layer sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of the conductive layer.

36. The process of claim **34**, wherein the building up the conductive layer includes building up the conductive layer sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of the dielectric material.

37. The process of claim **34**, wherein the building up the conductive layer includes building up the conductive layer sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of the conductive material and the dielectric material.

38. A process of making an electrical device, the process including:

combining a dielectric material with means for joining a conductive layer built up on a conductive coating on the dielectric material at a dielectric surface contact area greater than a dielectric surface contact area that would be produced by a single pass roughening,

the conductive layer forming a portion of circuitry, wherein the combining is carried out with the means for joining comprised of teeth within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of a plurality of cavities, respectively adjacent to the teeth, includes an upgrade slope with respect to an etched surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

39. A process of making an electrical device, the process including:

combining a dielectric material with means for joining a conductive layer built up on the dielectric material sufficiently that separation of the dielectric material from the conductive layer requires destroying integrity of at least one of the conductive layer and the dielectric material,

said means for joining comprising filled cavities that form a portion of circuitry of an electrical device, wherein the filled cavities comprise teeth that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to an etched surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

40. The process of any one of claims **1**, **7**, **11**, **18**, **19**, **23**, **27**, **28**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes a frequency of the teeth sufficient to provide at least 5,000 said teeth per linear inch.

41. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes a frequency of the teeth sufficient to provide at least 10,000 said teeth per linear inch.

42. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes a frequency of the teeth sufficient to provide at least 15,000 said teeth per linear inch.

43. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes a frequency of the teeth sufficient to provide at least 25,000 said teeth per square inch.

44. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes a frequency of the teeth sufficient to provide at least 100,000 said teeth per square inch.

45. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes a frequency of the teeth sufficient to provide at least 200,000 said teeth per square inch.

46. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein: a sample of the circuitry includes at least 20% of the teeth are shaped to mechanically grip the dielectric material.

47. The process of any one of claims **1**, **12**, **18**, **19**, **27**, **28**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes at least 50% of the teeth that are obtuse shaped.

48. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **32**, **33**, **38**, or **39** wherein:

a sample of the circuitry includes at least 20% of the teeth that are within the range of at least 1 tenth of a mil deep to 1.75 tenths of a mil deep.

49. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein: a sample of the circuitry includes at least 50% of the teeth that are within the range of at least 1 tenth of a mil deep to 1.75 tenths of a mil deep.

50. The process of any one of claims **1**, **3**, **7**, **12**, **18**, **19**, **27**, **28**, **32**, **33**, **38**, or **39** wherein: a sample of the circuitry includes at least 20% of the teeth that are within the range of 1 tenth of a mil deep to 1.5 tenths of a mil deep.

51. The process of any one of claims **1**, **2**, **3**, **7**, **12**, **18**, **19**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein: a sample of the circuitry includes at least 50% of the teeth that are within the range of 1 tenth of a mil deep to 1.5 tenths of a mil deep.

52. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein: a sample of the circuitry includes at least 20% of the teeth that are in the range of 1.5 tenths of a mil deep to 1.75 tenths of a mil deep.

53. The process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **29**, **32**, **33**, **38**, or **39** wherein: a sample of the circuitry includes at least 50% of the teeth that are in the range of 1.5 tenths of a mil deep to 1.75 tenths of a mil deep.

54. The process of claim **40**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

55. The process of claim **41**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

56. The process of claim **42**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

57. The process of claim **43**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

58. The process of claim **44**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

59. The process of claim **45**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

60. The process of claim **46**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

61. The process of claim **47**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

62. The process of claim **48**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

63. The process of claim **49**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

64. The process of claim **50**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

65. The process claim **51**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

66. The process of claim **52**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

67. The process of claim **53**, further including configuring the circuitry of the electrical device as multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising correspondingly made teeth.

68. The process of claim **40**, further including configuring the circuitry as of double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

69. The process of claim **41**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

70. The process of claim **42**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

71. The process of claim **43**, further including configuring the circuitry as of double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

72. The process of claim **44**, further including configuring the circuitry as of double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

73. The process of claim **45**, further including configuring the circuitry as of double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

74. The process of claim **46**, further including configuring the circuitry as of double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

75. The process of claim **47**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

76. The process of claim **48**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

77. The process of claim **49**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

78. The process of claim **50**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

79. The process of claim **51**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

80. The process of claim **52**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

81. The process of claim **53**, further including configuring the circuitry as double sided circuitry, one side comprising said teeth and another side comprising correspondingly made teeth.

82. A product produced by the process of any one of claims **1**, **7**, **12**, **18**, **19**, **23**, **27**, **28**, **32**, **29**, **33**, **38**, or **39**.

83. An electrical device including:

a dielectric material comprising a surface with cavities remaining from removal of a portion of the dielectric material;

a conductive layer built up on the dielectric material so as to fill the cavities and form teeth set in and under the surface of the dielectric material; and wherein:

the conductive layer is a portion of circuitry of an electrical device, and a plurality of the cavities are obtuse with respect to the top surface and are at least 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

84. The device of claim **83**, wherein, prior to the conductive layer of material being built up thereon, the surface with the cavities has a gloss sufficient to produce a surface gloss measurement at an angle of 60 degrees of less than 10%.

85. The device of claim **83**, wherein the electrical device comprises a micro via interconnect.

86. The device of claim **83**, wherein the teeth have a dielectric surface contact area greater than a dielectric surface contact area that would be produced by a single pass roughening, and some of the teeth comprise hooked teeth.

87. The device of claim **83**, wherein the conductive layer fills the cavities sufficiently to produce a peel strength greater than a peel strength that would be produced by a single desmear process, and some of the teeth mechanically grip the dielectric material, more than by adherence.

88. The device of claim **83**, wherein the conductive layer fills the cavities sufficiently that separation of the conductive layer from the dielectric material requires destroying integrity of at least one of the conductive layer and the portion of the dielectric material.

89. An electrical device including:

a dielectric material comprising a surface with cavities remaining after removal of some of the dielectric material;

a conductive layer built up on the dielectric material so as to fill the cavities and form substantially angular teeth set in the dielectric material; and wherein

the conductive layer is a portion of circuitry of an electrical device, and a plurality of the teeth being are at least 1 tenth of a mil deep and less than 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

90. The device of claim **89**, wherein, prior to the conductive layer of material being built up thereon, the surface with the cavities has a gloss sufficient to produce a surface gloss measurement at an angle of 60 degrees of less than 10%.

91. The device of claim **89**, wherein the teeth have a dielectric surface contact area greater than a dielectric surface contact area that would be produced by a single pass roughening, and some of the teeth comprise hooked teeth.

92. The device of claim **89**, wherein the the conductive layer fills the cavities sufficiently so as to produce a peel strength greater than a peel strength that would be produced by a single desmear process, and some of the teeth mechanically grip the dielectric material, more than by adherence.

93. The device of claim **89**, wherein the conductive layer built up is built up sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of at least one of the conductive layer and the dielectric material.

94. An electrical device including:

a conductive layer of material built up on a surface of a layer of a dielectric material, the layers joined in a sawtooth manner made of both materials in an interlocking bite; wherein

the conductive layer is a portion of circuitry of an electrical device, the conductive layer is comprised of teeth such that a sample of the circuitry has a frequency of the teeth sufficient to provide at least 5,000 of the teeth per linear inch, the teeth the teeth set respectively in cavities of the bite and a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface, and one of the teeth engages a portion of the dielectric material at the slope.

95. The device of claim **94**, wherein the electrical device comprises a micro via interconnect.

96. The device of claim **94**, wherein, prior to the conductive layer of material being built up thereon, the surface has a gloss sufficient to provide a surface gloss measurement at an angle of 60 degrees of less than 10%.

97. The device of claim **94**, wherein the teeth have a dielectric surface contact area that is greater than a dielectric surface contact area that would be produced by a single pass roughening, and some of the teeth comprise hooked teeth.

98. The device of claim **94**, wherein the conductive layer built up is built up sufficiently to produce a peel strength greater than a peel strength that would be produced by a single desmear process, and some of the teeth mechanically grip the dielectric material, more than by adherence.

99. The device of claim **94**, wherein the conductive layer built up is built up sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of at least one of the conductive layer and the dielectric material.

100. An electrical device including:

a conductive layer built up so as to fill undercuttings with respect to a surface of a dielectric material so as to form teeth in cavities, a plurality of the undercuttings being obtuse to the surface, wherein

the conductive layer is a portion of circuitry of an electrical device, and a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

101. An electrical device including:

a dielectric material surface with cavities sufficient to produce a surface gloss measurement at an angle of 60 degrees of less than 10%; and

electrical device circuitry comprised of a conductive layer built up so as to fill in the cavities and form teeth, wherein a plurality of the cavities are obtusely angled with respect to the surface, and a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

102. The device of claim **101**, wherein the teeth have a dielectric surface contact area that is greater than a dielectric surface contact area that would be produced by a single pass roughening, and some of the teeth comprise hooked teeth.

103. The device of claim **101**, wherein the conductive layer fills in the cavities sufficiently to produce a peel strength greater than a peel strength that would be produced by a single desmear process, and some of the teeth mechanically grip the dielectric material, more than by adherence.

104. The device of claim **101**, wherein the conductive layer is sufficiently built up that separation of the conductive layer from the dielectric material destroys integrity of at least one of the conductive layer and the dielectric material.

105. An electrical device including:

a dielectric material; and

electrical device circuitry comprising a conductive layer built up on the dielectric material at a dielectric surface having an area greater than a dielectric surface area that would be produced by a single pass roughening; and wherein

the conductive layer is comprised of plurality of the teeth within cavities that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

106. The device of claim **105**, wherein the electrical device comprises a micro via interconnect.

107. The device of claim **105**, wherein the conductive layer built up is built up in the cavities sufficiently to produce a peel strength greater than a peel strength that would be produced by a single desmear process, and some of the teeth mechanically grip the dielectric material, more than by adherence.

108. The device of claim **105**, wherein the conductive layer built up is built up sufficiently that separation of the conductive layer from the dielectric material requires destroying integrity of at least one of the conductive layer and the dielectric material.

109. An electrical device including:

a dielectric material comprising a surface;

a conductive layer forming a portion of circuitry of an electrical device; and

means for joining the conductive layer to the dielectric material, the means including a structuring of teeth built up on the dielectric material and comprised of the conductive layer and angled sufficiently for mechanically gripping the dielectric material in three dimensions, wherein a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

110. An electrical device including:

a dielectric material comprising a surface; and

means for joining a conductive layer built up on the dielectric material so as to produce a peel strength greater than a peel strength that would be produced by a single desmear process, wherein the conductive layer is a portion of circuitry, and portions of the conductive layer are in cavities obtuse to a top surface of the dielectric material, wherein the means for joining is comprised of teeth, and a plurality of the teeth that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

111. An electrical device including:

a dielectric material; and

electrical device circuitry comprising a conductive layer built up on a surface of the dielectric material so as to produce teeth set in cavities and a peel strength greater than a peel strength that would be produced by a single desmear process; and wherein

plurality of the teeth that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

112. The device of claim **111**, wherein the electrical device comprises a circuit board.

113. The device of claim **111**, wherein the conductive layer built up is built up sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of at least one of the conductive layer and the dielectric material.

114. An electrical device including:

a dielectric material having a surface remaining from removal of a portion of the dielectric material; and

means for mechanically gripping a conductive layer to the surface of the dielectric material so that the conductive layer is burrowed in and under the top surface of the dielectric material, wherein the conductive layer forms a portion of circuitry of an electrical device, wherein the means for mechanically gripping is comprised of teeth, and a plurality of the teeth are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

115. An electrical device including:

a dielectric material; and

electrical device circuitry comprising a conductive layer built up on the dielectric material sufficiently that separation of the conductive layer from the dielectric material would require destroying integrity of the conductive layer and of the dielectric material, wherein the conductive layer is comprised of teeth in cavities, a plurality of the teeth being within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

116. An electrical device including:

a dielectric material having a surface with a gloss sufficient for surface gloss measurement at an angle of 60 degrees of less than 10%; and

circuitry of an electrical device comprised of a conductive layer on the dielectric material, wherein the conductive layer is comprised of teeth in cavities, a plurality of the teeth being within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

117. The device of claim **116**, wherein the conductive layer built up on the dielectric material is built up sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of the conductive layer.

118. The device of claim **116**, wherein the conductive layer built up on the dielectric material is built up sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of the dielectric material.

119. The device of claim **116**, wherein the conductive layer built up on the dielectric material is built up sufficiently that separation of the conductive layer from the dielectric material would destroy integrity of the conductive layer and the dielectric material.

120. An electrical device including:

a dielectric material having a surface; and

means for joining a conductive layer built up on the dielectric material at a surface having a contact area greater than a dielectric surface contact area that would be produced by a single pass roughening, wherein the conductive layer is a portion of circuitry of an electrical device, wherein the conductive layer is comprised of teeth in cavities, a plurality of the teeth being within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

121. An electrical device including:

a dielectric materialincluding a surface; and

means for joining a conductive layer built up on the dielectric material sufficiently that separation of the conductive layer from the dielectric material requires destroying integrity of at least one of the conductive layer and the dielectric material, said means for joining comprising filled cavities that form a portion of circuitry of the electrical device comprised of teeth, a plurality of the teeth being within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep, and

wherein at least one of the cavities includes an upgrade slope with respect to the surface of the dielectric material, and one of the teeth engages a portion of the dielectric material at the slope.

122. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein:

a sample of the circuitry has a frequency of the teeth sufficient to provide at least 5,000 said teeth per linear inch.

123. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein:

a sample of the circuitry has a frequency of the teeth sufficient to provide at least 10,000 said teeth per linear inch.

124. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein:

a sample of the circuitry has a frequency of the teeth sufficient to provide at least 15,000 said teeth per linear inch.

125. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein:

a sample of the circuitry has a frequency of the teeth sufficient to provide at least 25,000 said teeth per square inch.

126. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** whereto:

a sample of the circuitry has a frequency of the teeth sufficient to provide at least 100,000 said teeth per square inch.

127. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** whereto: a sample of the circuitry has at least 200,000 said teeth per square inch.

128. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 20% of the teeth have a shape that mechanically grips the dielectric material.

129. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 50% of the teeth structured obtusely with respect to a line within a plane defined by a surface of the dielectric material that was removed.

130. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 20% of the teeth that are at least 1 tenth of a mil deep.

131. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 50% of the teeth that are at least 1 tenth of a mil deep.

132. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 20% of the teeth that are within the range of 1 tenth of a mil deep to 1.75 tenths of a mil deep.

133. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 50% of the teeth that are within the range of 1 tenth of a mil deep to 2 tenths of a mil deep.

134. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 20% of the teeth that are in the range of 1.5 tenths of a mil deep to 1.75 tenths of a mil deep.

135. The device of any one of claims **83**, **89**, **93**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **115**, **116**, **120**, or **121** wherein: a sample of the circuitry has at least 50% of the teeth that are in the range of 1.5 tenths of a mil deep to 1.75 tenths of a rail deep.

136. The device of claim **124**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

137. The device of claim **125**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

138. The device of claim **126**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

139. The device of claim **127**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

140. The device of claim **128**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

141. The device of claim **129**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

142. The device of claim **130**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

143. The device of claim **131**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

144. The device of claim **132**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

145. The device of claim **133**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

146. The device of claim **134**, wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

147. The device of claim **135** wherein the circuitry of the electrical device is comprised of multi-layer circuitry, one of said layers comprising said teeth and another of said layers comprising corresponding teeth.

148. The device of claim **122**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

149. The device of claim **123**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

150. The device of claim **124**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

151. The device of claim **125**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

152. The device of claim **126**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

153. The device of claim **127**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

154. The device of claim **128**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

155. The device of claim **129**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

156. The device of claim **130**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

157. The device of claim **131**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

158. The device of claim **132**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

159. The device of claim **133**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

160. The device of claim **134**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

161. The device of claim **135**, wherein the circuitry is comprised of double sided circuitry, one side comprising said teeth and another side comprising corresponding teeth.

162. A process of making the electrical device product of any one of claims **83**, **89**, **94**, **100**, **101**, **105**, **109**, **110**, **111**, **114**, **116**, **120**, or **121**, the method including: forming means for joining by building up a conductive layer on a dielectric material surface remaining from removal of a portion of the dielectric material to form a portion of circuitry in the electrical device.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,501,582 B2 Page 1 of 1
APPLICATION NO. : 10/790363
DATED : March 10, 2009
INVENTOR(S) : McDermott et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 9, line 35, after the, delete “top”.

Column 10, line 14, after surface, insert -- , --.

Column 11, line 31, insert -- a -- before portion.

Column 11, lines 35-36, delete “cavities are obtusely angled and”.

Column 12, line 47, delete “top”.

Column 17, line 21, delete “top”.

Column 24, line 33, delete “method” and there insert -- process --.

Column 24, line 38, add the following claims:

163. The process of any one of claims 1, 7, 12, 18, 19, 23, 27, 28, 32, 33, 38, 39, further including subjecting the dielectric material to a first etching of the dielectric material and a second etching of the dielectric material.

164. The device of any one of claims 83, 89, 94, 100, 101, 109, 110, 111, 114, 115, 116, 120, and 121, wherein the dielectric material is nonhomogeneous.

165. The device of any one of 83, 89, 94, 100, 101, 109, 110, 111, 114, 115, 116, 120, and 121, wherein the metal layer is comprised of a conductive coating.

Signed and Sealed this

Eleventh Day of May, 2010

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,501,582 B2
APPLICATION NO. : 10/790363
DATED : March 10, 2009
INVENTOR(S) : McDermott et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Delete the title page and substitute therefore the attached title page showing the corrected number of claims in the patent.

Column 9, line 35, after the, delete “top”.

Column 10, line 14, after surface, insert -- , --.

Column 11, line 31, insert -- a -- before portion.

Column 11, lines 35-36, delete “cavities are obtusely angled and”.

Column 12, line 47, delete “top”.

Column 17, line 21, delete “top”.

Column 24, line 33, delete “method” and there insert -- process --.

Column 24, line 38, add the following claims:

163. The process of any one of claims 1, 7, 12, 18, 19, 23, 27, 28, 32, 33, 38, 39, further including subjecting the dielectric material to a first etching of the dielectric material and a second etching of the dielectric material.

164. The device of any one of claims 83, 89, 94, 100, 101, 109, 110, 111, 114, 115, 116, 120, and 121, wherein the dielectric material is nonhomogeneous.

165. The device of any one of 83, 89, 94, 100, 101, 109, 110, 111, 114, 115, 116, 120, and 121, wherein the metal layer is comprised of a conductive coating.

This certificate supersedes the Certificate of Correction issued May 11, 2010.

Signed and Sealed this

Twenty-second Day of June, 2010

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

CERTIFICATE OF CORRECTION (continued)

(12) **United States Patent**
McDermott et al.

(10) **Patent No.: US 7,501,582 B2**
(45) **Date of Patent: Mar. 10, 2009**

(54) **ELECTRICAL DEVICE AND METHOD FOR MAKING SAME**

(75) Inventors: **Brian J. McDermott**, Winter Springs, FL (US); **Daniel McGowan**, Casselberry, FL (US); **Ralph Leo Spotts, Jr.**, Lake Mary, FL (US); **Sid Tryzbiak**, Winter Springs, FL (US)

(73) Assignee: **Peter K. Trzyna, Esq.**, Chicago, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 98 days.

(21) Appl. No.: **10/790,363**

(22) Filed: **Mar. 1, 2004**

(65) **Prior Publication Data**

US 2004/0163847 A1 Aug. 26, 2004

Related U.S. Application Data

(63) Continuation of application No. 09/694,099, filed on Oct. 20, 2000, now Pat. No. 6,700,069, and a continuation of application No. 08/905,619, filed on Aug. 4, 1997, now Pat. No. 6,141,870.

(51) **Int. Cl.**
H05K 1/03 (2006.01)

(52) **U.S. Cl.** **174/255**; 174/256; 174/257

(58) **Field of Classification Search** 174/255–262; 29/850–853; 216/15–16
See application file for complete search history.

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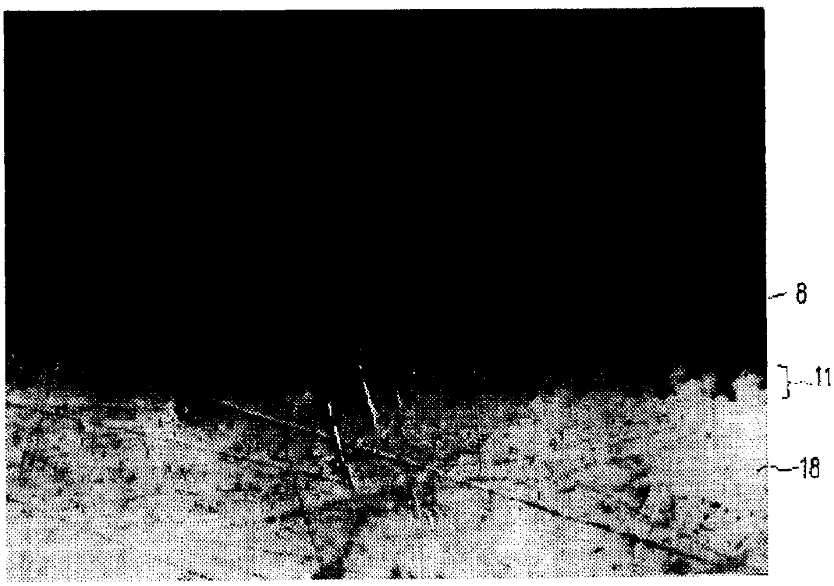
Primary Examiner—Tuan T. Dinh

(57) **ABSTRACT**

A multilayer electrical device, such as a printed circuit board, having a tooth structure including a metal layer set in a dielectric. The device includes a base; a conductive layer adjacent to the base; a dielectric material adjacent to conductive layer; a tooth structure including a metal layer set in the dielectric material to join the dielectric material to the metal layer; and wherein the metal layer forms a portion of circuitry in a circuit board having multiple layers of circuitry.

165 Claims, 2 Drawing Sheets
(1 of 2 Drawing Sheet(s) Filed in Color)



US008278560B2

(12) **United States Patent**
McDermott et al.

(10) **Patent No.: US 8,278,560 B2**
(45) **Date of Patent: Oct. 2, 2012**

(54) **ELECTRICAL DEVICE WITH TEETH JOINING LAYERS AND METHOD FOR MAKING THE SAME**

(76) Inventors: **Brian J. McDermott**, Winter Springs, FL (US); **Daniel McGowan**, Casselberry, FL (US); **Ralph Leo Spotts, Jr.**, Lake Mary, FL (US); **Sid Tryzbiak**, Winter Springs, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 43 days.

(21) Appl. No.: **12/363,501**

(22) Filed: **Jan. 30, 2009**

(65) **Prior Publication Data**

US 2009/0196980 A1 Aug. 6, 2009

Related U.S. Application Data

(63) Continuation of application No. 10/790,363, filed on Mar. 1, 2004, now Pat. No. 7,501,582, and a continuation of application No. 09/694,099, filed on Oct. 20, 2000, now Pat. No. 6,700,069, and a continuation of application No. 08/905,619, filed on Aug. 4, 1997, now Pat. No. 6,141,870.

(51) **Int. Cl.**
H05K 1/03 (2006.01)

(52) **U.S. Cl.** **174/255**

(58) **Field of Classification Search** 174/266
See application file for complete search history.

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Primary Examiner — Jeremy Norris
Assistant Examiner — Tremesha S Willis
(74) *Attorney, Agent, or Firm* — Peter K. Trzyna, Esq.

(57) **ABSTRACT**

A multilayer electrical device, such as a printed circuit board, having a tooth structure including a metal layer set in a dielectric. The device includes a base; a conductive layer adjacent to the base; a dielectric material adjacent to conductive layer; a tooth structure including a metal layer set in the dielectric material to join the dielectric material to the metal layer; and wherein the metal layer forms a portion of circuitry in a circuit board having multiple layers of circuitry.

21 Claims, 2 Drawing Sheets

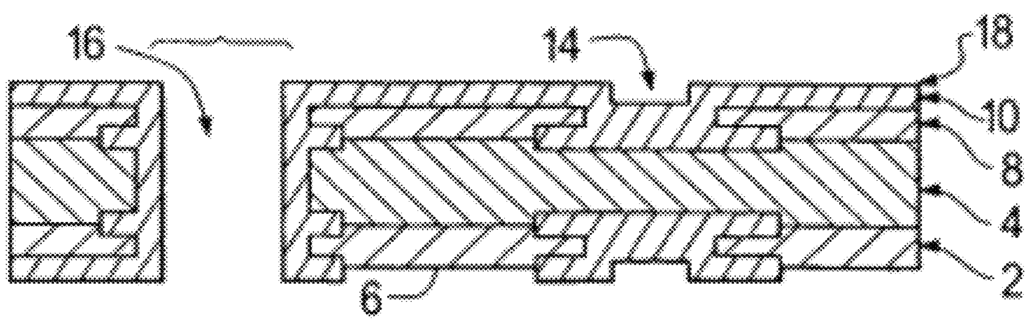

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FIG. 1

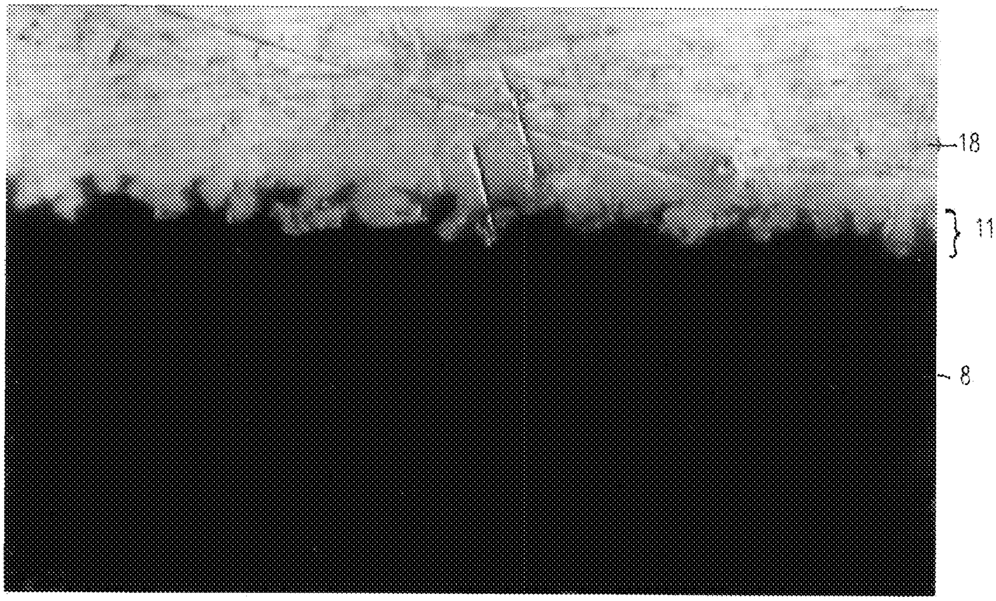


FIG. 2 PRIOR ART

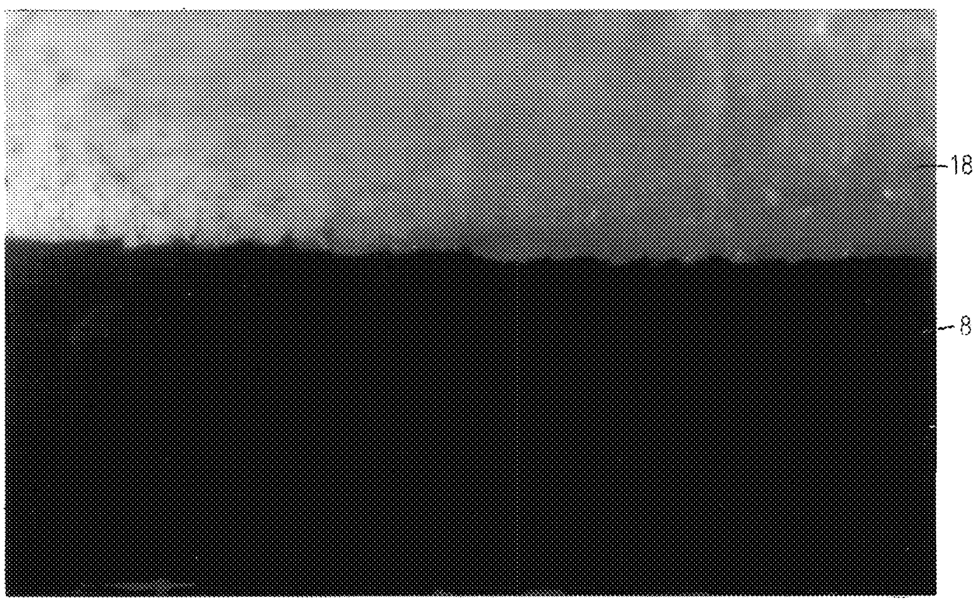


FIG. 3

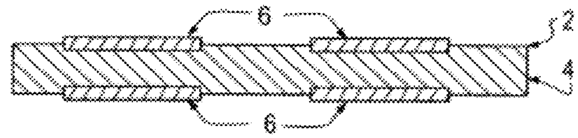


FIG. 4

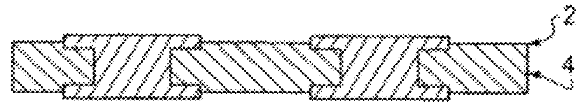


FIG. 5

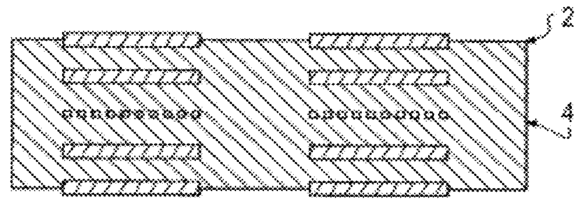


FIG. 6

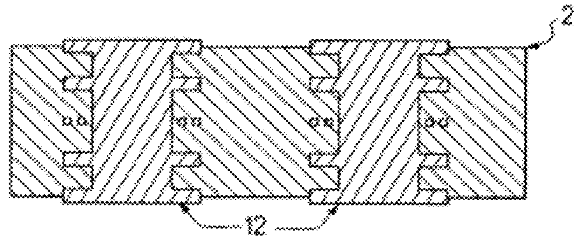


FIG. 7

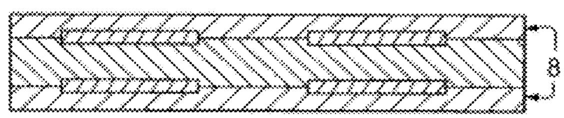


FIG. 8

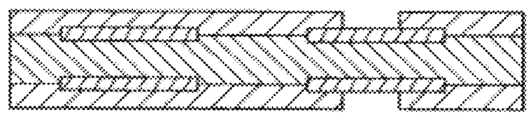


FIG. 9

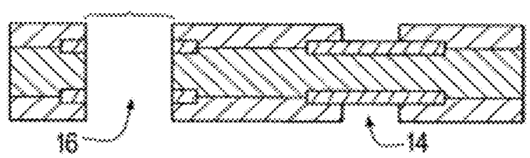


FIG. 10

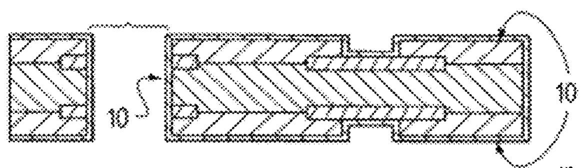
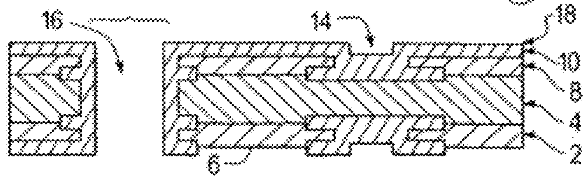


FIG. 11



ELECTRICAL DEVICE WITH TEETH JOINING LAYERS AND METHOD FOR MAKING THE SAME

I. CLAIM OF PRIORITY

This patent application is a continuation application that claims priority and incorporates by reference from: Ser. No. 10/790,363, filed Mar. 1, 2004, issuing Mar. 10, 2009, as U.S. Pat. No. 7,501,582; Ser. No. 08/905,619, filed Aug. 4, 1997, issuing on Nov. 7, 2000, as U.S. Pat. No. 6,141,870; and Ser. No. 09/694,099, filed Oct. 20, 2000, issuing on Mar. 2, 2004, as U.S. Pat. No. 6,700,069.

II. FIELD OF THE INVENTION

The present invention is directed to methods for making or manufacturing an electrical device, and the process, composition, and product thereof. More particularly, the present invention involves such multilayer electrical devices as circuit boards constructed by joining a dielectric material to a subsequently applied conductive material. Still more particularly, the present invention involves an electrical device having a substrate or base, an applied dielectric material thereon, which in turn has a thin conductive coating thereon, and a conductive layer formed upon the conductive coating, the conductive layer being joined to the applied dielectric material in an improved manner.

III. BACKGROUND OF THE INVENTION

Multilayer electrical devices—those made from layering a dielectric material and a conductive material on a base—suffer from delamination, blistering, and other reliability problems. This is particularly true when the laminates are subjected to thermal stress.

Known attempts to solve these problems seem to have focused on physical or chemical roughening, particularly of the base or substrate. See for example, U.S. Pat. No. 4,948,707. Although oxide-related chemical roughening processes have been used, an emphasis on physical roughening may reflect the use of materials that are relatively chemically resistant. Both physical and chemical roughening approaches have improved adherence to the base.

However, the extent to which this adherence can be increased by roughening has its limits. And despite a long standing recognition of delamination, blistering, and reliability problems, and the attempts to find a solution, these problems have been persistent in electrical devices made of layered materials.

IV. SUMMARY OF THE INVENTION

The inventors herein have observed that the general problem of poor adherence between the laminates or layers can be addressed by forming a unique surface structure, which is particularly suitable for joining the dielectric material to the conductive coating and conductive layer. The surface structure is comprised of teeth that are preferably angled or hooked like fangs or canine teeth to enable one layer to mechanically grip a second layer.

In comparison with the above-mentioned roughening techniques of the prior art, it is believed that a surface of the teeth is an improvement in that there is an increase in surface area. However, it is still better to use teeth that are fang-shaped to enable a mechanical grip that functions in a different manner than adherence by means of increased surface area. By using the fanged, angled, canine, or otherwise hooked teeth (in addition to increased surface area), there is a multidirectional, three dimensional interlacing or overlapping of layers. For example, in joining the dielectric material to the conductive coating and metal layer, the conductive coating and metal layer is actually burrowed in and under the dielectric material and vice versa. Thus, separating them not only involves breaking the surface area adherence, but also involves destroying the integrity of at least one of the layers by ripping the teeth, the layer pierced by them, or both.

Further, it has been found preferable to have numerous teeth sized and shaped so that they are not too large or too small. If the teeth are too small, wide, straight, and shallow, then the surface resembles the roughened surface of prior art techniques, vaguely analogous to a surface of molar teeth, and the adherence is not much better than that achieved by known prior art roughening techniques.

However, if the teeth are too large, deep, and fanged or hook-shaped, the teeth undercut the surface to such an extent that the strength of the dielectric material surface is weakened. As a result, adherence is decreased over the preferred embodiment.

Not too great and not too slight, the right sized and shaped teeth, set in a fanged orientation and with sufficient frequency, have been found to be the best structure. If the correct balance of these critically important factors is created, the result is a greatly improved circuit board or other such electrical device.

It is theorized by the inventors that the best methods for producing the teeth is to use non-homogeneous materials and/or techniques. For example, a dielectric material can have a non-homogeneous composition or thickness to bring about an uneven chemical resistance, such that slowed and/or repeated etching will form teeth instead of a uniform etch.

V. BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a conductive coating and metal layer applied dielectric material with a desirable tooth structure;

FIG. **2** is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes;

FIG. **3** is an illustration of a double sided printed circuit board without plated through holes;

FIG. **4** is an illustration of a multilayer printed circuit board with plated through holes, filled or unfilled with conductive or nonconductive material;

FIG. **5** is an illustration of a multilayer printed circuit board without plated through holes;

FIG. **6** is an illustration of a multilayer printed circuit board having more than two layers with plated through holes filled or unfilled with conductive or nonconductive material;

FIG. **7** is an illustration of any of the foregoing printed circuit boards after applying a dielectric material thereon;

FIG. **8** is an illustration of the multilayer printed circuit board of FIG. **7** after forming micro vias;

FIG. **9** is an illustration of the multilayer printed circuit board of FIG. **7** after opening the through holes and after etching the applied dielectric material to produce the teeth illustrated in FIG. **1**;

FIG. **10** is an illustration of the multilayer printed circuit board of FIG. **9** after application of a conductive coating to fill in around the teeth and connect micro via holes and the through holes; and

FIG. **11** is an illustration of the multilayer printed circuit board of FIG. **10** after plating the conductive coating to form a metal layer and complete forming circuitry.

VI. DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a conductive coating and metal layer on the applied dielectric material with a desirable tooth structure. In contrast, FIG. **2** is an illustration of a prior art conductive coating **18** and metal layer on the applied dielectric material with the surface produced by roughening processes. In both FIGS. **1** and **2**, show a dielectric material and a combination of a thin conductive coating and metal later. Compare FIG. **1** and FIG. **2**, and note particularly the size, shape, frequency, and depth of the teeth **11** in FIG. **1** with the surface produced by roughening in FIG. **2**.

A way of articulating this "teeth" **11** concept is to view each tooth as being made of one layer and set in a second layer. However, the perspective is arbitrary, and one could equally view each tooth as made of the second layer set in the first. It could also be said that the layers join in a saw-toothed manner, i.e., teeth **11** made of both materials in an interlocking bite. In any case, however, there are teeth **11**, and for the sake of consistency, this specification will adopt the convention of referring to the teeth **11** as being made of the conductive coating and metal layer set in the dielectric material.

A further way of articulating the "teeth" **11** concept is to view each tooth as being substantially triangular in shape, with the base of the triangle being defined by a plane of the applied dielectric material before it is etched, or more precisely by the exterior surface thereof. The invention can be carried by forming cavities in the applied dielectric material **8** for receiving the teeth **11**, and then forming the teeth **11** from the conductive coating and metal layer formed thereon. Generally, the teeth **11** can be of any triangular shape (e.g., equilateral, isosceles, scalene, right, obtuse, or any combination thereof). Preferably, though, the teeth **11** are obtuse so as to hook or angle under the exterior surface of the applied dielectric material.

The use of any shape of teeth **11** increases the surface area where the conductive coating is on the applied dielectric material. However, the preferred embodiment utilizes a surface of obtuse, canine, or fang-shaped teeth **11** to help the conductive coating and metal layer hook under the exterior surface of the applied dielectric material to mechanically grip the applied dielectric material. The obtuse, canine, or fang-shaped teeth **11** are in contrast to the shallower, more rounded surface typically produced by known roughening techniques. Note in FIG. **2** that roughing techniques can produce some occasional gouging, but nothing on the order of the present invention.

As to size of the teeth **11**, as mentioned above, it is preferable that the teeth **11** be within a certain size range. The optimal size range for obtuse, canine, or hook-shaped teeth **11** involves a balance between maximizing surface area and mechanical grip, but not undercutting the surface of the applied dielectric material **8** to such an extent as to weaken it. Accordingly, the teeth **11** should be sized at least 1 tenth of a mil deep. Better is at least 1.25 tenths of a mil deep, and even better is at least 1.5 tenths of a mil deep. However, 1.75 tenths of a mil is acceptable, and about 2 tenths of a mil is reaching the limit.

As to frequency, the teeth **11** should be quite frequent in number; at least about 5,000 teeth **11** per linear inch, and preferably at least about 10,000 teeth **11** per linear inch; and even better is at least about 15,000 teeth **11** per linear inch.

As to surface area, there should be at least about 25,000 teeth **11** per square inch, better still is essentially at least about 100,000 per square inch, and preferably at least about per 200,000 per square inch, or even greater.

It should be recognized that the teeth **11** generally are not formed to a precise dimension. As shown in FIG. **1**, some of the teeth **11** are somewhat differently sized, angled, and proportioned. Thus, a representative sample of the electrical device should have teeth **11** in about these ranges. Having at least about 20% of the teeth **11** in one or more of these ranges, and preferably at least 50%, is a preferred balance of mechanical grip without a weakening the integrity of the layering, particularly in combination.

As illustrated in FIGS. **3-11**, there is an electrical device, such as a printed circuit board **2** having a base **4**. The base **4** has a conductive layer **6** thereon. A dielectric material **8** is applied on the conductive layer **6**, and a conductive coating **10** (such as a thin coating of palladium) is deposited on the dielectric material **8**. Metal layer **12** is formed on the conductive coating **10**.

FIG. **3** illustrates one of the many ways to begin the process of forming the teeth **11** in accordance with the present invention. A first step (step **1**), includes providing a base **4** for constructing an electrical device, such as a printed circuit board **2**. FIG. **3** illustrates one such construction, namely a base **4** for constructing a multilayer printed circuit board **2**, the base **4** having any positive number of layers or laminates, for example the two layers shown in FIGS. **3** and **4**, or more than two layers as illustrated in FIGS. **5** and **6**, etc. One configuration or another is not significant, except that multiple layers provide a better medium for constructing circuitry of increased complexity or density. FIGS. **3-6** illustrate an embodiment in which the conductive layer **6** is on at least an upper side, and preferably also on a lower side of the base **4**.

As may be needed for a particular circuitry design, FIG. **4** illustrates that the electrical device can be further manipulated, for example, by forming through holes **12** by mechanical drilling, laser drilling, punching, or the like. The plated through holes **12** are shown in FIGS. **4** and **6** as filled or unfilled with a conductive or a nonconductive material.

FIG. **5** illustrates a configuration for the multilayer printed circuit board **2** with base **4** having more than two layers or laminates, the conductive layers **6** located there between.

FIG. **6** shows the multilayer printed circuit board **2** after forming, plating, and if needed, filling the through holes **12** in the manner of FIG. **4**.

To summarize, step **1** of the process includes providing a base **4** for forming an electrical device such as a printed circuit board **2**, wherein the base **4** can be formed to have one or more layers or laminates. At least one conductive layer **6** is on the base **4**. The base **4** can be double sided with the conductive layer **6** being located outside the base **4** and between the layers or laminates.

The printed circuit board **2** can be further prepared, as may be desirable for a particular circuitry design, by forming open through holes **12** and plating and if needed, filling the through holes **12** to electrically connect to that portion of the conductive layer **6** appropriate for whatever circuitry design is being constructed, e.g., each side of a double sided circuit board **2**. In other words, step **1** involves providing one of the configurations described in FIGS. **3-6**.

Step **2** includes preparing an outer-most surface of the conductive layer **6** for any of the above-mentioned configurations. The step of preparing is carried out to enable adherence, e.g., of the applied dielectric material **8** to the conductive layer **6**, preferably in a manner that utilizes a respective tooth structure. The step of preparing can be carried out, for example, by using an oxide or an oxide replacement process to treat the conductive layer **6** to such an extent that the teeth **11** (or cavities for teeth **11**) are formed.

As to using an oxide process, a copper oxide can be chemically deposited on a copper surface to produce a tooth-like structure on the surface of the copper. This process is carried out to prepare the copper surface prior to applying another layer of material, thereby providing increased bond strength between the two materials.

As to using an oxide replacement process to form a tooth structure, a micro etch on the surface of the copper is followed by a coating of an adhesion promoter to enhance a bond between copper and the dielectric material **8**. For example, Alpha Metals, Inc. offers a PC-7023 product which is suitable for an oxide replacement process.

Step **3** includes applying the dielectric material **8** to the outermost surface of the conductive layer **10** (and the base **4** if appropriate for the circuitry or electrical device at issue) prepared in accordance with the step **2**. The dielectric material **8** can be applied by as a (dry) film, a (liquid) curtain coating, a (liquid) roller coating, or an analogous application or bonding technique. FIG. **7**, in comparison with FIGS. **3**-**6**, illustrates the dielectric material **8** on the outermost surface(s) of the conductive layer **4** (and the base **2**).

Step **4** includes preparing the applied dielectric material **8** for receipt of a conductive coating **10**, which to exemplify, is detailed more particularly below. Generally, though, the preparing step **4** can include exposing, developing, and curing the applied dielectric material **8** to form patterns for further construction of the circuitry, including such features as constructing a via or photo via **14**, for optionally filling by conductive or non-conductive materials, e.g., screened, roller coated, etc. Compare FIGS. **6** and **7**.

Step **5** includes forming open through holes **16** as shown in FIG. **9**. As indicated above with regard to filled through holes **12**, the open through holes **16** can be formed by such methods as drilling, boring, punching, and the like.

Step **6**, as discussed subsequently in greater detail, involves the etching cavities, veins, openings, or gaps in the applied dielectric material **8**, or more particularly an outermost surface thereof, to accommodate the teeth **11**. One technique for forming the teeth **11** is somewhat similar to what has been known as the swell and etch or desmear process, except that contrary to all known teachings in the prior art, in effect, a "double desmear process" is utilized. That is, not merely increasing the times and temperatures and other parameters for the desmear process, but instead completing the process a first time, and then completing the process a second time. Consider using the following Shipley products for the double desmear process: CIRCUPOSIT MLB conditioner **211**, promoter **213**B, and neutralizer **216**. Non-homogeneous materials and/or processes seem to be determinative.

Step **7** includes applying a conductive coating **10** to the cavities in the applied dielectric material **8**. The conductive coating **10** is also applied to the photo-defined via holes **14** and the open through holes **16**. Techniques for applying the conductive coating **10** include a direct plate process or an electroless copper process. To carry out the present invention, it is preferable to use a palladium-based direct plate process or other non-electroless process. In this regard, a Crimson product of Shipley is suitable, though the desmear process as disclosed herein is contrary to the manufacturer's specifications, i.e., a "double desmear process," rather than the single desmear process of the known prior art. Compare FIGS. **1**, **2**, and **9**.

Step **8** includes forming a metal layer **18** on the conductive coating **10**, by such metal deposition techniques as electrolytic or non-electrolytic plating, to form the tooth structure and teeth **11** as discussed above. The metal layer **18** and conductive coating **10** collectively form circuitry on the outermost surface of the applied dielectric material **8**, which can connect to whatever portion of conductive layer **6** as may be needed for a particular design, preferably by making at least one connection through a micro via. See FIG. **10**. A direct plate process, followed as needed by say a semi-additive or fully additive pattern plating process, is recommended.

A direct plate process is a replacement for traditional electroless copper plating of non-conductive surfaces. Direct plate processes apply a very thin conductive coating (e.g., using palladium or graphite) to the non-conductive surface, thus enabling electroplating of copper or other conductive material onto the previously non-conductive surface. Thus, "direct plate" is used to describe directly plating onto a non-conductive surface without first requiring a non electrolytic (electroless) plating process.

A semi-additive plating process involves first electroplating a thin conductive layer onto the total non-conductive surface, before applying a photoresist and subsequently pattern plating the required circuitry. For semi-additive plating, the thin conductive layer must be removed (etched) from the non-conductive surface. For fully additive plating, photoresist is applied directly on the non-conductive surface, followed by pattern plating the required circuitry (after applying the thin conductive coating in the direct plate process). That is, the fully additive plating forms only the required circuitry and requires no etching.

It should be recognized that the present invention can optionally be carried out by initially skipping step **5** (forming the open through holes **16**) during initial "sets" of the foregoing steps, i.e., completing steps **6** and **7**; then repeating steps **2** through **8**, again skipping step **5** each time until the last set of steps, as required to form the electrical device or circuitry of interest. This will produce an electrical device with a second tooth structure that is not set in the first layer of dielectric material **8**, and indeed the idea of using a toothed structure is not limited to any one layer and is best employed in holding multiple layers together. Step **5** can be carried out after the desired layers have been formed.

Turning now more particularly to the process for forming the teeth **11** and the cavities for the teeth **11**, the present invention can be carried out by a new use of a Ciba-Geigy product known as Probelec XB 7081 as a photoimagable dielectric material **8**. Generally, and in accordance with its specification sheet, Probelec XB 7081 is a single component, 100% epoxy photodielectric material specially developed for Sequential Build Up (SBU) of multilayer boards.

Probelec XB7081 is a negative working, high resolution liquid photo-imageable (LPI) material which allows mass-forming of micro vias for fabrication of high-density interconnects (HDI). Compatible with conventional plating and circuitization techniques, Probelec XB 7081 also provides outstanding electrical and physical properties for most circuit board applications, and is compatible with most circuit board substrate materials.

Probelec XB 7081 is specially developed to act as a dielectric between circuit layers in fabrication of blind and buried micro via MLBS. The high resolution photo dielectric allows mass forming of micro vias for the construction of high density interconnects. Probelec XB 7081 has wide process latitudes, excellent handling characteristics, and is known as self-leveling and having an adjustable dry thickness of 1-3 mils. Probelec XB 7081 has a high resolution capability of 1-2 mil micro vias, and is known for chemical resistance, even for additive plating; there are excellent electrical and physical properties and a UL 94V-0 rating. Probelec is specified to demonstrate more than a 6 lb/in peel strength. By application of this invention this peel strength should be significantly increased due to the formation of the teeth **11**. Accordingly the peel strength produced in accordance with the present invention is greater than the peal strength produced by the desmear process of the prior art, i.e., a single pass desmear process. For example, if a prior art desmear process is used to produce a 6 lb/in average peel strength, the present invention may produce an average peel strength on the order of 10 lb/in or more.

As to the general properties of Probelec XB 7081, there is a storage stability (1-component system) for more than 6 months at 25° C.; the pot life in a coater machine is more than 1 week; the hold time of the coating is more than 1 week (dark or exposed) and more than 1 day in yellow light.

When using Probelec XB 7081 to carry out the above-mentioned step **3** of applying a coating of the dielectric material, there is a pre-cleaning sub-step A. Pre-cleaning should be carried out in chemical, mechanical brushing, or pumice spray units. Extra precaution is needed to ensure that the pre-cleaning equipment and chemistry is not contaminated by materials from previous processing steps. Contrary to Ciba specifications, it is preferred to use an oxide or oxide replacement to prepare the surface prior to applying a coating of the dielectric. Hold times after pre-cleaning should be minimized to avoid oxidation of copper surfaces. In all coating applications, pre-cleaned substrates should be free of particles. Additional cleaning steps, e.g., with detergents, may be required to remove organic residues.

Next there is a coating sub-step B. Probelec XB7081 seems to have been primarily designed for curtain coating and is delivered with a solid content of 58%. Substrates should be heated to about 40° C. prior to coating to ensure all residual moisture is removed and to prepare substrate for curtain coating. For initial charging of a coater machine, Probelec XB 7081 needs to be premixed with about 15% of PMA (PMA is 1-methoxy-2-propyl acetate) to ensure proper viscosity. The additional PMA thins the coating down to about 50% solids.

The resin temperature should be 25±1° C., with a conveyor speed of 90 m/min. The viscosity is at 25° C., DIN AK4 cup at 60 sec. (400 cps), with a coater gap width of 500 mm. The wet weight is 7.5-1 0.0 gms/600 CM sq. and 11.6-1 5.5 gms/ft sq. The dry thickness is 45-60 mm.

Next is a flash dry sub-step C. Coated panels must be held in a horizontal position under dust-free conditions to air dry. At this stage, minimal air flow is recommended. The drying time is 12-18 min. at a drying temperature of 30-40° C.

Next is a final dry sub-step D. After flash air drying, final drying at an elevated temperature is needed to achieve better than 95% removal of solvents for tack-free handling. This can be accomplished in batch or conveyorized tunnel ovens, as follows:

	Tunnel Oven	Batch Oven
Drying Temperature:	130-140° C.	90° C.
Drying Time:	2-3 minutes	30 minutes

After cooling, the panels can have a second side coating (sub-steps A through D) if appropriate for the circuit design, and then for an exposure sub-step E.

In the exposure sub-step E, catalyst for cross linking of epoxy resin is generated. The main spectral sensitivity of Probelec XB 7081 is in the range of 350-420 nm. Conventional exposure units, collimated or non-collimated, with peak spectral emission of 365 nm are recommended. Both diazo and silver halide films are suitable as working photo-

tools. Good artwork to coating contact is essential for consistent micro via reproduction. The exposure energy is 1200-1600 mJ/cm sq. and the exposure time (7 kW) is 30-40 seconds. The Stouffer Step (21 scale) is 5-7.

Next is a thermal bump step F. Thermal bump provides the energy for crosslinking the catalyzed epoxy resin. This process can be done in convection batch or conveyorized tunnel ovens. For a batch oven, 110° C. for 60 min. is appropriate, and for a conveyorized tunnel oven, 130° C. for 10-20 min. is appropriate.

Next is a developing sub-step G. The unexposed areas of Probelec XB7081 are developed away in continuous spray developing machines. Various models with different processing capacities are available for this purpose. A Ciba-Geigy product DY 950 (Gamma-Butyrolactone (GBL)) developer is recommended for processing Probelec XB7081. This developer is a halogen-free, high-boiling organic solvent suitable for on-site distillation or recycling. Probimer 450/470 spray developing equipment is specially designed for use with this developer solution. The temperature is 20±2° C., and the spray pressure is 2-4 bar. The speed for Probimer 450 is 2-3 m/min; for Probimer 470, 3-4 m/min.

Next is a final cure sub-step H. Final thermal curing is needed to impart good mechanical, chemical, and electrical properties to the dielectric film. The thermal curing can take place in batch or conveyorized tunnel ovens. The thermal curing temperature is 150° C., with a thermal curing time of 60 minutes.

Next can come the step **5** of further preparing, for example, by forming through holes **16**. If plated through holes **16** (PTH's) are needed for interconnecting layers to the bottom or back side of the printed circuit board **2**, drilling should of course be done before plating. This allows the plating of the surface together with the through holes **16**. Plating and such post-processing of the photoimagable dielectric material **8** is dependent on particular process preferences. Probelec XB7081 is compatible with panel-plate, pattern-plate or additive plating.

The following process sub-steps of the above-mentioned step **6** describe a generic sequence for a desmear process to form cavities in the dielectric. Although Probelec XB7081 apparently was intended for use in the common desmear (swell and etch) process as used in conventional plated through hole plating lines, Probelec XB7081 can alternatively be used in carrying out the present invention. For example, the present invention differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth **11**. Sub-step A, swelling the dielectric material **8**, can be carried out with butyl diglycol/sodium hydroxide/water 80° C. for 3-5 minutes. Sub-step B is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step C is etching the dielectric material **8**, which can be carried out using potassium permanganate/sodium hydroxide/water 80° C., 6-10 minutes. Sub-step D is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step D includes a further rinsing of the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step E is neutralizing the dielectric material **8** in sulfuric peroxide (1.5%) for 3 to 5 minutes. Finally step F is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes.

In stark contrast with the etch and swell process of the known prior art, however, a second pass through the process (sub-steps A through F) is used. The second pass seems to make use of non-homogenaities in bringing about a formation of the teeth **11**. Thus, unlike the prior swell and etch chemical roughening process, which produces a surface characterized by a surface gloss measurement at an angle of 60° which is between 15 and 45%, the present invention has less gloss (<10%).

Turn now in greater detail to the step **7** of applying the conductive coating **10** for subsequent deposition of the metal layer **18** by, say, plating. Good results can be achieved with a flash plate of 0.7-1.0 mm (30-40 micro inches). The flash plate is followed by baking at 130-150° C., for 2 hours.

For pattern plating, plating resist can be applied after baking. Depositing the metal layer **18** by electroplating can be carried out such that there is 10-25 mm (0.4-1.0 mil.).

While a particular embodiment of the present invention has been disclosed, it is to be understood that various different modifications are possible and are within the true spirit of the invention, the scope of which is to be determined with reference to the claims set forth below. There is no intention, therefore, to limit the invention to the exact disclosure presented herein as a teaching of one embodiment of the invention.

We claim:

1. An article of manufacture, the article comprising:

an epoxy dielectric material delivered with solid content sufficient that etching the epoxy forms a non-uniformly roughened surface of angular tooth-shaped cavities located in and underneath an initial surface of the dielectric material, sufficient that the etching of the epoxy uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface of the angular tooth-shaped cavities and sufficient that the etching of the epoxy is such that a plurality of the cavities have a cross-sectional width that is greater than a maximum depth with respect to the initial surface, wherein the etching forms the non-uniformly roughened surface of angular tooth-shaped cavities, and a conductive material, a portion of the conductive material in the cavities thereby forming angular teeth in the cavities, and wherein the conductive material forms a portion of circuitry of an electrical device.

2. The article of claim **1**, wherein some of the cavities comprise veins.

3. The article of claim **1**, wherein the cavities comprise cavities which exhibit one or more of the following shapes: fanged, angled, canine, and otherwise hooked teeth.

4. The article of claim **1**, wherein the cavities comprise cavities which exhibit one or more of the following shapes: equilateral, isosceles, scalene, right, obtuse, or any combination thereof.

5. The article of claim **3**, wherein the cavities comprise cavities which exhibit one or more of the following shapes: equilateral, isosceles, scalene, right, obtuse, or any combination thereof.

6. The article of claim **1**, wherein the etching includes a first etching and a second etching.

7. The article of claim **1**, further including a conductive layer, comprising the conductive material, and wherein the cavities are not in the conductive material by physical roughening.

8. The article of claim **1**, wherein at least one of the teeth has a depth in a range of 1 tenth of a mil and less than about 2 tenths of a mil.

9. The article of claim **1**, wherein a sample of the circuitry has at least about 5,000 of the teeth per linear inch.

10. The article of claim **1**, wherein the portion of the circuitry is portion of multilayer circuitry of an electrical device.

11. The article of claim **1**, wherein the electrical device is a multi-layer printed circuit board.

12. The article of claim **1**, wherein the portion of the conductive material further comprises a second portion of the conductive material connected to the first portion through at least one micro via.

13. The article of claim **1**, wherein the conductive material is part of a micro via.

14. An article of manufacture, the article comprising:

an epoxy dielectric material delivered with solid content sufficient that etching the epoxy forms a non-uniformly roughened surface comprising cavities located in and underneath a surface of the dielectric material, and sufficient that the etching of the epoxy uses non-homogeneity with the solid content to bring about formation of the non-uniformly roughened surface with at least some of the cavities having a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface, and a conductive material, whereby the etching of the epoxy forms the cavities, and a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the non-homogeneous composition forms the cavities, and wherein the conductive material forms a portion of circuitry of an electrical device.

15. The article of claim **14**, wherein the substantially greater cross-sectional distance is at least twice the first cross-sectional distance.

16. An article of manufacture, the article comprising:

an epoxy dielectric material delivered with solid content sufficient that etching the epoxy forms a non-uniformly roughened surface comprising molar-shaped cavities located in and underneath an initial surface of the dielectric material and sufficient that the etching of the epoxy uses non-homogeneity with the solid content to bring about formation of the non-uniformly roughened surface comprising the molar-shaped cavities and a plurality of the cavities have a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface, and a conductive material, a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the epoxy forms the cavities, and wherein the conductive material forms a portion of circuitry of an electrical device.

17. The article of claim **16**, wherein the substantially greater cross-sectional distance is at least twice the first cross-sectional distance.

18. An article of manufacture, the article comprising:

an epoxy dielectric material delivered with sufficient solid content that etching of the epoxy forms a non-uniformly roughened surface of molar-shaped cavities located in and underneath an initial surface of the dielectric material and sufficient that the etching of the epoxy uses the non-homogeneity with the solid content to bring about formation of the non-uniformly roughened surface of the molar-shaped cavities and a plurality of the cavities have a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface, and a conductive material, a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the epoxy forms the cavities so that a plurality of the teeth each expand below a respective narrower region which is closer to the initial surface, and wherein the conductive material forms a portion of circuitry of an electrical device.

19. The article of claim **14**, wherein the etching includes a first etching and a second etching.

20. The article of claim **16**, wherein the etching includes a first etching and a second etching.

21. The article of claim **18**, wherein the etching includes a first etching and a second etching.

* * * * *

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(12) **United States Patent**
McDermott et al.

(10) **Patent No.: US 8,581,105 B2**
(45) **Date of Patent: Nov. 12, 2013**

(54) **ELECTRICAL DEVICE WITH TEETH JOINING LAYERS AND METHOD FOR MAKING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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Related U.S. Application Data

(63) Continuation of application No. 12/363,501, filed on Jan. 30, 2009, now Pat. No. 8,278,560, which is a continuation of application No. 10/790,363, filed on Mar. 1, 2004, now Pat. No. 7,501,582, which is a continuation of application No. 09/694,099, filed on Oct. 20, 2000, now Pat. No. 6,700,069, which is a continuation of application No. 08/905,619, filed on Aug. 4, 1997, now Pat. No. 6,141,870.

(51) **Int. Cl.**
H05K 1/03 (2006.01)

(52) **U.S. Cl.**
USPC **174/255**

(58) **Field of Classification Search**
USPC 174/255–262, 264, 266; 29/829, 831; 216/13, 16–18; 205/125
See application file for complete search history.

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Primary Examiner — Jeremy Norris
Assistant Examiner — Tremesha S Willis
(74) *Attorney, Agent, or Firm* — Peter K. Trzyna, Esq.

(57) **ABSTRACT**

A process of making an article of manufacture, the process including constructing an electrical device which implements circuitry having a portion in cavities, the portion defined by an epoxy dielectric material delivered with solid content sufficient that etching the epoxy forms cavities located in, and underneath an initial surface of, the dielectric material, sufficient that the etching of the epoxy uses non-homogeneity with the solid content in bringing about formation of the cavities and sufficient that the etching of the epoxy is such that a plurality of the cavities have a cross-sectional width that is greater than a maximum depth with respect to the initial surface, wherein the etching forms the cavities, and a conductive material, a portion of the conductive material in the cavities thereby forming teeth in the cavities, such that the conductive material forms the portion of the circuitry of the electrical device.

103 Claims, 2 Drawing Sheets

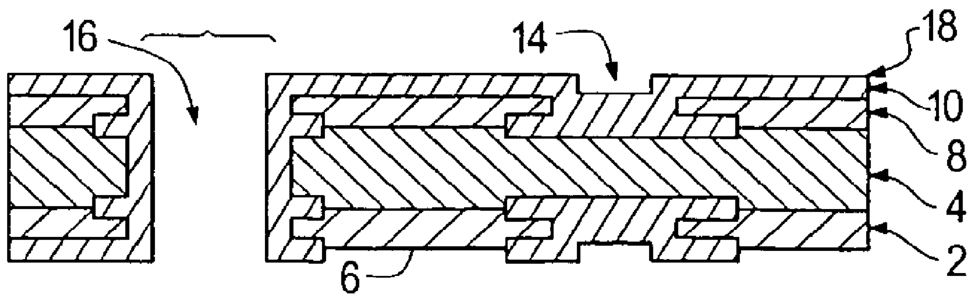

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FIG. 1

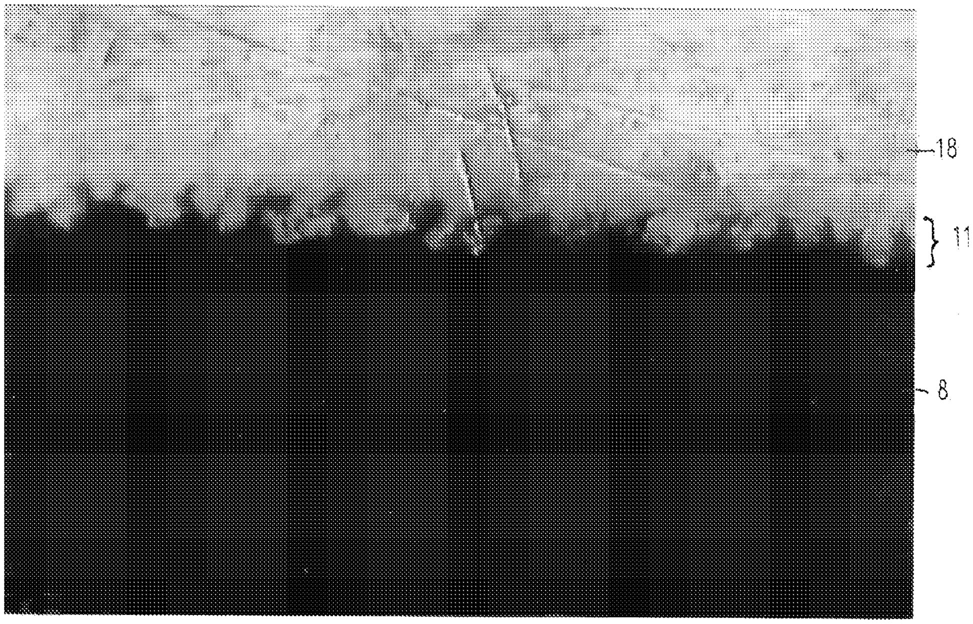


FIG. 2 PRIOR ART

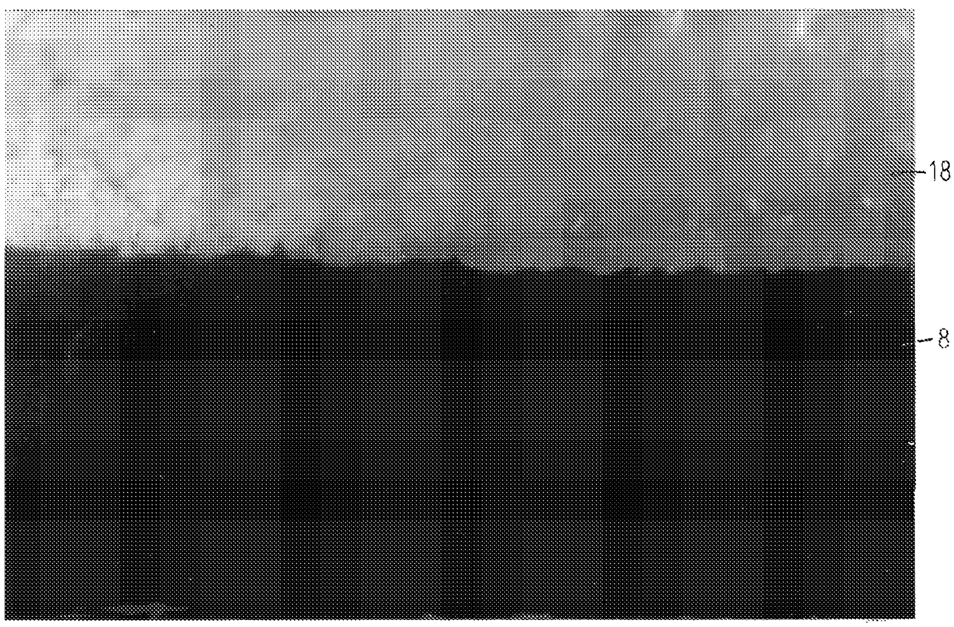


FIG. 3

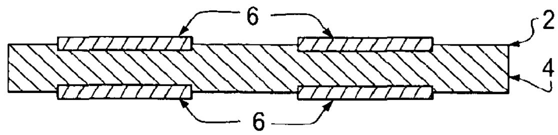


FIG. 4

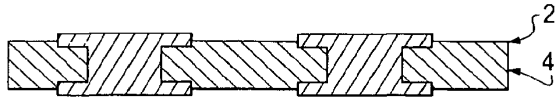


FIG. 5

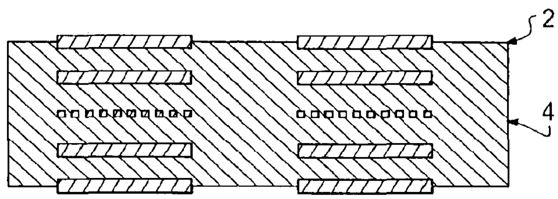


FIG. 6

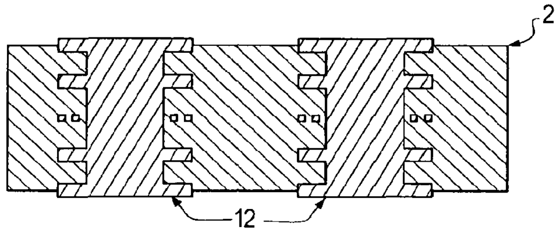


FIG. 7

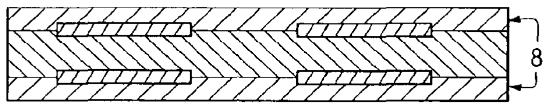


FIG. 8

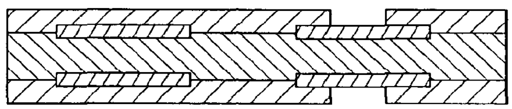


FIG. 9

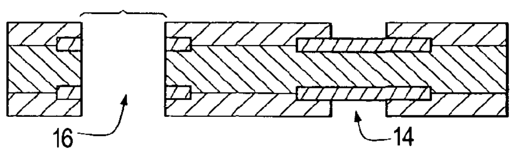


FIG. 10

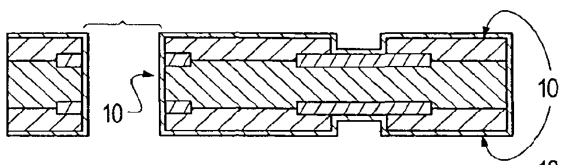
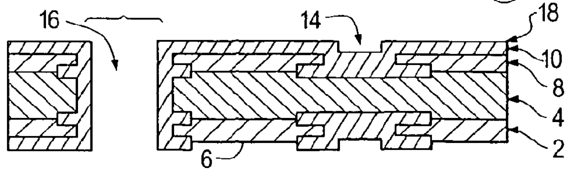


FIG. 11



ELECTRICAL DEVICE WITH TEETH JOINING LAYERS AND METHOD FOR MAKING THE SAME

I. CLAIM OF PRIORITY

The present patent application is a continuation of, and incorporates by reference as if fully restated herein, U.S. patent application Ser. No. 12/363,501, filed Jan. 30, 2009, pending. Ser. No. 12/363,501 is a continuation of and incorporates by reference as if fully restated herein, Ser. No. 10/790,363, filed Mar. 1, 2004, issuing Mar. 10, 2009, as U.S. Pat. No. 7,501,582. Ser. No. 10/790,363 is a continuation of and incorporates by reference as if fully restated herein, Ser. No. 09/694,099, filed Oct. 20, 2000, issuing on Mar. 2, 2004, as U.S. Pat. No. 6,700,069. Ser. No. 09/694,099 is a continuation of and incorporates by reference as if fully restated herein, Ser. No. 08/905,619, filed Aug. 4, 1997, issuing on Nov. 7, 2000, as U.S. Pat. No. 6,141,870. The present patent application incorporates by reference all of the patent applications and patents listed above.

II. FIELD OF THE INVENTION

The present invention is directed to methods for making or manufacturing an electrical device, and the process, composition, and product thereof. More particularly, the present invention involves such multilayer electrical devices as circuit boards constructed by joining a dielectric material to a subsequently applied conductive material. Still more particularly, the present invention involves an electrical device having a substrate or base, an applied dielectric material thereon, which in turn has a thin conductive coating thereon, and a conductive layer formed upon the conductive coating, the conductive layer being joined to the applied dielectric material in an improved manner.

III. BACKGROUND OF THE INVENTION

Multilayer electrical devices—those made from layering a dielectric material and a conductive material on a base—suffer from delamination, blistering, and other reliability problems. This is particularly true when the laminates are subjected to thermal stress.

Known attempts to solve these problems seem to have focused on physical or chemical roughening, particularly of the base or substrate. See for example, U.S. Pat. No. 4,948,707. Although oxide-related chemical roughening processes have been used, an emphasis on physical roughening may reflect the use of materials that are relatively chemically resistant. Both physical and chemical roughening approaches have improved adherence to the base.

However, the extent to which this adherence can be increased by roughening has its limits. And despite a long standing recognition of delamination, blistering, and reliability problems, and the attempts to find a solution, these problems have been persistent in electrical devices made of layered materials.

IV. SUMMARY OF THE INVENTION

The inventors herein have observed that the general problem of poor adherence between the laminates or layers can be addressed by forming a unique surface structure, which is particularly suitable for joining the dielectric material to the conductive coating and conductive layer. The surface structure is comprised of teeth that are preferably angled or hooked like fangs or canine teeth to enable one layer to mechanically grip a second layer.

In comparison with the above-mentioned roughening techniques of the prior art, it is believed that a surface of the teeth is an improvement in that there is an increase in surface area. However, it is still better to use teeth that are fang-shaped to enable a mechanical grip that functions in a different manner than adherence by means of increased surface area. By using the fanged, angled, canine, or otherwise hooked teeth (in addition to increased surface area), there is a multidirectional, three dimensional interlacing or overlapping of layers. For example, in joining the dielectric material to the conductive coating and metal layer, the conductive coating and metal layer is actually burrowed in and under the dielectric material and vice versa. Thus, separating them not only involves breaking the surface area adherence, but also involves destroying the integrity of at least one of the layers by ripping the teeth, the layer pierced by them, or both.

Further, it has been found preferable to have numerous teeth sized and shaped so that they are not too large or too small. If the teeth are too small, wide, straight, and shallow, then the surface resembles the roughened surface of prior art techniques, vaguely analogous to a surface of molar teeth, and the adherence is not much better than that achieved by known prior art roughening techniques.

However, if the teeth are too large, deep, and fanged or hook-shaped, the teeth undercut the surface to such an extent that the strength of the dielectric material surface is weakened. As a result, adherence is decreased over the preferred embodiment.

Not too great and not too slight, the right sized and shaped teeth, set in a fanged orientation and with sufficient frequency, have been found to be the best structure. If the correct balance of these critically important factors is created, the result is a greatly improved circuit board or other such electrical device.

It is theorized by the inventors that the best methods for producing the teeth is to use non-homogeneous materials and/or techniques. For example, a dielectric material can have a non-homogeneous composition or thickness to bring about an uneven chemical resistance, such that slowed and/or repeated etching will form teeth instead of a uniform etch.

V. BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a conductive coating and metal layer applied dielectric material with a desirable tooth structure;

FIG. **2** is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes;

FIG. **3** is an illustration of a double sided printed circuit board without plated through holes;

FIG. **4** is an illustration of a multilayer printed circuit board with plated through holes, filled or unfilled with conductive or nonconductive material;

FIG. **5** is an illustration of a multilayer printed circuit board without plated through holes;

FIG. **6** is an illustration of a multilayer printed circuit board having more than two layers with plated through holes filled or unfilled with conductive or nonconductive material;

FIG. **7** is an illustration of any of the foregoing printed circuit boards after applying a dielectric material thereon;

FIG. **8** is an illustration of the multilayer printed circuit board of FIG. **7** after forming micro vias;

FIG. **9** is an illustration of the multilayer printed circuit board of FIG. **7** after opening the through holes and after etching the applied dielectric material to produce the teeth illustrated in FIG. **1**;

FIG. **10** is an illustration of the multilayer printed circuit board of FIG. **9** after application of a conductive coating to fill in around the teeth and connect micro via holes and the through holes; and

FIG. **11** is an illustration of the multilayer printed circuit board of FIG. **10** after plating the conductive coating to form a metal layer and complete forming circuitry.

VI. DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a conductive coating and metal layer on the applied dielectric material with a desirable tooth structure. In contrast, FIG. **2** is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes. Both FIGS. **1** and **2** show a dielectric material and a combination of a thin conductive coating and metal later. Compare FIG. **1** and FIG. **2**, and note particularly the size, shape, frequency, and depth of the teeth **11** in FIG. **1** with the surface produced by roughening in FIG. **2**.

A way of articulating this “teeth” concept is to view each tooth as being made of one layer and set in a second layer. However, the perspective is arbitrary, and one could equally view each tooth as made of the second layer set in the first. It could also be said that the layers join in a saw-toothed manner, i.e., teeth made of both materials in an interlocking bite. In any case, however, there are teeth, and for the sake of consistency, this specification will adopt the convention of referring to the teeth as being made of the conductive coating and metal layer set in the dielectric material.

A further way of articulating the “teeth” concept is to view each tooth as being substantially triangular in shape, with the base of the triangle being defined by a plane of the applied dielectric material before it is etched, or more precisely by the exterior surface thereof. The invention can be carried by forming cavities in the applied dielectric material **6** for receiving the teeth, and then forming the teeth from the conductive coating and metal layer formed thereon. Generally, the teeth can be of any triangular shape (e.g., equilateral, isosceles, scalene, right, obtuse, or any combination thereof). Preferably, though, the teeth are obtuse so as to hook or angle under the exterior surface of the applied dielectric material.

The use of any shape of teeth increases the surface area where the conductive coating is on the applied dielectric material. However, the preferred embodiment utilizes a surface of obtuse, canine, or fang-shaped teeth to help the conductive coating and metal layer hook under the exterior surface of the applied dielectric material to mechanically grip the applied dielectric material. The obtuse, canine, or fang-shaped teeth are in contrast to the shallower, more rounded surface typically produced by known roughening techniques. Note in FIG. **2** that roughing techniques can produce some occasional gouging, but nothing on the order of the present invention.

As to size of the teeth, as mentioned above, it is preferable that the teeth be within a certain size range. The optimal size range for obtuse, canine, or hook-shaped teeth involves a balance between maximizing surface area and mechanical grip, but not undercutting the surface of the applied dielectric material **8** to such an extent as to weaken it. Accordingly, the teeth should be sized at least 1 tenth of a mil deep. Better is at least 1.25 tenths of a mil deep, and even better is at least 1.5 tenths of a mil deep. However, 1.75 tenths of a mil is acceptable, and about 2 tenths of a mil is reaching the limit.

As to frequency, the teeth should be quite frequent in number; at least about 5,000 teeth per linear inch, and preferably at least about 10,000 teeth per linear inch; and even better is at least about 15,000 teeth per linear inch.

As to surface area, there should be at least about 25,000 teeth per square inch, better still is essentially at least about 100,000 per square inch, and preferably at least about per 200,000 per square inch, or even greater.

It should be recognized that the teeth generally are not formed to a precise dimension. As shown in FIG. **1**, some of the teeth are somewhat differently sized, angled, and proportioned. Thus, a representative sample of the electrical device should have teeth in about these ranges. Having at least about 20% of the teeth in one or more of these ranges, and preferably at least 50%, is a preferred balance of mechanical grip without a weakening the integrity of the layering, particularly in combination.

As illustrated in FIGS. **3**-**11**, there is an electrical device, such as a printed circuit board **2** having a base **4**. The base **4** has a conductive layer **6** thereon. A dielectric material **8** is applied on the conductive layer **6**, and a conductive coating **10** (such as a thin coating of palladium) is deposited on the dielectric material **8**. Metal layer **12** is formed on the conductive coating **10**.

FIG. **3** illustrates one of the many ways to begin the process of forming the teeth in accordance with the present invention. A first step (step 1), includes providing a base **4** for constructing an electrical device, such as a printed circuit board **2**. FIG. **3** illustrates one such construction, namely a base **4** for constructing a multilayer printed circuit board **2**, the base **4** having any positive number of layers or laminates, for example the two layers shown in FIGS. **3** and **4**, or more than two layers as illustrated in FIGS. **5** and **6**, etc. One configuration or another is not significant, except that multiple layers provide a better medium for constructing circuitry of increased complexity or density. FIGS. **3**-**6** illustrate an embodiment in which the conductive layer **6** is on at least an upper side, and preferably also on a lower side of the base **4**.

As may be needed for a particular circuitry design, FIG. **4** illustrates that the electrical device can be further manipulated, for example, by forming through holes **12** by mechanical drilling, laser drilling, punching, or the like. The plated through holes **12** are shown in FIGS. **4** and **6** as filled or unfilled with a conductive or a nonconductive material.

FIG. **5** illustrates a configuration for the multilayer printed circuit board **2** with base **4** having more than two layers or laminates, the conductive layers **6** located there between.

FIG. **6** shows the multilayer printed circuit board **2** after forming, plating, and if needed, filling the through holes **12** in the manner of FIG. **4**.

To summarize, step 1 of the process includes providing a base **4** for forming an electrical device such as a printed circuit board **2**, wherein the base **4** can be formed to have one or more layers or laminates. At least one conductive layer **6** is on the base **4**. The base **4** can be double sided with the conductive layer **6** being located outside the base **4** and between the layers or laminates.

The printed circuit board **2** can be further prepared, as may be desirable for a particular circuitry design, by forming open through holes **12** and plating and if needed, filling the through holes **12** to electrically connect to that portion of the conductive layer **6** appropriate for whatever circuitry design is being constructed, e.g., each side of a double sided circuit board **2**. In other words, step 1 involves providing one of the configurations described in FIGS. **3**-**6**.

Step 2 includes preparing an outer-most surface of the conductive layer **6** for any of the above-mentioned configurations. The step of preparing is carried out to enable adherence, e.g., of the applied dielectric material **8** to the conductive layer **6**, preferably in a manner that utilizes a respective tooth structure. The step of preparing can be carried out, for example, by using an oxide or an oxide replacement process to treat the conductive layer **6** to such an extent that the teeth (or cavities for teeth) are formed.

As to using an oxide process, a copper oxide can be chemically deposited on a copper surface to produce a tooth-like structure on the surface of the copper. This process is carried out to prepare the copper surface prior to applying another layer of material, thereby providing increased bond strength between the two materials.

As to using an oxide replacement process to form a tooth structure, a micro etch on the surface of the copper is followed by a coating of an adhesion promoter to enhance a bond between copper and the dielectric material **8**. For example, Alpha Metals, Inc. offers a PC-7023 product which is suitable for an oxide replacement process.

Step 3 includes applying the dielectric material **8** to the outermost surface of the conductive layer **10** (and the base **4** if appropriate for the circuitry or electrical device at issue) prepared in accordance with the step 2. The dielectric material **8** can be applied by as a (dry) film, a (liquid) curtain coating, a (liquid) roller coating, or an analogous application or bonding technique. FIG. **7**, in comparison with FIGS. **3**-**6**, illustrates the dielectric material **8** on the outermost surface(s) of the conductive layer **4** (and the base **2**).

Step 4 includes preparing the applied dielectric material **8** for receipt of a conductive coating **10**, which to exemplify, is detailed more particularly below. Generally, though, the preparing step 4 can include exposing, developing, and curing the applied dielectric material **8** to form patterns for further construction of the circuitry, including such features as constructing a via or photo via **14**, for optionally filling by conductive or non-conductive materials, e.g., screened, roller coated, etc. Compare FIGS. **6** and **7**.

Step 5 includes forming open through holes **16** as shown in FIG. **9**. As indicated above with regard to filled through holes **12**, the open through holes **16** can be formed by such methods as drilling, boring, punching, and the like.

Step 6, as discussed subsequently in greater detail, involves the etching cavities, veins, openings, or gaps in the applied dielectric material **8**, or more particularly an outermost surface thereof, to accommodate the teeth. One technique for forming the teeth is somewhat similar to what has been known as the swell and etch or desmear process, except that contrary to all known teachings in the prior art, in effect, a "double desmear process" is utilized. That is, not merely increasing the times and temperatures and other parameters for the desmear process, but instead completing the process a first time, and then completing the process a second time. Consider using the following Shipley products for the double desmear process: CIRCUPOSIT MLB conditioner **211**, promoter **213**B, and neutralizer **216**. Non-homogeneous materials and/or processes seem to be determinative.

Step 7 includes applying a conductive coating **10** to the cavities in the applied dielectric material **8**. The conductive coating **10** is also applied to the photo-defined via holes **14** and the open through holes **16**. Techniques for applying the conductive coating **10** include a direct plate process or an electroless copper process. To carry out the present invention, it is preferable to use a palladium-based direct plate process or other non-electroless process. In this regard, a Crimson product of Shipley is suitable, though the desmear process as disclosed herein is contrary to the manufacturer's specifications, i.e., a "double desmear process," rather than the single desmear process of the known prior art. Compare FIGS. **1**, **2**, and **9**.

Step 8 includes forming a metal layer **18** on the conductive coating **10**, by such metal deposition techniques as electrolytic or non-electrolytic plating, to form the tooth structure and teeth as discussed above. The metal layer **18** and conductive coating **10** collectively form circuitry on the outermost surface of the applied dielectric material **8**, which can connect to whatever portion of conductive layer **6** as may be needed for a particular design, preferably by making at least one connection through a micro via. See FIG. **10**. A direct plate process, followed as needed by say a semi-additive or fully additive pattern plating process, is recommended.

A direct plate process is a replacement for traditional electroless copper plating of non-conductive surfaces. Direct plate processes apply a very thin conductive coating (e.g., using palladium or graphite) to the non-conductive surface, thus enabling electroplating of copper or other conductive material onto the previously non-conductive surface. Thus, "direct plate" is used to describe directly plating onto a non-conductive surface without first requiring a non electrolytic (electroless) plating process.

A semi-additive plating process involves first electroplating a thin conductive layer onto the total non-conductive surface, before applying a photoresist and subsequently pattern plating the required circuitry. For semi-additive plating, the thin conductive layer must be removed (etched) from the non-conductive surface. For fully additive plating, photoresist is applied directly on the non-conductive surface, followed by pattern plating the required circuitry (after applying the thin conductive coating in the direct plate process). That is, the fully additive plating forms only the required circuitry and requires no etching.

It should be recognized that the present invention can optionally be carried out by initially skipping step 5 (forming the open through holes **16**) during initial "sets" of the foregoing steps, i.e., completing steps 6 and 7; then repeating steps 2 through 8, again skipping step 5 each time until the last set of steps, as required to form the electrical device or circuitry of interest. This will produce an electrical device with a second tooth structure that is not set in the first layer of dielectric material **8**, and indeed the idea of using a toothed structure is not limited to any one layer and is best employed in holding multiple layers together. Step 5 can be carried out after the desired layers have been formed.

Turning now more particularly to the process for forming the teeth and the cavities for the teeth, the present invention can be carried out by a new use of a Ciba-Geigy product known as Probelec XB 7081 as a photoimagable dielectric material **8**. Generally, and in accordance with its specification sheet, Probelec XB 7081 is a single component, 100% epoxy photodielectric material specially developed for Sequential Build Up (SBU) of multilayer boards.

Probelec XB7081 is a negative working, high resolution liquid photo-imageable (LPI) material which allows mass-forming of micro vias for fabrication of high-density interconnects (HDI). Compatible with conventional plating and circuitization techniques, Probelec XB 7081 also provides outstanding electrical and physical properties for most circuit board applications, and is compatible with most circuit board substrate materials.

Probelec XB 7081 is specially developed to act as a dielectric between circuit layers in fabrication of blind and buried micro via MLBS. The high resolution photo dielectric allows mass forming of micro vias for the construction of high density interconnects. Probelec XB 7081 has wide process latitudes, excellent handling characteristics, and is known as self-leveling and having an adjustable dry thickness of 1-3 mils. Probelec XB 7081 has a high resolution capability of 1-2 mil micro vias, and is known for chemical resistance, even for additive plating; there are excellent electrical and physical properties and a UL 94V-0 rating. Probelec is specified to demonstrate more than a 6 lb/in peel strength. By application of this invention this peel strength should be significantly increased due to the formation of the teeth. Accordingly the peel strength produced in accordance with the present invention is greater than the peal strength produced by the desmear process of the prior art, i.e., a single pass desmear process. For example, if a prior art desmear process is used to produce a 6 lb/in average peel strength, the present invention may produce an average peel strength on the order of 10 lb/in or more.

As to the general properties of Probelec XB 7081, there is a storage stability (1-component system) for more than 6 months at 25° C.; the pot life in a coater machine is more than 1 week; the hold time of the coating is more than 1 week (dark or exposed) and more than 1 day in yellow light.

When using Probelec XB 7081 to carry out the above-mentioned step 3 of applying a coating of the dielectric material, there is a pre-cleaning sub-step A. Pre-cleaning should be carried out in chemical, mechanical brushing, or pumice spray units. Extra precaution is needed to ensure that the pre-cleaning equipment and chemistry is not contaminated by materials from previous processing steps. Contrary to Ciba specifications, it is preferred to use an oxide or oxide replacement to prepare the surface prior to applying a coating of the dielectric. Hold times after pre-cleaning should be minimized to avoid oxidation of copper surfaces. In all coating applications, pre-cleaned substrates should be free of particles. Additional cleaning steps, e.g., with detergents, may be required to remove organic residues.

Next there is a coating sub-step B. Probelec XB7081 seems to have been primarily designed for curtain coating and is delivered with a solid content of 58%. Substrates should be heated to about 40° C. prior to coating to ensure all residual moisture is removed and to prepare substrate for curtain coating. For initial charging of a coater machine, Probelec XB 7081 needs to be premixed with about 15% of PMA (PMA is 1-methoxy-2-propyl acetate) to ensure proper viscosity. The additional PMA thins the coating down to about 50% solids.

The resin temperature should be 25±1° C., with a conveyor speed of 90 m/min. The viscosity is at 25° C., DIN AK4 cup at 60 sec. (400 cps), with a coater gap width of 500 mm. The wet weight is 7.5-10.0 gms/600 CM sq. and 11.6-15.5 gms/ft sq. The dry thickness is 45-60 mm.

Next is a flash dry sub-step C. Coated panels must be held in a horizontal position under dust-free conditions to air dry. At this stage, minimal air flow is recommended. The drying time is 12-18 min. at a drying temperature of 30-40° C.

Next is a final dry sub-step D. After flash air drying, final drying at an elevated temperature is needed to achieve better than 95% removal of solvents for tack-free handling. This can be accomplished in batch or conveyorized tunnel ovens, as follows:

	Tunnel Oven	Batch Oven
Drying Temperature:	130-140° C.	90° C.
Drying Time:	2-3 minutes	30 minutes

After cooling, the panels can have a second side coating (sub-steps A through D) if appropriate for the circuit design, and then for an exposure sub-step E.

In the exposure sub-step E, catalyst for cross linking of epoxy resin is generated. The main spectral sensitivity of Probelec XB 7081 is in the range of 350-420 nm. Conventional exposure units, collimated or non-collimated, with peak spectral emission of 365 nm are recommended. Both diazo and silver halide films are suitable as working phototools. Good artwork to coating contact is essential for consistent micro via reproduction. The exposure energy is 1200-1600 mJ/cm sq. and the exposure time (7 kW) is 30-40 seconds. The Stouffer Step (21 scale) is 5-7.

Next is a thermal bump step F. Thermal bump provides the energy for crosslinking the catalyzed epoxy resin. This process can be done in convection batch or conveyorized tunnel ovens. For a batch oven, 110° C. for 60 min. is appropriate, and for a conveyorized tunnel oven, 130° C. for 10-20 min. is appropriate.

Next is a developing sub-step G. The unexposed areas of Probelec XB7081 are developed away in continuous spray developing machines. Various models with different processing capacities are available for this purpose. A Ciba-Geigy product DY 950 (Gamma-Butyrolactone (GBL)) developer is recommended for processing Probelec XB7081. This developer is a halogen-free, high-boiling organic solvent suitable for on-site distillation or recycling. Probimer 450/470 spray developing equipment is specially designed for use with this developer solution. The temperature is 20±2° C., and the spray pressure is 2-4 bar. The speed for Probimer 450 is 2-3 m/min; for Probimer 470, 3-4 m/min.

Next is a final cure sub-step H. Final thermal curing is needed to impart good mechanical, chemical, and electrical properties to the dielectric film. The thermal curing can take place in batch or conveyorized tunnel ovens. The thermal curing temperature is 150° C., with a thermal curing time of 60 minutes.

Next can come the step 5 of further preparing, for example, by forming through holes **16**. If plated through holes **16** (PTH's) are needed for interconnecting layers to the bottom or back side of the printed circuit board **2**, drilling should of course be done before plating. This allows the plating of the surface together with the through holes **16**. Plating and such post-processing of the photoimagable dielectric material **8** is dependent on particular process preferences. Probelec XB7081 is compatible with panel-plate, pattern-plate or additive plating.

The following process sub-steps of the above-mentioned step 6 describe a generic sequence for a desmear process to form cavities in the dielectric. Although Probelec XB7081 apparently was intended for use in the common desmear (swell and etch) process as used in conventional plated through hole plating lines, Probelec XB7081 can alternatively be used in carrying out the present invention. For example, the present invention differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth. Sub-step A, swelling the dielectric material **8**, can be carried out with butyl diglycol/sodium hydroxide/water 80° C. for 3-5 minutes. Sub-step B is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step C is etching the dielectric material **8**, which can be carried out using potassium permanganate/sodium hydroxide/water 80° C., 6-10 minutes. Sub-step D is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step D includes a further rinsing of the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step

E is neutralizing the dielectric material **8** in sulfuric peroxide (1.5%) for 3 to 5 minutes. Finally step F is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes.

In stark contrast with the etch and swell process of the known prior art, however, a second pass through the process (sub-steps A through F) is used. The second pass seems to make use of non-homogeneities in bringing about a formation of the teeth. Thus, unlike the prior swell and etch chemical roughening process, which produces a surface characterized by a surface gloss measurement at an angle of 60° which is between 15 and 45%, the present invention has less gloss (<10%).

Turn now in greater detail to the step 7 of applying the conductive coating **10** for subsequent deposition of the metal layer **18** by, say, plating. Good results can be achieved with a flash plate of 0.7-1.0 mm (30-40 micro inches). The flash plate is followed by baking at 130-150° C., for 2 hours.

For pattern plating, plating resist can be applied after baking. Depositing the metal layer **18** by electroplating can be carried out such that there is 10-25 mm (0.4-1.0 mil.).

While a particular embodiment of the present invention has been disclosed, it is to be understood that various different modifications are possible and are within the true spirit of the invention, the scope of which is to be determined with reference to the claims set forth below. There is no intention, therefore, to limit the invention to the exact disclosure presented herein as a teaching of one embodiment of the invention.

We claim:

1. A process of making an article of manufacture, the process comprising: implementing a circuit design for an electrical device by coupling an epoxy dielectric material delivered with solid content sufficient that etching the epoxy forms a non-uniformly roughened surface of angular tooth-shaped cavities located in, and underneath an initial surface of, the dielectric material, sufficient that the etching of the epoxy uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface of the angular tooth-shaped cavities and sufficient that the etching of the epoxy is such that a plurality of the cavities have a cross-sectional width that is greater than a maximum depth with respect to the initial surface, wherein the etching forms the non-uniformly roughened surface of angular tooth-shaped cavities, with a conductive material, a portion of the conductive material in the cavities thereby forming angular teeth in the cavities, in circuitry of the electrical device.

2. The process of claim **1**, wherein some of the cavities comprise veins.

3. The process of claim **1**, wherein the cavities comprise cavities which substantially exhibit one or more of the following shapes: fanged, canine, and otherwise hooked teeth.

4. The process of claim **1**, wherein the cavities comprise cavities which substantially exhibit one or more of the following angled shapes: equilateral, isosceles, scalene, right, obtuse, or any combination thereof.

5. The process of claim **3**, wherein the cavities comprise cavities which substantially exhibit one or more of the following angled shapes: equilateral, isosceles, scalene, right, obtuse, or any combination thereof.

6. The process of claim **1**, wherein a conductive layer is intermediate the conductive material and the dielectric material, and wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

7. The process of claim **6**, wherein at least one of the teeth has a depth in a range of 1 tenth of a mil and less than about 2 tenths of a mil.

8. The process of claim **6**, wherein a sample of the circuitry has at least about 5,000 of the teeth per linear inch.

9. The process of claim **1**, wherein the portion of the circuitry is multilayer circuitry of the electrical device.

10. The process of claim **1**, wherein the electrical device is a circuit board.

11. The process of claim **1**, wherein the portion of the conductive material is connected to a second portion of the conductive material through at least one micro via.

12. The process of claim **1**, wherein the conductive material comprises a micro via in a multi-layer circuit board.

13. A process of making an article of manufacture, the process comprising: implementing a circuit design for an electrical device by coupling an epoxy dielectric material delivered with solid content sufficient that etching the epoxy forms a non-uniformly roughened surface comprising cavities located in, and underneath a surface of, the dielectric material, and sufficient that the etching of the epoxy uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface with at least some of the cavities having a first cross-sectional distance proximate the surface and a substantially greater cross-sectional distance distant from the surface, with a conductive material, whereby the etching of the epoxy forms the cavities, and a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the non-homogeneous composition forms the cavities, in circuitry of the electrical device.

14. The process of claim **13**, wherein the substantially greater cross-sectional distance is at least twice the first cross-sectional distance.

15. The process of claim **13**, wherein the electrical device is a circuit board.

16. A process of making an article of manufacture, the process comprising: implementing a circuit design for an electrical device by coupling an epoxy dielectric material delivered with solid content sufficient that etching the epoxy forms a non-uniformly roughened surface comprising substantially molar-shaped cavities located in, and underneath an initial surface of, the dielectric material and sufficient that the etching of the epoxy uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface comprising the molar-shaped cavities and a plurality of the cavities have a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface, with a conductive material, a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the epoxy forms the cavities, in circuitry of the electrical device.

17. The process of claim **16**, wherein the substantially greater cross-sectional distance is at least twice the first cross-sectional distance.

18. The process of claim **16**, wherein the electrical device is a circuit board.

19. A process of making an article of manufacture, the process comprising: implementing a circuit design for an electrical device by coupling an epoxy dielectric material delivered with sufficient solid content that etching of the epoxy forms a non-uniformly roughened surface of molar-shaped cavities located in, and underneath an initial surface of, the dielectric material and sufficient that the etching of the epoxy uses the non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface of the molar-shaped cavities and a plurality of the cavities have a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface, and a conductive material, a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the epoxy forms the cavities so that a plurality of the teeth each expand below a respective narrower region which is closer to the initial surface, in circuitry of the electrical device.

20. The process of claim **19**, wherein the electrical device is a circuit board.

21. A process of making an article of manufacture, the process comprising: implementing a circuit design for an electrical device with circuitry comprising means for interlocking a conductor part of the circuitry configured for filling cavities with an epoxy dielectric material disposed in combination with the circuitry and coupled with the conductor part in a configuration where the dielectric material comprises a non-uniformly roughened surface comprising cavities located in and underneath an initial surface of the dielectric material delivered with solid content being non-homogeneous and configured to bring about formation of the non-uniformly roughened surface by etching of the epoxy, at least some the cavities having a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface.

22. The process of claim **2**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

23. The process of claim **3**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

24. The process of claim **4**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

25. The process of claim **5**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

26. The process of claim **7**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

27. The process of claim **8**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

28. The process of claim **9**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

29. The process of claim **10**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

30. The process of claim **11**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

31. The process of claim **12**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

32. The process of claim **13**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

33. The process of claim **14**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

34. The process of claim **15**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

35. The process of claim **16**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

36. The process of claim **17**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

37. The process of claim **18**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

38. The process of claim **19**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

39. The process of claim **20**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

40. The process of claim **21**, wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

41. The process of claim **1**, wherein the etching includes a first etching and a second etching.

42. The process of claim **2**, wherein the etching includes a first etching and a second etching.

43. The process of claim **3**, wherein the etching includes a first etching and a second etching.

44. The process of claim **4**, wherein the etching includes a first etching and a second etching.

45. The process of claim **5**, wherein the etching includes a first etching and a second etching.

46. The process of claim **6**, wherein the etching includes a first etching and a second etching.

47. The process of claim **7**, wherein the etching includes a first etching and a second etching.

48. The process of claim **8**, wherein the etching includes a first etching and a second etching.

49. The process of claim **9**, wherein the etching includes a first etching and a second etching.

50. The process of claim **10**, wherein the etching includes a first etching and a second etching.

51. The process of claim **11**, wherein the etching includes a first etching and a second etching.

52. The process of claim **12**, wherein the etching includes a first etching and a second etching.

53. The process of claim **13**, wherein the etching includes a first etching and a second etching.

54. The process of claim **14**, wherein the etching includes a first etching and a second etching.

55. The process of claim **15**, wherein the etching includes a first etching and a second etching.

56. The process of claim **16**, wherein the etching includes a first etching and a second etching.

57. The process of claim **17**, wherein the etching includes a first etching and a second etching.

58. The process of claim **18**, wherein the etching includes a first etching and a second etching.

59. The process of claim **19**, wherein the etching includes a first etching and a second etching.

60. The process of claim **21**, wherein the etching includes a first etching and a second etching.

61. The process of claim **22**, wherein the etching includes a first etching and a second etching.

62. The process of claim **23**, wherein the etching includes a first etching and a second etching.

63. The process of claim **24**, wherein the etching includes a first etching and a second etching.

64. The process of claim **25**, wherein the etching includes a first etching and a second etching.

65. The process of claim **26**, wherein the etching includes a first etching and a second etching.

66. The process of claim **27**, wherein the etching includes a first etching and a second etching.

67. The process of claim **28**, wherein the etching includes a first etching and a second etching.

68. The process of claim **29**, wherein the etching includes a first etching and a second etching.

69. The process of claim **30**, wherein the etching includes a first etching and a second etching.

70. The process of claim **31**, wherein the etching includes a first etching and a second etching.

71. The process of claim **32**, wherein the etching includes a first etching and a second etching.

72. The process of claim **33**, wherein the etching includes a first etching and a second etching.

73. The process of claim **34**, wherein the etching includes a first etching and a second etching.

74. The process of claim **35**, wherein the etching includes a first etching and a second etching.

75. The process of claim **36**, wherein the etching includes a first etching and a second etching.

76. The process of claim **37**, wherein the etching includes a first etching and a second etching.

77. The process of claim **38**, wherein the etching includes a first etching and a second etching.

78. The process of claim **39**, wherein the etching includes a first etching and a second etching.

79. The process of claim **40**, wherein the etching includes a first etching and a second etching.

80. An electrical device comprising:

circuitry;

conductive material being part of the circuitry and configured as angular teeth in filling cavities; and

an epoxy dielectric material, disposed in combination with the circuitry and coupled with the conductive material in a configuration where the dielectric material comprises a non-uniformly roughened surface comprising cavities located in and underneath an initial surface of the dielectric material delivered with solid content being non-homogeneous and configured to bring about formation of the non-uniformly roughened surface by etching of the epoxy, at least some the cavities having a first cross-sectional distance proximate the initial surface and a substantially greater cross-sectional distance distant from the initial surface.

81. The electrical device of claim **80**, wherein some of the cavities comprise veins.

82. The electrical device of claim **80**, wherein the cavities comprise cavities which substantially exhibit one or more of the following shapes: fanged and canine, and otherwise hooked teeth.

83. The electrical device of claim **80**, wherein the cavities comprise cavities which substantially exhibit one or more of the following angled shapes: equilateral, isosceles, scalene, right, obtuse, or any combination thereof.

84. The electrical device of claim **83**, wherein the cavities comprise cavities which substantially exhibit one or more of the following angled shapes: equilateral, isosceles, scalene, right, obtuse, or any combination thereof.

85. The electrical device of claim **80**, wherein a conductive layer is intermediate the conductive material and the dielectric material, and wherein the bringing about the formation of the non-uniformly roughened surface does not include bringing about formation of cavities in the conductive material by physical roughening.

86. The electrical device of claim **80**, wherein at least one of the teeth has a depth in a range of 1 tenth of a mil and less than about 2 tenths of a mil.

87. The electrical device of claim **80**, wherein a sample of the circuitry has at least about 5,000 of the teeth per linear inch.

88. The electrical device of claim **80**, wherein the circuitry comprises multilayer circuitry of the electrical device.

89. The electrical device of claim **80**, wherein the electrical device is a circuit board.

90. The electrical device of claim **81**, wherein the etching includes a first etching and a second etching.

91. The electrical device of claim **82**, wherein the etching includes a first etching and a second etching.

92. The electrical device of claim **83**, wherein the etching includes a first etching and a second etching.

93. The electrical device of claim **84**, wherein the etching includes a first etching and a second etching.

94. The electrical device of claim **85**, wherein the etching includes a first etching and a second etching.

95. The electrical device of claim **86**, wherein the etching includes a first etching and a second etching.

96. The electrical device of claim **87**, wherein the etching includes a first etching and a second etching.

97. The electrical device of claim **88**, wherein the etching includes a first etching and a second etching.

98. The electrical device of claim **89**, wherein the etching includes a first etching and a second etching.

99. The electrical device of claim **90**, wherein the etching includes a first etching and a second etching.

100. A product produced by the process of **1**.

101. A product produced by the process of **13**.

102. A product produced by the process of **16**.

103. A product produced by the process of **21**.

* * * * *

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(54) **ELECTRICAL DEVICE WITH TEETH JOINING LAYERS AND METHOD FOR MAKING THE SAME**

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CPC ***H05K 3/381*** (2013.01); ***H05K 3/4661*** (2013.01); *H05K 3/0023* (2013.01); *H05K 3/0055* (2013.01); *H05K 2203/0796* (2013.01); *Y10T 29/49117* (2015.01); *Y10T 29/49126* (2015.01); *Y10T 29/49155* (2015.01); *Y10T 29/49165* (2015.01); *Y10T 428/12361* (2015.01); *Y10T 428/24331* (2015.01)

(58) **Field of Classification Search**
USPC 174/255–262, 264, 266; 29/829, 831; 216/13, 16–18; 205/125
See application file for complete search history.

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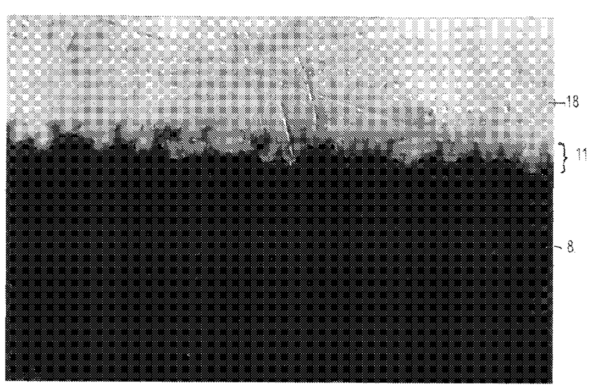
Primary Examiner — Tremesha S Willis
(74) *Attorney, Agent, or Firm* — Peter K Trzyna

(57) **ABSTRACT**

A multilayer electrical device, such as a printed circuit board, having a tooth structure including a metal layer set in a dielectric. The device includes a base; a conductive layer adjacent to the base; a dielectric material adjacent to conductive layer; a tooth structure including a metal layer set in the dielectric material to join the dielectric material to the metal layer; and wherein the metal layer forms a portion of circuitry.

48 Claims, 2 Drawing Sheets



Related U.S. Application Data

continuation of application No. 10/790,363, filed on Mar. 1, 2004, now Pat. No. 7,501,582, which is a continuation of application No. 09/694,099, filed on Oct. 20, 2000, now Pat. No. 6,700,069, which is a continuation of application No. 08/905,619, filed on Aug. 4, 1997, now Pat. No. 6,141,870.

(51) **Int. Cl.**
H05K 3/46 (2006.01)
H05K 3/00 (2006.01)

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FIG. 1

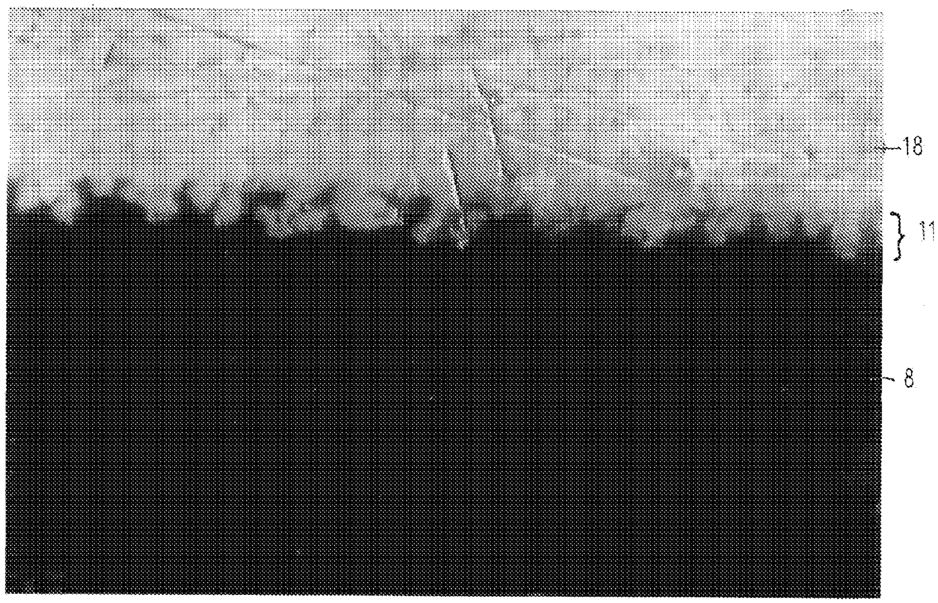


FIG. 2 PRIOR ART

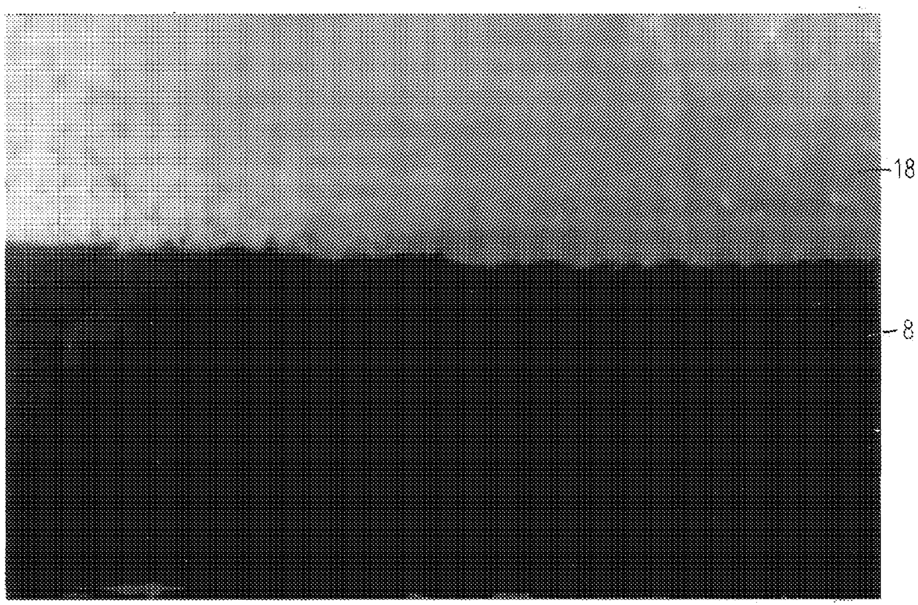


FIG. 3

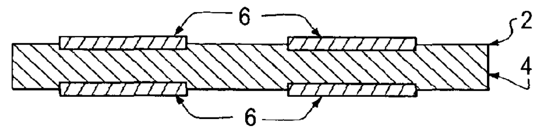


FIG. 4

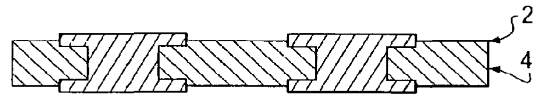


FIG. 5

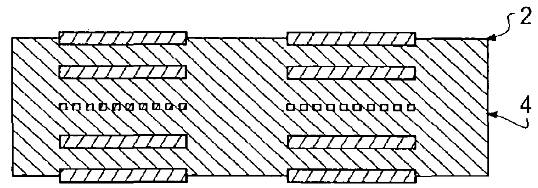


FIG. 6

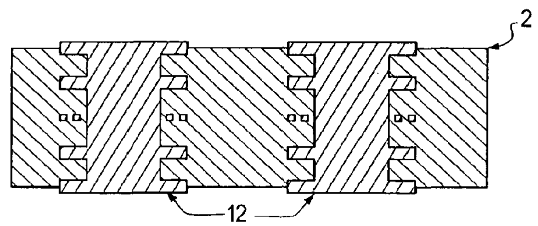


FIG. 7

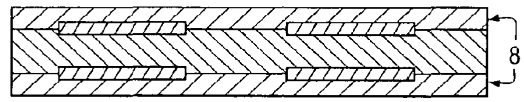


FIG. 8

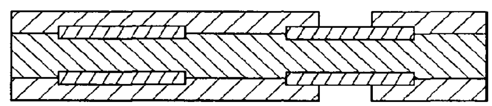


FIG. 9

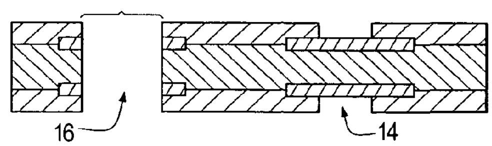


FIG. 10

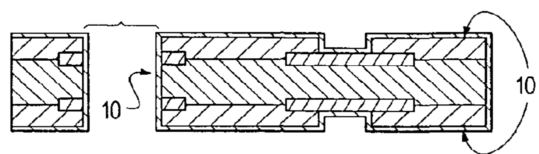
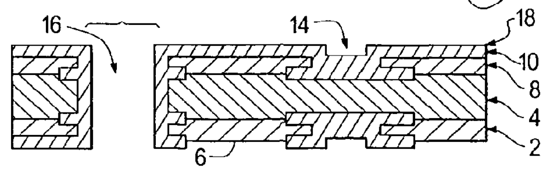


FIG. 11



ELECTRICAL DEVICE WITH TEETH JOINING LAYERS AND METHOD FOR MAKING THE SAME

I. CLAIM OF PRIORITY

The present patent application is a continuation of, and incorporates by reference as if fully restated herein, U.S. patent application Ser. No. 13/632,742, filed Oct. 1, 2012, pending. U.S. Ser. No. 13/632,742 is a continuation of and incorporates by reference as if fully restated herein, U.S. patent application Ser. No. 12/363,501, filed Jan. 30, 2009, issuing on Oct. 2, 2012, as U.S. Pat. No. 8,278,560. Ser. No. 12/363,501 is a continuation of and incorporates by reference as if fully restated herein, Ser. No. 10/790,363, filed Mar. 1, 2004, issuing Mar. 10, 2009, as U.S. Pat. No. 7,501,582. Ser. No. 10/790,363 is a continuation of and incorporates by reference as if fully restated herein, Ser. No. 09/694,099, filed Oct. 20, 2000, issuing on Mar. 2, 2004, as U.S. Pat. No. 6,700,069. Ser. No. 09/694,099 is a continuation of and incorporates by reference as if fully restated herein, Ser. No. 08/905,619, filed Aug. 4, 1997, issuing on Nov. 7, 2000, as U.S. Pat. No. 6,141,870. The present patent application incorporates by reference all of the patent applications and patents listed above.

II. FIELD OF THE INVENTION

The present invention is directed to methods for making or manufacturing an electrical device, and the process, composition, and product thereof. More particularly, the present invention involves such multilayer electrical devices as circuit boards constructed by joining a dielectric material to a subsequently applied conductive material. Still more particularly, the present invention involves an electrical device having a substrate or base, an applied dielectric material thereon, which in turn has a thin conductive coating thereon, and a conductive layer formed upon the conductive coating, the conductive layer being joined to the applied dielectric material in an improved manner.

III. BACKGROUND OF THE INVENTION

Multilayer electrical devices—those made from layering a dielectric material and a conductive material on a base—suffer from delamination, blistering, and other reliability problems. This is particularly true when the laminates are subjected to thermal stress.

Known attempts to solve these problems seem to have focused on physical or chemical roughening, particularly of the base or substrate. See for example, U.S. Pat. No. 4,948,707. Although oxide-related chemical roughening processes have been used, an emphasis on physical roughening may reflect the use of materials that are relatively chemically resistant. Both physical and chemical roughening approaches have improved adherence to the base.

However, the extent to which this adherence can be increased by roughening has its limits. And despite a long standing recognition of delamination, blistering, and reliability problems, and the attempts to find a solution, these problems have been persistent in electrical devices made of layered materials.

IV. SUMMARY OF THE INVENTION

The inventors herein have observed that the general problem of poor adherence between the laminates or layers can be addressed by forming a unique surface structure, which is particularly suitable for joining the dielectric material to the conductive coating and conductive layer. The surface structure is comprised of teeth that are preferably angled or hooked like fangs or canine teeth to enable one layer to mechanically grip a second layer.

In comparison with the above-mentioned roughening techniques of the prior art, it is believed that a surface of the teeth is an improvement in that there is an increase in surface area. However, it is still better to use teeth that are fang-shaped to enable a mechanical grip that functions in a different manner than adherence by means of increased surface area. By using the fanged, angled, canine, or otherwise hooked teeth (in addition to increased surface area), there is a multidirectional, three dimensional interlacing or overlapping of layers. For example, in joining the dielectric material to the conductive coating and metal layer, the conductive coating and metal layer is actually burrowed in and under the dielectric material and vice versa. Thus, separating them not only involves breaking the surface area adherence, but also involves destroying the integrity of at least one of the layers by ripping the teeth, the layer pierced by them, or both.

Further, it has been found preferable to have numerous teeth sized and shaped so that they are not too large or too small. If the teeth are too small, wide, straight, and shallow, then the surface resembles the roughened surface of prior art techniques, vaguely analogous to a surface of molar teeth, and the adherence is not much better than that achieved by known prior art roughening techniques.

However, if the teeth are too large, deep, and fanged or hook-shaped, the teeth undercut the surface to such an extent that the strength of the dielectric material surface is weakened. As a result, adherence is decreased over the preferred embodiment.

Not too great and not too slight, the right sized and shaped teeth, set in a fanged orientation and with sufficient frequency, have been found to be the best structure. If the correct balance of these critically important factors is created, the result is a greatly improved circuit board or other such electrical device.

It is theorized by the inventors that the best methods for producing the teeth is to use non-homogeneous materials and/or techniques. For example, a dielectric material can have a non-homogeneous composition or thickness to bring about an uneven chemical resistance, such that slowed and/or repeated etching will form teeth instead of a uniform etch.

V. BRIEF DESCRIPTION OF THE DRAWINGS

The file of this patent contains at least one drawing executed in color. Copies of this patent with the color drawing (s) will be provided by the Patent and Trademark Office upon request and payment of the necessary fee.

FIG. **1** is an illustration of a conductive coating and metal layer applied dielectric material with a desirable tooth structure;

FIG. **2** is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes;

FIG. **3** is an illustration of a double sided printed circuit board without plated through holes;

FIG. **4** is an illustration of a multilayer printed circuit board with plated through holes, filled or unfilled with conductive or nonconductive material;

FIG. **5** is an illustration of a multilayer printed circuit board without plated through holes;

FIG. **6** is an illustration of a multilayer printed circuit board having more than two layers with plated through holes filled or unfilled with conductive or nonconductive material;

FIG. **7** is an illustration of any of the foregoing printed circuit boards after applying a dielectric material thereon;

FIG. **8** is an illustration of the multilayer printed circuit board of FIG. **7** after forming micro vias;

FIG. **9** is an illustration of the multilayer printed circuit board of FIG. **7** after opening the through holes and after etching the applied dielectric material to produce the teeth illustrated in FIG. **1**;

FIG. **10** is an illustration of the multilayer printed circuit board of FIG. **9** after application of a conductive coating to fill in around the teeth and connect micro via holes and the through holes; and

FIG. **11** is an illustration of the multilayer printed circuit board of FIG. **10** after plating the conductive coating to form a metal layer and complete forming circuitry.

VI. DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a conductive coating and metal layer on the applied dielectric material with a desirable tooth structure. In contrast, FIG. **2** is an illustration of a prior art conductive coating and metal layer on the applied dielectric material with the surface produced by roughening processes. In both FIGS. **1** and **2**, show a dielectric material and a combination of a thin conductive coating and metal later. Compare FIG. **1** and FIG. **2**, and note particularly the size, shape, frequency, and depth of the teeth in FIG. **1** with the surface produced by roughening in FIG. **2**.

A way of articulating this "teeth" concept is to view each tooth as being made of one layer and set in a second layer. However, the perspective is arbitrary, and one could equally view each tooth as made of the second layer set in the first. It could also be said that the layers join in a saw-toothed manner, i.e., teeth made of both materials in an interlocking bite. In any case, however, there are teeth, and for the sake of consistency, this specification will adopt the convention of referring to the teeth as being made of the conductive coating and metal layer set in the dielectric material.

A further way of articulating the "teeth" concept is to view each tooth as being substantially triangular in shape, with the base of the triangle being defined by a plane of the applied dielectric material before it is etched, or more precisely by the exterior surface thereof. The invention can be carried by forming cavities in the applied dielectric material **6** for receiving the teeth, and then forming the teeth from the conductive coating and metal layer formed thereon. Generally, the teeth can be of any triangular shape (e.g., equilateral, isosceles, scalene, right, obtuse, or any combination thereof). Preferably, though, the teeth are obtuse so as to hook or angle under the exterior surface of the applied dielectric material.

The use of any shape of teeth increases the surface area where the conductive coating is on the applied dielectric material. However, the preferred embodiment utilizes a surface of obtuse, canine, or fang-shaped teeth to help the conductive coating and metal layer hook under the exterior surface of the applied dielectric material to mechanically grip the applied dielectric material. The obtuse, canine, or fang-shaped teeth are in contrast to the shallower, more rounded surface typically produced by known roughening techniques. Note in FIG. **2** that roughing techniques can produce some occasional gouging, but nothing on the order of the present invention.

As to size of the teeth, as mentioned above, it is preferable that the teeth be within a certain size range. The optimal size range for obtuse, canine, or hook-shaped teeth involves a balance between maximizing surface area and mechanical grip, but not undercutting the surface of the applied dielectric material **8** to such an extent as to weaken it. Accordingly, the teeth should be sized at least 1 tenth of a mil deep. Better is at least 1.25 tenths of a mil deep, and even better is at least 1.5 tenths of a mil deep. However, 1.75 tenths of a mil is acceptable, and about 2 tenths of a mil is reaching the limit.

As to frequency, the teeth should be quite frequent in number; at least about 5,000 teeth per linear inch, and preferably at least about 10,000 teeth per linear inch; and even better is at least about 15,000 teeth per linear inch.

As to surface area, there should be at least about 25,000 teeth per square inch, better still is essentially at least about 100,000 per square inch, and preferably at least about per 200,000 per square inch, or even greater.

It should be recognized that the teeth generally are not formed to a precise dimension. As shown in FIG. **1**, some of the teeth are somewhat differently sized, angled, and proportioned. Thus, a representative sample of the electrical device should have teeth in about these ranges. Having at least about 20% of the teeth in one or more of these ranges, and preferably at least 50%, is a preferred balance of mechanical grip without a weakening the integrity of the layering, particularly in combination.

As illustrated in FIGS. **3-11**, there is an electrical device, such as a printed circuit board **2** having a base **4**. The base **4** has a conductive layer **6** thereon. A dielectric material **8** is applied on the conductive layer **6**, and a conductive coating **10** (such as a thin coating of palladium) is deposited on the dielectric material **8**. Metal layer **12** is formed on the conductive coating **10**.

FIG. **3** illustrates one of the many ways to begin the process of forming the teeth in accordance with the present invention. A first step (step **1**), includes providing a base **4** for constructing an electrical device, such as a printed circuit board **2**. FIG. **3** illustrates one such construction, namely a base **4** for constructing a multilayer printed circuit board **2**, the base **4** having any positive number of layers or laminates, for example the two layers shown in FIGS. **3** and **4**, or more than two layers as illustrated in FIGS. **5** and **6**, etc. One configuration or another is not significant, except that multiple layers provide a better medium for constructing circuitry of increased complexity or density. FIGS. **3-6** illustrate an embodiment in which the conductive layer **6** is on at least an upper side, and preferably also on a lower side of the base **4**.

As may be needed for a particular circuitry design, FIG. **4** illustrates that the electrical device can be further manipulated, for example, by forming through holes **12** by mechanical drilling, laser drilling, punching, or the like. The plated through holes **12** are shown in FIGS. **4** and **6** as filled or unfilled with a conductive or a nonconductive material.

FIG. **5** illustrates a configuration for the multilayer printed circuit board **2** with base **4** having more than two layers or laminates, the conductive layers **6** located there between.

FIG. **6** shows the multilayer printed circuit board **2** after forming, plating, and if needed, filling the through holes **12** in the manner of FIG. **4**.

To summarize, step **1** of the process includes providing a base **4** for forming an electrical device such as a printed circuit board **2**, wherein the base **4** can be formed to have one or more layers or laminates. At least one conductive layer **6** is on the base **4**. The base **4** can be double sided with the conductive layer **6** being located outside the base **4** and between the layers or laminates.

The printed circuit board **2** can be further prepared, as may be desirable for a particular circuitry design, by forming open through holes **12** and plating and if needed, filling the through holes **12** to electrically connect to that portion of the conductive layer **6** appropriate for whatever circuitry design is being constructed, e.g., each side of a double sided circuit board **2**. In other words, step **1** involves providing one of the configurations described in FIGS. **3**-**6**.

Step **2** includes preparing an outer-most surface of the conductive layer **6** for any of the above-mentioned configurations. The step of preparing is carried out to enable adherence, e.g., of the applied dielectric material **8** to the conductive layer **6**, preferably in a manner that utilizes a respective tooth structure. The step of preparing can be carried out, for example, by using an oxide or an oxide replacement process to treat the conductive layer **6** to such an extent that the teeth (or cavities for teeth) are formed.

As to using an oxide process, a copper oxide can be chemically deposited on a copper surface to produce a tooth-like structure on the surface of the copper. This process is carried out to prepare the copper surface prior to applying another layer of material, thereby providing increased bond strength between the two materials.

As to using an oxide replacement process to form a tooth structure, a micro etch on the surface of the copper is followed by a coating of an adhesion promoter to enhance a bond between copper and the dielectric material **8**. For example, Alpha Metals, Inc. offers a PC-7023 product which is suitable for an oxide replacement process.

Step **3** includes applying the dielectric material **8** to the outermost surface of the conductive layer **10** (and the base **4** if appropriate for the circuitry or electrical device at issue) prepared in accordance with the step **2**. The dielectric material **8** can be applied by as a (dry) film, a (liquid) curtain coating, a (liquid) roller coating, or an analogous application or bonding technique. FIG. **7**, in comparison with FIGS. **3**-**6**, illustrates the dielectric material **8** on the outermost surface(s) of the conductive layer **4** (and the base **2**).

Step **4** includes preparing the applied dielectric material **8** for receipt of a conductive coating **10**, which to exemplify, is detailed more particularly below. Generally, though, the preparing step **4** can include exposing, developing, and curing the applied dielectric material **8** to form patterns for further construction of the circuitry, including such features as constructing a via or photo via **14**, for optionally filling by conductive or non-conductive materials, e.g., screened, roller coated, etc. Compare FIGS. **6** and **7**.

Step **5** includes forming open through holes **16** as shown in FIG. **9**. As indicated above with regard to filled through holes **12**, the open through holes **16** can be formed by such methods as drilling, boring, punching, and the like.

Step **6**, as discussed subsequently in greater detail, involves the etching cavities, veins, openings, or gaps in the applied dielectric material **8**, or more particularly an outermost surface thereof, to accommodate the teeth. One technique for forming the teeth is somewhat similar to what has been known as the swell and etch or desmear process, except that contrary to all known teachings in the prior art, in effect, a "double desmear process" is utilized. That is, not merely increasing the times and temperatures and other parameters for the desmear process, but instead completing the process a first time, and then completing the process a second time. Consider using the following Shipley products for the double desmear process: CIRCUPOSIT MLB conditioner 211, promoter 213B, and neutralizer 216. Non-homogeneous materials and/or processes seem to be determinative.

Step **7** includes applying a conductive coating **10** to the cavities in the applied dielectric material **8**. The conductive coating **10** is also applied to the photo-defined via holes **14** and the open through holes **16**. Techniques for applying the conductive coating **10** include a direct plate process or an electroless copper process. To carry out the present invention, it is preferable to use a palladium-based direct plate process or other non-electroless process. In this regard, a Crimson product of Shipley is suitable, though the desmear process as disclosed herein is contrary to the manufacturer's specifications, i.e., a "double desmear process," rather than the single desmear process of the known prior art. Compare FIGS. **1**, **2**, and **9**.

Step **8** includes forming a metal layer **18** on the conductive coating **10**, by such metal deposition techniques as electrolytic or non-electrolytic plating, to form the tooth structure and teeth as discussed above. The metal layer **18** and conductive coating **10** collectively form circuitry on the outermost surface of the applied dielectric material **8**, which can connect to whatever portion of conductive layer **6** as may be needed for a particular design, preferably by making at least one connection through a micro via. See FIG. **10**. A direct plate process, followed as needed by say a semi-additive or fully additive pattern plating process, is recommended.

A direct plate process is a replacement for traditional electroless copper plating of non-conductive surfaces. Direct plate processes apply a very thin conductive coating (e.g., using palladium or graphite) to the non-conductive surface, thus enabling electroplating of copper or other conductive material onto the previously non-conductive surface. Thus, "direct plate" is used to describe directly plating onto a non-conductive surface without first requiring a non electrolytic (electroless) plating process.

A semi-additive plating process involves first electroplating a thin conductive layer onto the total non-conductive surface, before applying a photoresist and subsequently pattern plating the required circuitry. For semi-additive plating, the thin conductive layer must be removed (etched) from the non-conductive surface. For fully additive plating, photoresist is applied directly on the non-conductive surface, followed by pattern plating the required circuitry (after applying the thin conductive coating in the direct plate process). That is, the fully additive plating forms only the required circuitry and requires no etching.

It should be recognized that the present invention can optionally be carried out by initially skipping step **5** (forming the open through holes **16**) during initial "sets" of the foregoing steps, i.e., completing steps **6** and **7**; then repeating steps **2** through **8**, again skipping step **5** each time until the last set of steps, as required to form the electrical device or circuitry of interest. This will produce an electrical device with a second tooth structure that is not set in the first layer of dielectric material **8**, and indeed the idea of using a toothed structure is not limited to any one layer and is best employed in holding multiple layers together. Step **5** can be carried out after the desired layers have been formed.

Turning now more particularly to the process for forming the teeth and the cavities for the teeth, the present invention can be carried out by a new use of a Ciba-Geigy product known as Probelec XB 7081 as a photoimagable dielectric material **8**. Generally, and in accordance with its specification sheet, Probelec XB 7081 is a single component, 100% epoxy photodielectric material specially developed for Sequential Build Up (SBU) of multilayer boards.

Probelec XB7081 is a negative working, high resolution liquid photo-imageable (LPI) material which allows mass-forming of micro vias for fabrication of high-density interconnects (HDI). Compatible with conventional plating and circuitization techniques, Probelec XB 7081 also provides outstanding electrical and physical properties for most circuit board applications, and is compatible with most circuit board substrate materials. Probelec XB 7081 is specially developed to act as a dielectric between circuit layers in fabrication of blind and buried micro via MLBS. The high resolution photo dielectric allows mass forming of micro vias for the construction of high density interconnects. Probelec XB 7081 has wide process latitudes, excellent handling characteristics, and is known as self-leveling and having an adjustable dry thickness of 1-3 mils. Probelec XB 7081 has a high resolution capability of 1-2 mil micro vias, and is known for chemical resistance, even for additive plating; there are excellent electrical and physical properties and a UL 94V-0 rating. Probelec is specified to demonstrate more than a 6 lb/in peel strength. By application of this invention this peel strength should be significantly increased due to the formation of the teeth. Accordingly the peel strength produced in accordance with the present invention is greater than the peal strength produced by the desmear process of the prior art, i.e., a single pass desmear process. For example, if a prior art desmear process is used to produce a 6 lb/in average peel strength, the present invention may produce an average peel strength on the order of 10 lb/in or more.

As to the general properties of Probelec XB 7081, there is a storage stability (1-component system) for more than 6 months at 25° C.; the pot life in a coater machine is more than 1 week; the hold time of the coating is more than 1 week (dark or exposed) and more than 1 day in yellow light.

When using Probelec XB 7081 to carry out the above-mentioned step **3** of applying a coating of the dielectric material, there is a pre-cleaning sub-step A. Pre-cleaning should be carried out in chemical, mechanical brushing, or pumice spray units. Extra precaution is needed to ensure that the pre-cleaning equipment and chemistry is not contaminated by materials from previous processing steps. Contrary to Ciba specifications, it is preferred to use an oxide or oxide replacement to prepare the surface prior to applying a coating of the dielectric. Hold times after pre-cleaning should be minimized to avoid oxidation of copper surfaces. In all coating applications, pre-cleaned substrates should be free of particles. Additional cleaning steps, e.g., with detergents, may be required to remove organic residues.

Next there is a coating sub-step B. Probelec XB7081 seems to have been primarily designed for curtain coating and is delivered with a solid content of 58%. Substrates should be heated to about 40° C. prior to coating to ensure all residual moisture is removed and to prepare substrate for curtain coating. For initial charging of a coater machine, Probelec XB 7081 needs to be premixed with about 15% of PMA (PMA is 1-methoxy-2-propyl acetate) to ensure proper viscosity. The additional PMA thins the coating down to about 50% solids.

The resin temperature should be 25±1° C., with a conveyor speed of 90 m/min. The viscosity is at 25° C., DIN AK4 cup at 60 sec. (400 cps), with a coater gap width of 500 mm. The wet weight is 7.5-10.0 gms/600 CM sq. and 11.6-15.5 gms/ft sq. The dry thickness is 45-60 mm.

Next is a flash dry sub-step C. Coated panels must be held in a horizontal position under dust-free conditions to air dry. At this stage, minimal air flow is recommended. The drying time is 12-18 min. at a drying temperature of 30-40° C.

Next is a final dry sub-step D. After flash air drying, final drying at an elevated temperature is needed to achieve better than 95% removal of solvents for tack-free handling. This can be accomplished in batch or conveyorized tunnel ovens, as follows:

	Tunnel Oven	Batch Oven
Drying Temperature:	130-140° C.	90° C.
Drying Time:	2-3 minutes	30 minutes

After cooling, the panels can have a second side coating (sub-steps A through D) if appropriate for the circuit design, and then for an exposure sub-step E.

In the exposure sub-step E, catalyst for cross linking of epoxy resin is generated. The main spectral sensitivity of Probelec XB 7081 is in the range of 350-420 nm. Conventional exposure units, collimated or non-collimated, with peak spectral emission of 365 nm are recommended. Both diazo and silver halide films are suitable as working phototools. Good artwork to coating contact is essential for consistent micro via reproduction. The exposure energy is 1200-1600 mJ/cm sq. and the exposure time (7 kW) is 30-40 seconds. The Stouffer Step (21 scale) is 5-7.

Next is a thermal bump step F. Thermal bump provides the energy for crosslinking the catalyzed epoxy resin. This process can be done in convection batch or conveyorized tunnel ovens. For a batch oven, 110° C. for 60 min. is appropriate, and for a conveyorized tunnel oven, 130° C. for 10-20 min. is appropriate.

Next is a developing sub-step G. The unexposed areas of Probelec XB7081 are developed away in continuous spray developing machines. Various models with different processing capacities are available for this purpose. A Ciba-Geigy product DY 950 (Gamma-Butyrolactone (GBL)) developer is recommended for processing Probelec XB7081. This developer is a halogen-free, high-boiling organic solvent suitable for on-site distillation or recycling. Probimer 450/470 spray developing equipment is specially designed for use with this developer solution. The temperature is 20±2° C., and the spray pressure is 2-4 bar. The speed for Probimer 450 is 2-3 m/min; for Probimer 470, 3-4 m/min.

Next is a final cure sub-step H. Final thermal curing is needed to impart good mechanical, chemical, and electrical properties to the dielectric film. The thermal curing can take place in batch or conveyorized tunnel ovens. The thermal curing temperature is 150° C., with a thermal curing time of 60 minutes.

Next can come the step **5** of further preparing, for example, by forming through holes **16**. If plated through holes **16** (PTH's) are needed for interconnecting layers to the bottom or back side of the printed circuit board **2**, drilling should of course be done before plating. This allows the plating of the surface together with the through holes **16**. Plating and such post-processing of the photoimagable dielectric material **8** is dependent on particular process preferences. Probelec XB7081 is compatible with panel-plate, pattern-plate or additive plating.

The following process sub-steps of the above-mentioned step **6** describe a generic sequence for a desmear process to form cavities in the dielectric. Although Probelec XB7081 apparently was intended for use in the common desmear (swell and etch) process as used in conventional plated through hole plating lines, Probelec XB7081 can alternatively be used in carrying out the present invention. For example, the present invention differs from the common desmear process in that sub-steps in the desmear process are repeated as a way of forming the teeth. Sub-step A, swelling the dielectric material **8**, can be carried out with butyl diglycol/sodium hydroxide/water 80° C. for 3-5 minutes. Sub-step B is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step C is etching the dielectric material **8**, which can be carried out using potassium permanganate/sodium hydroxide/water 80° C., 6-10 minutes. Sub-step D is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step D includes a further rinsing of the dielectric material **8** in deionized water at room temperature for 4 minutes. Sub-step E is neutralizing the dielectric material **8** in sulfuric peroxide (1.5%) for 3 to 5 minutes. Finally step F is rinsing the dielectric material **8** in deionized water at room temperature for 4 minutes.

In stark contrast with the etch and swell process of the known prior art, however, a second pass through the process (sub-steps A through F) is used. The second pass seems to make use of non-homogenaities in bringing about a formation of the teeth. Thus, unlike the prior swell and etch chemical roughening process, which produces a surface characterized by a surface gloss measurement at an angle of 60° which is between 15 and 45%, the present invention has less gloss (<10%).

Turn now in greater detail to the step **7** of applying the conductive coating **10** for subsequent deposition of the metal layer **18** by, say, plating. Good results can be achieved with a flash plate of 0.7-1.0 mm (30-40 micro inches). The flash plate is followed by baking at 130-150° C., for 2 hours.

For pattern plating, plating resist can be applied after baking. Depositing the metal layer **18** by electroplating can be carried out such that there is 10-25 mm (0.4-1.0 mil.).

While a particular embodiment of the present invention has been disclosed, it is to be understood that various different modifications are possible and are within the true spirit of the invention, the scope of which is to be determined with reference to the claims set forth below. There is no intention, therefore, to limit the invention to the exact disclosure presented herein as a teaching of one embodiment of the invention.

We claim:

1. A process of making an article of manufacture, the process comprising:

implementing a circuit design for an electrical device by coupling a dielectric material delivered with solid content, the dielectric material and the solid content being non-homogeneous materials, sufficient that etching the dielectric material forms a non-uniformly roughened surface of cavities located in, and underneath an initial surface of, the dielectric material, sufficient that the etching of the dielectric material uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface of the cavities and sufficient that the etching of the dielectric material is such that a plurality of the cavities have a cross-sectional width that is greater than a maximum depth with respect to the initial surface, wherein the etching forms the non-uniformly roughened surface of cavities, with

a conductive material, a portion of the conductive material in the cavities thereby forming numerous sized and shaped teeth in the cavities, in circuitry of the electrical device.

2. A process of making an article of manufacture, the process comprising:

implementing a circuit design for an electrical device by coupling a dielectric material delivered with solid content, the dielectric material and the solid content being non-homogeneous materials, sufficient that etching the dielectric material forms a non-uniformly roughened surface comprising cavities located in, and underneath a surface of, the dielectric material, and sufficient that the etching of the dielectric material uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface with at least some of the cavities having a first cross-sectional distance proximate the surface and a greater cross-sectional distance distant from the surface, with

a conductive material, whereby the etching of the dielectric material forms the cavities, and a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the non-homogeneous composition forms the cavities, in circuitry of the electrical device.

3. A process of making an article of manufacture, the process comprising:

implementing a circuit design for an electrical device by coupling a dielectric material delivered with sufficient solid content, the dielectric material and the solid content being non-homogeneous materials, that etching of the dielectric material forms a non-uniformly roughened surface of cavities located in, and underneath an initial surface of, the dielectric material and sufficient that the etching of the dielectric material uses non-homogeneity with the solid content in bringing about formation of the non-uniformly roughened surface of the cavities, and the cavities have a cross-sectional distance proximate the initial surface and a greater cross-sectional distance distant from the initial surface, and

a conductive material, a portion of the conductive material in the cavities thereby forming teeth in the cavities, wherein the etching of the dielectric material forms the cavities so that a plurality of the teeth each expand below a respective narrower region which is closer to the initial surface, in circuitry of the electrical device.

4. A process of making an article of manufacture, the process comprising:

implementing a circuit design for an electrical device with circuitry comprising interlocking a conductor part of the circuitry configured to fill cavities in a dielectric material disposed in combination with the circuitry and coupled with the conductor part in a configuration where the dielectric material comprises a non-uniformly roughened surface comprising said cavities which are located in and underneath an initial surface of the dielectric material that is delivered with solid content, the dielectric material and the solid content being non-homogeneous materials, configured to bring about formation of the non-uniformly roughened surface by etching of the dielectric material, at least some the cavities having a first cross-sectional distance proximate the initial surface and a greater cross-sectional distance distant from the initial surface.

5. The process of claim **1**, wherein at least about 20% of the teeth are at least 1 tenth of a mil deep and some of the teeth have a hooked-shaped crosssectional portion.

6. The process of claim **2**, wherein at least about 20% of the teeth are at least 1 tenth of a mil deep and and some of the teeth have a hooked-shaped crosssectional portion.

7. The process of claim **3**, wherein at least about 20% of the teeth are at least 1 tenth of a mil deep and and some of the teeth have a hooked-shaped crosssectional portion.

8. The process of claim **4**, wherein at least about 20% of the teeth are at least 1 tenth of a mil deep and and some of the teeth have a hooked-shaped crosssectional portion.

9. The process of claim **1**, wherein the etching includes a first etching and a second etching.

10. The process of claim **2**, wherein the etching includes a first etching and a second etching.

11. The process of claim **3**, wherein the etching includes a first etching and a second etching.

12. The process of claim **4**, wherein the etching includes a first etching and a second etching.

13. The process of claim **5**, wherein the etching includes a first etching and a second etching.

14. The process of claim **6**, wherein the etching includes a first etching and a second etching.

15. The process of claim **7**, wherein the etching includes a first etching and a second etching.

16. The process of claim **8**, wherein the etching includes a first etching and a second etching.

17. A product produced by the process of claim **1**.

18. A product produced by the process of claim **2**.

19. A product produced by the process of claim **3**.

20. A product produced by the process of claim **4**.

21. A product produced by the process of claim **5**.

22. A product produced by the process of claim **6**.

23. A product produced by the process of claim **7**.

24. A product produced by the process of claim **8**.

25. A product produced by the process of claim **9**.

26. A product produced by the process of claim **10**.

27. A product produced by the process of claim **11**.

28. A product produced by the process of claim **12**.

29. A product produced by the process of claim **13**.

30. A product produced by the process of claim **14**.

31. A product produced by the process of claim **15**.

32. A product produced by the process of claim **16**.

33. A process of making an article of manufacture, the process comprising:

implementing a circuit design for an electrical device with circuitry comprising interlocking a conductor part of the circuitry configured to fill cavities in a dielectric material disposed in combination with the circuitry and coupled with the conductor part in a configuration where

the dielectric material comprises a non-uniformly roughened surface comprising said cavities which are located in and underneath an initial surface of the dielectric material that is delivered with solid content, the dielectric material and the solid content being non-homogeneous materials, to bring about formation of the non-uniformly roughened surface by etching of the dielectric material, at least some the cavities having a first cross-sectional distance proximate the initial surface and a greater cross-sectional distance distant from the initial surface.

34. The process of claim **33**, wherein at least about 20% of the teeth are at least 1 tenth of a mil deep.

35. The process of claim **33**, wherein the etching includes a first etching and a second etching.

36. The process of claim **34**, wherein the etching includes a first etching and a second etching.

37. The process of claim **33**, wherein the etching includes etching using potassium permanganate.

38. The process of claim **34**, wherein the etching includes etching using potassium permanganate.

39. The process of claim **35**, wherein the etching includes etching using potassium permanganate.

40. The process of claim **36**, wherein the etching includes etching using potassium permanganate.

41. A product produced by the process of claim **33**.

42. A product produced by the process of claim **34**.

43. A product produced by the process of claim **35**.

44. A product produced by the process of claim **36**.

45. A product produced by the process of claim **37**.

46. A product produced by the process of claim **38**.

47. A product produced by the process of claim **39**.

48. A product produced by the process of claim **40**.

* * * * *

CERTIFICATE OF SERVICE

I certify that today, January 31, 2018, I electronically filed the foregoing Non-Confidential Brief for Plaintiff-Appellant Continental Circuits LLC with the Clerk of the Court for the U.S. Court of Appeals for the Federal Circuit using the appellate CM/ECF system. All participants in the case are registered CM/ECF users and will be served by the appellate CM/ECF system.

January 31, 2018 /s/ Jeffrey A. Lamken

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