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STEVEN F. REIBER and MARY L. REIBER
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8 UNITED STATES DISTRICT COURT
9 EASTERN DISTRICT OF CALIFORNIA
10

11 STEVEN F. REIBER and MARY L. REIBER,
California residents,

12 Plaintiffs,

13 v.

14 TDK CORPORATION, a Japanese corporation,
15 SAE MAGNETICS (H.K.) LTD, Hong Kong
company, HUSKO, INC., a California
16 corporation, HEADWAY TECHNOLOGIES,
INC., a Delaware corporation,

17 Defendants.
18

CASE NO.

**COMPLAINT FOR PATENT
INFRINGEMENT**

(U.S. Patent Nos. 6,354,479 and 6,651,864)

DEMAND FOR JURY TRIAL

19
20 Plaintiffs Steven F. Reiber and Mary L. Reiber (collectively, “Plaintiffs” or the “Reibers”)
21 hereby allege for their Complaint against defendants TDK Corporation, SAE Magnetics (H.K.) Ltd,
22 Husko Inc. and Headway Technologies Inc. (collectively, “Defendants”), as follows.
23

24 **JURISDICTION AND VENUE**

25 1. The United States District Court for the Eastern District of California (the “Court”)
26 has jurisdiction over this matter because it is an action for infringement arising under the United
27 States Patent Act (35 U.S.C. § 1 *et seq.*). Accordingly, the Court has jurisdiction pursuant to 28
28 U.S.C. §§ 1331 and 1338(a).

1 being used in computers and increasingly, in consumer electronics such as digital video recorders,
2 MP3 players, or even mobile phones.” SAE supplies state-of-the-art magnetic recording heads,
3 and their subassemblies including Head Gimbal Assembly (“HGA”) and Head Stack Assembly
4 (“HSA”) to HDD manufacturers in the United States and around the world, and SAE’s
5 comprehensive range of head product families cover disk drive applications from server class
6 drives for corporate environment, to mobile class drives in the ubiquitous notebook computers, and
7 lately micro drives for consumer electronics. SAE operates the offices of defendant Husko, Inc.
8 and defendant Headway Technologies, Inc., both in Milpitas, California.

9 7. Plaintiffs are informed and believe, and thereon allege, that defendant Husko, Inc.
10 (“Husko”) is a corporation formed under the laws of California with its principal place of business
11 at 100 South Milpitas Boulevard, Milpitas, California 95035 and doing business as SAE Magnetics
12 (H.K.) Ltd. Plaintiffs are informed and believe, and thereon allege, that Husko is operated and/or
13 managed by defendant SAE Magnetics (H.K.) Ltd. and is involved in the research, development,
14 sale and marketing of recording heads for HDDs.

15 8. Plaintiffs are informed and believe, and thereon allege, that defendant Headway
16 Technologies, Inc. (“Headway”) is a corporation formed under the laws of Delaware with its
17 principal place of business at 678 South Hillview Drive, Milpitas, California 95035. Plaintiffs are
18 informed and believe, and thereon allege, that Headway is a wholly owned subsidiary of defendant
19 TDK Corporation and is operated and/or managed by defendant SAE Magnetics (H.K.) Ltd.
20 Headway is involved in the design and manufacture of recording heads for HDDs.

21 9. Plaintiffs are informed and believe, and thereon allege, that at all times relevant
22 hereto, each of the defendants was the agent, affiliate or co-conspirator of the other defendants and
23 in committing the acts hereinafter set forth, acted within the scope of such agency, affiliation, or
24 conspiracy and/or ratified or acquiesced in the acts of the other defendants.

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GENERAL ALLEGATIONS

The Patents-in-Suit

10. Plaintiffs have developed – and continue to develop – an intellectual property portfolio related to their bonding machine business, including United States Patent No. 6,354,479 and United States Patent No. 6,651,864 (collectively, the “Patents-in-Suit”).

11. On March 12, 2002, the United States Patent and Trademark Office duly and legally issued United States Patent No. 6,354,479 (the “’479 Patent”), entitled *Dissipative Ceramic Bonding Tip*. A true and accurate copy of the ’479 Patent is attached hereto as Exhibit A. Steven F. Reiber and Mary L. Reiber are the named inventors of, and are the owners of, the ’479 Patent.

12. On November 25, 2003, the United States Patent and Trademark Office duly and legally issued United States Patent No. 6,651,864 (the “’864 Patent”), entitled *Dissipative Ceramic Bonding Tool Tip*. A true and accurate copy of the ’864 patent is attached hereto as Exhibit B. Steven F. Reiber and Mary L. Reiber are the named inventors of, and are the owners of, the ’864 Patent.

13. In general terms, the Patents-in-Suit are directed to dissipative bonding tool tips used to form electrical connections and methods of using such bonding tool tips. The patented bonding tool tips and methods enable bonding of delicate electronic devices while avoiding damage caused by electrostatic discharge. Such damage is avoided because the patented dissipative bonding tool tips conduct electricity at a rate sufficient to prevent electrostatic charge buildup, but are sufficiently resistive as to prevent damage to the device being bonded. The dissipative bonding tool tips claimed by the Patents-in-Suit are used in the manufacture of HDDs, including HDD components such as head gimbal assemblies and head stack assemblies.

14. By virtue of the Patents-in-Suit, the Reibers have the exclusive right to exclude others from making, using, offering to sell, and sell in the United States importing into the United States, using, offering to sell, and selling the articles claimed therein and articles made by the methods claimed therein. The Reibers have not licensed or otherwise authorized any defendant to make, use, offer to sell, sell or import the articles claimed in the Patents-in-Suit and have not

1 licensed or otherwise authorized any defendant to practice the methods claimed in the Patents-in-
2 Suit.

3
4 **SAE's Unlawful Conduct Relating to the Patents-in-Suit**

5 15. The Reibers are informed and believe, and thereon allege, that Defendants, without
6 authority, make, use, offer to sell, and sell in the United States and import into the United States,
7 including within this District, HDD components that infringe the Patents-in-Suit. Plaintiffs are
8 informed and believe, and thereon allege, that these HDD components include, but are not limited
9 to, HGAs and HSAs manufactured using infringing bonding tool tips other than those acquired
10 from CoorsTek, Inc.

11 16. Defendants' unlawful activities have resulted in an unjust enrichment to Defendants
12 and immediate and irreparable harm to the Reibers. If Defendants' unlawful activities are not
13 immediately enjoined, Defendants will continue to be unjustly enriched and will continue to
14 irreparably harm the Reibers. The Reibers have no adequate remedy at law.

15
16 **COUNT I**

17 **(Infringement of United States Patent No. 6,354,479)**

18 17. The Reibers repeat and re-allege each of the allegations set forth in paragraphs 1
19 through 16, as though fully set forth herein.

20 18. The Reibers are the owners of the entire right title and interest in the '479 Patent.

21 19. The Reibers are informed and believe, and thereon allege, that Defendants' actions
22 in making, using, distributing, offering for sale and selling in the United States and importing into
23 the United States HDD components including, but not limited to, head gimbal assemblies and head
24 stack assemblies, infringe the '479 Patent. The Reibers are informed and believe, and thereon
25 allege, that Defendants will continue to infringe the '479 Patent unless enjoined by the Court.

26 20. The Reibers are informed and believe, and thereon allege, that Defendants are
27 actively inducing others to infringe one or more claims of the '479 Patent and/or committing acts of
28 contributory infringement with respect to one or more claims of the '479 Patent through

1 Defendants' activities related to making, using, distributing, offering for sale and selling in the
2 United States and importing into the United States HDD components including, but not limited to
3 head gimbal assemblies and head stack assemblies, in violation of 35 U.S.C. § 271(b) and 35
4 U.S.C. § 271(c), respectively.

5 21. The Reibers have been damaged by Defendants' infringing conduct. Defendants are
6 therefore liable to the Reibers for actual damages suffered and any profits realized on the sale of the
7 HDD components including, but not limited to, head gimbal assemblies and head stack assemblies,
8 which are not taken into account in the computation of actual damages, as well as any statutory
9 damages, such as treble damages. Moreover, such conduct is likely to cause substantial harm to the
10 Reibers unless the Court enjoins the infringing conduct.

11 WHEREFORE, the Reibers pray for relief as set forth herein.

12
13 **COUNT II**

14 **(Infringement of United States Patent No. 6,651,864)**

15 22. The Reibers repeat and re-allege each of the allegations set forth in paragraphs 1
16 through 21, as though fully set forth herein.

17 23. The Reibers are the owners of the entire right title and interest in the '864 Patent.

18 24. The Reibers are informed and believe, and thereon allege, that Defendants' actions
19 in making, using, distributing, offering for sale and selling in the United States and importing into
20 the United States HDD components including, but not limited to, head gimbal assemblies and head
21 stack assemblies, infringe the '864 Patent. The Reibers are informed and believe, and thereon
22 allege, that Defendants will continue to infringe the '864 Patent unless enjoined by the Court.

23 25. The Reibers are informed and believe, and thereon allege, that Defendants are
24 actively inducing others to infringe one or more claims of the '864 Patent and/or committing acts of
25 contributory infringement with respect to one or more claims of the '864 Patent through
26 Defendants' activities related to making, using, distributing, offering for sale and selling in the
27 United States and importing into the United States HDD components including, but not limited to
28

1 head gimbal assemblies and head stack assemblies, in violation of 35 U.S.C. § 271(b) and 35
2 U.S.C. § 271(c), respectively.

3 26. The Reibers have been damaged by Defendants' infringing conduct. Defendants are
4 therefore liable to the Reibers for actual damages suffered and any profits realized on the sale of the
5 HDD components including, but not limited to, head gimbal assemblies and head stack assemblies,
6 which are not taken into account in the computation of actual damages, as well as any statutory
7 damages, such as treble damages. Moreover, such conduct is likely to cause substantial harm to the
8 Reibers unless the Court enjoins the infringing conduct.

9 WHEREFORE, the Reibers pray for relief as set forth herein.

10
11 **PRAYER FOR RELIEF**

12 WHEREFORE, the Reibers request entry of judgment in their favor and against Defendants
13 as follows:

14 A. On Counts I-II, declaring that the Patents-in-Suit are valid and enforceable;

15 B. On Counts I-II, declaring that the Defendants have infringed one or more claims of
16 the Patents-in-Suit;

17 C. On Counts I-II, preliminarily and/or permanently enjoining Defendants and their
18 officers, agents, servants, employees, and attorneys, and all persons acting in active concert or
19 participation with them, from further infringing, contributing to, and/or inducing the infringement
20 of the Patents-in-Suit, in accordance with 35 U.S.C. § 283;

21 D. On Counts I-II, awarding the Reibers a reasonable royalty in an amount adequate to
22 compensate the Reibers for Defendants' infringement, in accordance with 35 U.S.C. § 154;

23 E. On Counts I-II, awarding the Reibers damages in an amount adequate to compensate
24 the Reibers for Defendants' infringement, in accordance with 35 U.S.C. § 284;

25 F. On all counts, for actual damages according to proof;

26 G. On all counts, for interest on all the foregoing amounts, at the legal rate, with effect
27 from the due date for payment;

28

1 H. On all counts, awarding the Reibers their costs of suit, including reasonable
2 attorneys' fees; and

3 I. On all counts, granting such other and further relief as this Court may deem just and
4 appropriate.


5

6 Dated: April 19, 2011

CARR & FERRELL *LLP*

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By: 
ROBERT J. YORIO
CHRISTOPHER P. GREWE
Attorneys for Plaintiffs
STEVEN F. REIBER and MARY L. REIBER

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DEMAND FOR JURY TRIAL

Plaintiffs Steven F. Reiber and Mary L. Reiber hereby demand a jury trial of all issues in the above-captioned action that are triable to a jury.

Dated: April 19, 2011

CARR & FERRELL *LLP*

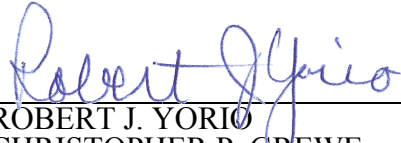
By: 
ROBERT J. YORIO
CHRISTOPHER P. GREWE
Attorneys for Plaintiffs
STEVEN F. REIBER and MARY L. REIBER

EXHIBIT A

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

(10) **Patent No.:** **US 6,354,479 B1**
 (45) **Date of Patent:** **Mar. 12, 2002**

- (54) **DISSIPATIVE CERAMIC BONDING TIP**
- (75) Inventors: **Steven Frederick Reiber**, Sunnyvale;
Mary Louise Reiber, Los Altos, both
 of CA (US)
- (73) Assignee: **SJM Technologies**, Mountain View, CA
 (US)
- (*) Notice: Subject to any disclaimer, the term of this
 patent is extended or adjusted under 35
 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/514,454**
 (22) Filed: **Feb. 25, 2000**

Related U.S. Application Data

- (60) Provisional application No. 60/121,694, filed on Feb. 25,
 1999.
- (51) **Int. Cl.**⁷ **B23K 37/00**; B23K 1/00;
 B23K 5/00
- (52) **U.S. Cl.** **228/4.5**; 228/180.5; 228/6.1;
 228/6.2; 219/56.21
- (58) **Field of Search** 228/4.5, 180.5,
 228/6.1, 6.2; 219/56.21

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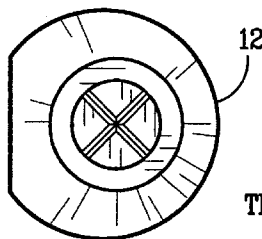
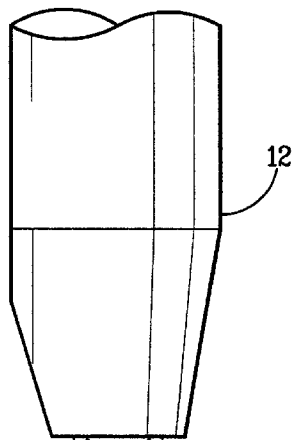
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Primary Examiner—Tom Dunn
Assistant Examiner—L. Edmondson
 (74) *Attorney, Agent, or Firm*—Carr & Ferrell LLP; John S. Ferrell; Davis Lewis

(57) **ABSTRACT**

Dissipative ceramic bonding tips for wire bonding electrical connections to bonding pads on integrated circuits chips and packages are disclosed. In accordance with the principles of the present invention, to avoid damaging delicate electronic devices by any electrostatic discharge, an ultrasonic bonding wedge tool tip must conduct electricity at a rate sufficient to prevent charge buildup, but not at so high a rate as to overload the device being bonded. For best results, a resistance in the tip assembly itself should range from 10⁵ to 10¹² ohms. In addition, the wedges must also have specific mechanical properties to function satisfactorily.

51 Claims, 4 Drawing Sheets



TIP DETAIL

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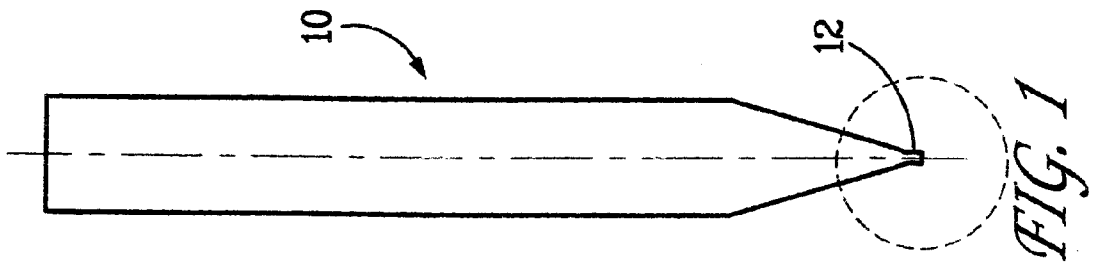
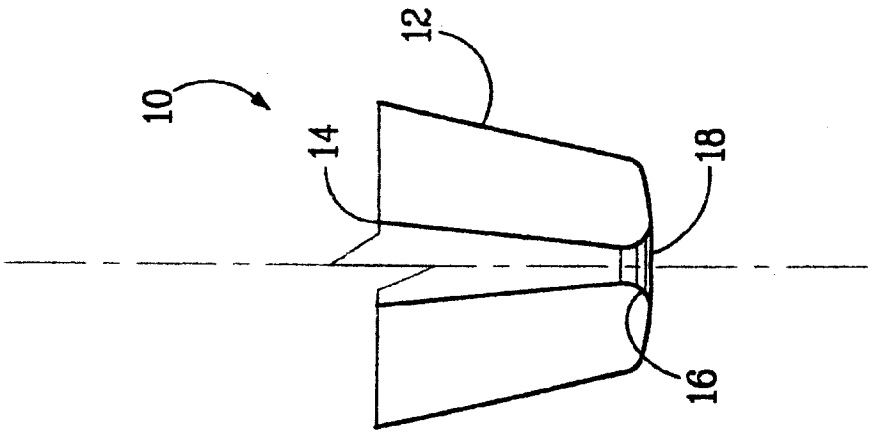
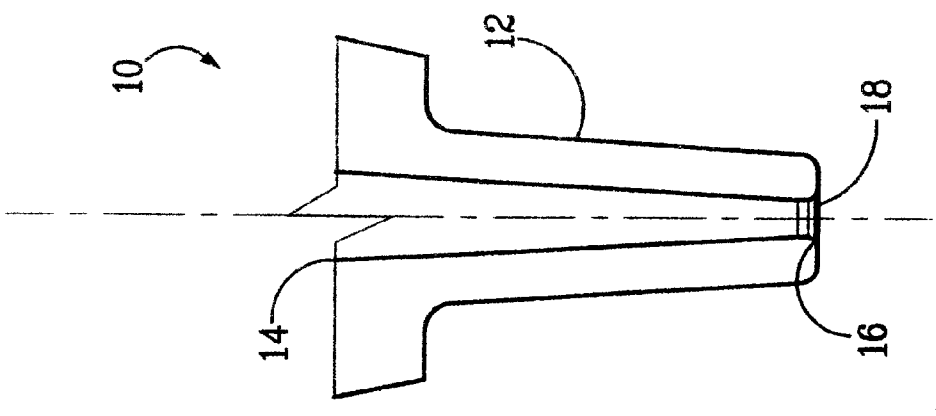


FIG. 1



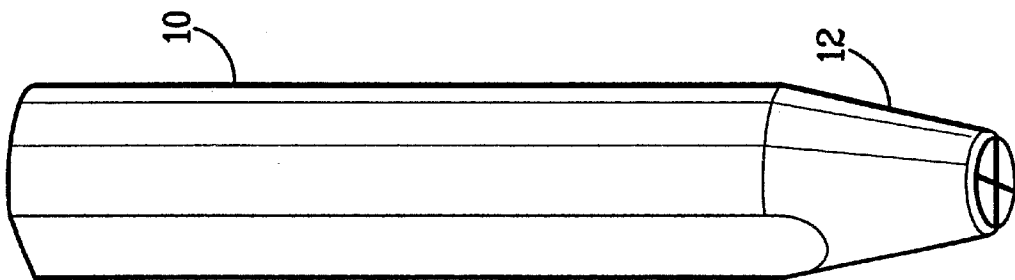
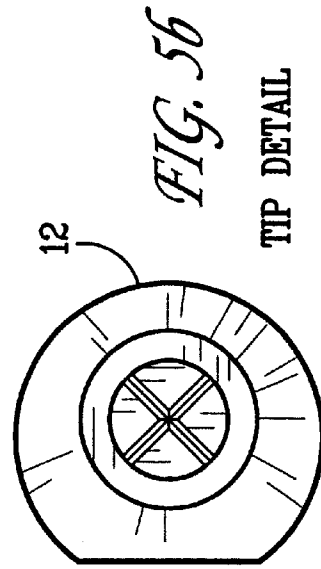
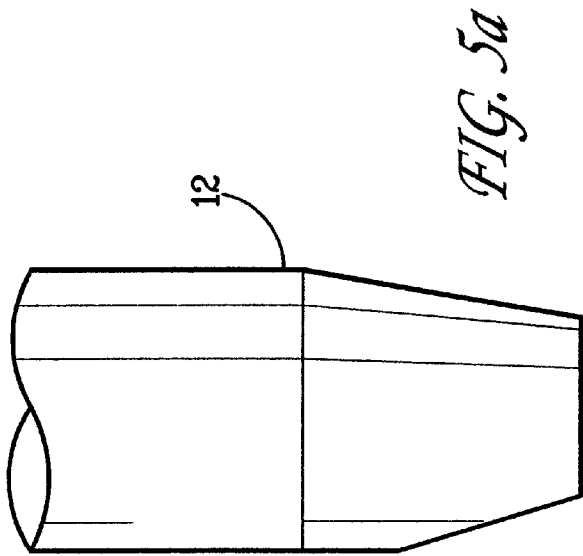
NORMAL CAPILLARY

FIG. 2



BOTTLE-NECK CAPILLARY

FIG. 3



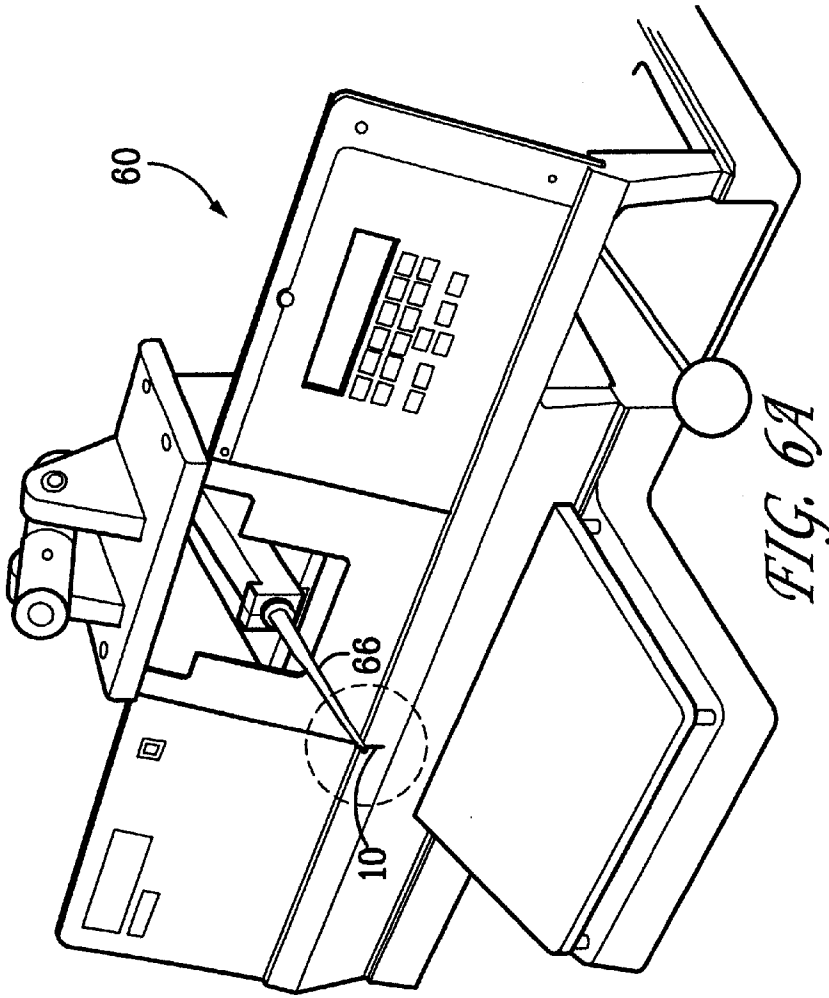
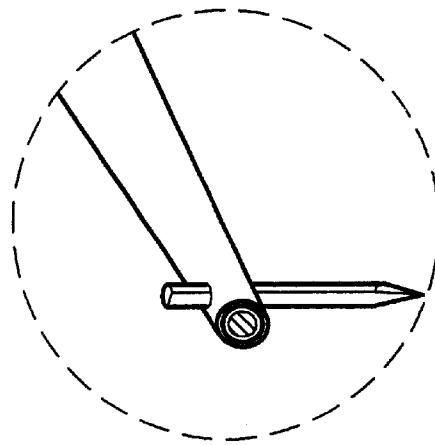
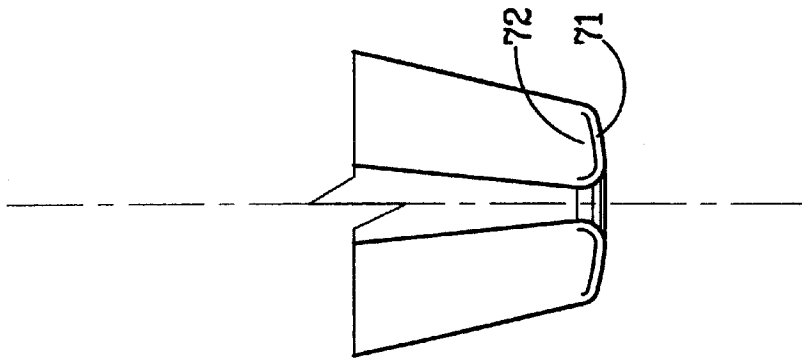


FIG. 6A



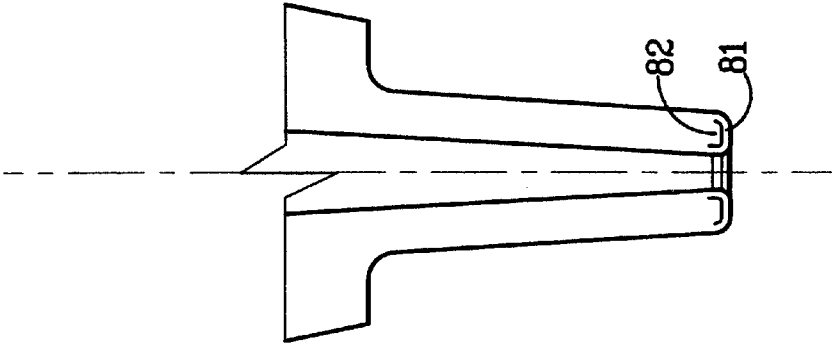
Transducer Horn Tip and Wedge Detail

FIG. 6B



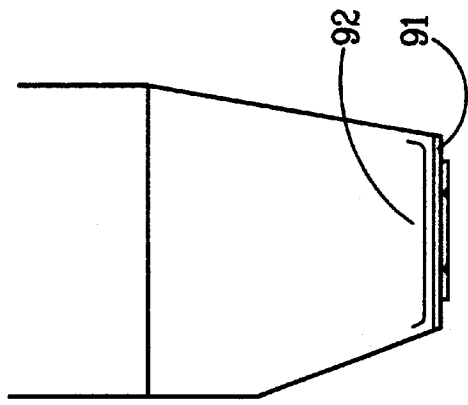
NORMAL CAPILLARY

FIG. 7



BOTTLE-NECK CAPILLARY

FIG. 8



TIP DETAIL

FIG. 9

US 6,354,479 B1

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DISSIPATIVE CERAMIC BONDING TIP**CROSS REFERENCE TO RELATED APPLICATIONS**

This application claims benefits of Provisional Application Ser. No. 60/121,694, filed Feb. 25, 1999, entitled Dissipative Ceramic Bonding Tip.

BACKGROUND OF THE INVENTION**Field of the Invention**

This invention relates to bonding tool tips and more particularly to dissipative ceramic bonding tips for bonding electrical connections.

Description of the Prior Art

Integrated circuits are typically attached to a lead frame, and individual leads are connected to individual bond pads on the integrated circuit with wire. The wire is fed through a tubular bonding tool tip having a bonding pad at the output end. These tips are called capillary tips. An electrical discharge at the bonding tool tip supplied by a separate EFO (electronic flame off) device melts a bit of the wire, forming a bonding ball. Other bonding tools do not have the center tube, but have a feed hole or other feature for feeding the wire along, as needed. Some bonding tips have no such wire arrangement, as the wire is supplied, as in magnetic disk recording devices, where the wire is insulated and bonded to a magnetic head and then to a flexible wire circuit.

When the bonding tip is on the integrated circuit die side of the wire connection, the wire will have a ball formed on the end of the wire, as above, before reaching the next die bonding pad. The ball then makes intimate contact with the film formed on the die pad on the integrated circuit. The bonding tip is then moved from the integrated circuit die pad, with gold wire being fed out as the tool is moved, onto the bond pad on the lead frame, and then scrubbed laterally by an ultrasonic transducer. Pressure from the bonding tool tip and the transducer, and capillary action, 'flows' the wire onto the bonding pad where molecular bonds produce a reliable electrical and mechanical connection.

Bonding tool tips must be sufficiently hard to prevent deformation under pressure, and mechanically durable so that many bonds can be made before replacement. Prior art bonding tool tips were made of aluminum oxide, which is an insulator, but provides the wearability to form thousands of bonding connections. Bonding tool tips must also be electrically designed to produce a reliable electrical contact, yet prevent electrostatic discharge damage to the part being bonded. Certain prior art devices have a one or more volt emission when the tip makes bonding contact. This could present a problem, as a one volt static discharge could generate a 20 milliamp current to flow, which, in certain instances, could cause the integrated circuit to fail due to this unwanted current.

U.S. Pat. No. 5,816,472 to Linn describes a durable alumina bonding tool "without electrically conductive metallic binders." U.S. Pat. No. 5,616,257 to Harada describes covering the bonding tool electrode with an insulating cap or covering "made of a ceramic material" to produce a large electrostatic discharge that creates bonding balls of stable diameter. U.S. Pat. No. 5,280,979 to Poli describes a vacuum wafer-handling tool having a ceramic coating "made with a controlled conductivity" to prevent a large electrostatic discharge.

SUMMARY OF THE INVENTION

Electrically, dissipative ceramic bonding tips for bonding electrical connections to bonding pads on electrical devices

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are disclosed. In accordance with the principles of the present invention, to avoid damaging delicate electronic devices by any electrostatic discharge, a bonding tool tip must conduct electricity at a rate sufficient to prevent charge buildup, but not at so high a rate as to overload the device being bonded. In other words, it is desirable for the bonding tip to discharge slowly. The tip needs to discharge to avoid a sudden surge of current that could damage the part being bonded. For best results, a resistance in the tip assembly itself should range from 10^5 to 10^{12} ohms. The tools must also have specific mechanical properties to function satisfactorily. The high stiffness and high abrasion resistance requirements have limited the possible material to ceramics (electrical non-conductors) or metals, such as tungsten carbide (electrical conductor).

In the present invention, bonding tool tips with the desired electrical conduction can be made with three different configurations.

First, the tools can be made from a uniform extrinsic semiconducting material which has dopant atoms in the appropriate concentration and valence states to produce sufficient mobile charge carrier densities (unbound electrons or holes) which will result in electrical conduction in the desired range. For example, polycrystalline silicon carbide uniformly doped with boron.

Second, the tools can be made by forming a thin layer of a highly doped semiconductor on an insulating core. In this case the core provides the mechanical stiffness and the semiconductor surface layer provides abrasion resistance and provides a charge carrier path from the tip to mount which will permit dissipation of electrostatic charge at an acceptable rate. For example, a diamond tip wedge that is ion implanted with boron.

Third, the tools can be made by forming a lightly doped semiconductor layer on a conducting core. The conducting core provides the mechanical stiffness and the semiconductor layer provides abrasion resistance and provides a charge carrier path from the tip to conducting core, which is electrically connected to the mount. The doping level is chosen to produce conductivity through the layer which will permit dissipation of electrostatic charge at an acceptable rate. For example, cobalt bonded tungsten carbide coated with titanium nitride carbide.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view vastly enlarged of a capillary bonding tool tip;

FIG. 2 is a cross-sectional view, vastly enlarged, of a capillary-type construction of the operating end or tip of a bonding tool;

FIG. 3 is a cross-sectional view of a bottle-neck capillary bonding tool tip;

FIG. 4 is an isometric view of a wedge bonding tool tip;

FIGS. 5a and 5b are top and front views, respectively, of the wedge design bonding tool tip as shown in conjunction with FIG. 4; and

FIG. 6 is an isometric view of a typical commercial apparatus utilized in the wire bonding of a semiconductor integrated circuit chip or other apparatus.

FIG. 7 a cross section of embodiments of FIG. 2 having two layers.

FIG. 8 a cross section of embodiments of FIG. 3 having two layers.

FIG. 9 a cross section of embodiments of FIG. 5 having two layers.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a typical capillary bonding tool **10**. Such bonding tools are usually about one-half inch (12–13 mm) long and about one-sixteenth inch (1.6 mm) in diameter. The bonding tool tip **12** itself is usually from 3 to 10 mils (0.08 to 0.25 mm) long. Running the length of the tool itself, but not viewable in FIG. 1, is a tube hole which would accommodate a continuous fed length of gold wire (not shown).

FIG. 2 is a highly enlarged, cross-sectional view of the capillary bonding tool **10** as shown and described in FIG. 1. Only that portion of the bonding tool **10** shown within the dotted circle in FIG. 1 is shown in FIG. 2. Tool tip **12** has the hole tube **14** which may run the entire length of bonding tool **10**. The exit hole **18** is where the wire (not shown) would exit the tool tip **12**. If a ball is formed on the wire, the ball would be seen immediately adjacent the exit hole **18**. The chamfer **16** at the exit hole **18** is there for at least two reasons. First, to accommodate a ball that has been formed at the end of the gold wire. Also, the chamfer surface **16** is provided to allow for smoother looping of the wire as the bonding tool **10** is moved from the bonding pad on an integrated circuit to the bonding pad (not shown) on a lead frame of an integrated circuit assembly. The wedge tool for disk drive bonding is used to capture the insulated wire, lay it on the head and ultrasonically bond it there.

FIG. 3 is an alternative embodiment of a bonding tool **10** showing similar features, as the hole tube **14**, chamfer surface **16**, and exit hole **18**. This bonding tool tip, named a bottle-neck capillary tip, is provided for narrower bond situations where the bonding pitch (distance between the centers of the bonding pads) is smaller and smaller as the dimensions of an integrated circuit get smaller, or the number of circuits on a chip get larger, but the die area remains more or less constant.

FIG. 4 shows still another type of bonding tool **10**. This bonding tool is typically used with an integrated circuit die mounted on a lead frame (not shown). This is the case where the wires from the integrated circuit are not connected from the die to connections directly in an integrated circuit package, but from the integrated circuit die to a lead frame, which technology is well known to skilled practitioners in the art. The composition of the lead frame being different than the composition of an integrated circuit package, the tip **12** of the bonding tool **10** must be different to accommodate the different physical attributes of the integrated circuit lead frame, as seen in FIGS. 5 *a* and 5*b*.

FIG. 6*a* illustrates a typical wire bonding machine **60** for use in bonding wire leads in magnetic disk drive units. Shown within the dotted circle is the bonding tool **10**. The bonding tool **10** is mounted to arm **66** which is moved in the desired directions by the apparatus of wire bonding machine **60**. Such a machine is available as Model 7400 from the West Bond Company in Anaheim, Calif.

Typical bonding tips available on the market today are made of an insulator of alumina (Al_2O_3), sometimes termed aluminum oxide. This is a very hard compound which has been used on commercial machines with success as it provides a reasonably long life in use as a wire bonding tool. To insure that it is an insulator no conductive binders are used in these bonding tips. However, as stated previously, the problem has existed that an electrostatic discharge from the bonding tool making contact with the bonding pad of the desired circuit can damage the very circuit it is wiring up.

However, in accordance with the principles of the present invention, to avoid damaging delicate electronic devices by

this electrostatic discharge, a bonding tool tip must conduct electricity at a rate sufficient to prevent charge buildup, but not at so high a rate as to overload the device being bonded. It has been determined that the tool must have electrical conduction greater than one ten-billionth of a mho (i.e. $>1 \times 10$ raised to the minus 12th power reciprocal ohms) but its electrical conductivity must be less than one one-hundred thousandth of a mho (i.e. $<1 \times 10$ raised to the minus fifth power reciprocal ohms). The resistance should be low enough so that the material is not an insulator, not allowing for any dissipation of charge and high enough so that it is not a conductor, allowing a current flow. For best results, a resistance in the tip assembly itself should range from 10^5 – 10^{12} ohms. For example, for today's magnetic recording heads 5 milliamps of current will damage them. Preferably, for today's magnetic recording heads, no more than 2 to 3 milliamps of current should be allowed to pass through the tip to the head.

The tools must also have specific mechanical properties to function satisfactorily. The high stiffness and high abrasion resistance requirements have limited the possible material to ceramics (electrical non-conductors) or metal, such as tungsten carbide (electrical conductor). The tip should have a Rockwell hardness of about 25 or above, preferably of about 32 or above. The tip needs to be able to last for at least two bondings.

In the present invention, bonding tool tips with the desired electrical conduction can be made with three different configurations.

First, the tools can be made from a uniform extrinsic semiconducting material which has dopant atoms in the appropriate concentration and valence states to produce sufficient mobile charge carrier densities (unbound electrons or holes) which will result in electrical conduction in the desired range. For example, polycrystalline silicon carbide uniformly doped with boron.

Second, the tools can be made by forming a thin layer of a highly doped semiconductor on an insulating core. In this case the core provides the mechanical stiffness and the semiconductor surface layer provides abrasion resistance and provides a charge carrier path from the tip to the mount, which will permit dissipation of electrostatic charge at an acceptable rate. For example, a diamond tip wedge that has a surface that is ion implanted with boron or a doped ceramic.

Third, the tools can be made by forming a lightly doped semiconductor layer on a conducting core. The conducting core provides the mechanical stiffness and the semiconductor layer provides abrasion resistance and provides a charge carrier path from the tip to conducting core, which is electrically connected to the mount. The doping level is chosen to produce conductivity through the layer which will permit dissipation of electrostatic charge at an acceptable rate. For example, cobalt bonded tungsten carbide coated with titanium nitride carbide.

FIGS. 7, 8 and 9 illustrate the two-layered structure of the last two configurations. This structure is not intended to be specific to the type of tool tip. Rather, it could be used for any bonding tool tip. In the second and third configurations, the outer layers are labeled **71**, **81** and **91** and the cores are labeled **72**, **82** and **92**. In the second configuration, mentioned above, layers **71**, **81** and **91** are highly doped semiconductor and the cores **72**, **82** and **92** are insulators. In the third configuration, mentioned above, layers **71**, **81** and **91** are lightly doped semiconductor and the cores **72**, **82** and **92** are conductors. No significance should be attached to the

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relative thickness or scale of the portions of the layer 71. Layer 71 may or may not have a uniform thickness.

Dissipative tools can be manufactured by any of the following methods.

1. Mixing, molding and sintering reactive powders. Fine particles of the desired composition are mixed with organic and inorganic solvents, dispersants, binders, and sintering aids are then molded into oversize wedges. The pieces are carefully dried, and heated slowly to remove the binders and dispersants and then heated to a high enough temperature so that the individual particles sinter together into a solid structure with low porosity. The heat-treating atmosphere is chosen to facilitate the removal of the binder at a low temperature and to control the valence of the dopant atoms at the higher temperature and while cooling. After cooling, the pieces may be machined to achieve the required tolerances. The pieces may then be treated to produce the desired surface layer by ion implementation, vapor deposition, chemical vapor deposition, physical deposition, electro-plating deposition, neutron bombardment, or combinations of the above. The pieces may be subsequently heat treated in a controlled atmosphere to produce the desired layer properties through diffusion, recrystallization, dopant activation, or valence changes of metallic ions.
2. Hot pressing reactive powders. Fine particles of the desired composition are mixed with binders and sintering aids and then pressed in a mold at a high enough temperature to cause consolidation and binding of the individual particles into a solid structure with low porosity. The hot pressing atmosphere is chosen to control the valence of the dopant atoms. After cooling and removal from the hot press, the pieces may be machined to achieve the required tolerances. The pieces may then be treated to produce the desired surface layer by ion implantation, vapor deposition, chemical vapor deposition, physical deposition, electro-plating deposition, neutron bombardment or combinations of the above. The pieces may subsequently be heat treated in a controlled atmosphere to produce the desired layer properties through diffusion, recrystallization, dopant activation, or valence changes of metallic ions.
3. Fusion casting. Metals of the desired composition are melted in a non-reactive crucible then cast into an ingot. The ingot is then rolled, extruded, drawn, pressed, heat treated in a suitable atmosphere and chemically treated. The pieces are then machined to achieve the required tolerances. The metallic pieces are then heat treated to produce the desired surface layer by vapor deposition, chemical vapor deposition, physical deposition, electroplating deposition, or combinations of the above. The pieces may be subsequently heat treated in a controlled atmosphere to produce the desired layer properties through diffusion, recrystallization, dopant activation, or valence changes of metallic ions.

The invention further includes that the layer used in the bonding process could be the following composition of matter. More specifically, a formula for dissipated ceramic comprising alumina (aluminum oxide Al_2O_3) and zirconia (zirconium oxide ZrO_2) and other elements. This mixture is both somewhat electrically conductive and mechanically durable. The tip of a bonding tool will be coated with this material or it could be made completely out of this material. The shape of the tip may be wedge or circular shaped as shown and described in the earlier FIGS. 1 to 5.

One actual sample was constructed with the following elements:

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ELEMENT

Iron
Oxygen
Sodium
Carbon
Zirconium
Silicon
Aluminum
Yttrium

While the range of alumina could extend from 15% to 85% and the range of zirconia from 15% to 85%, another sample included alumina at 40% and zirconia at 60%.

The bonding tip of the present invention could be used for any number of different types of bonding. Two examples are ultrasonic and thermal bonding.

While the invention has been described with reference to specific embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the true spirit and scope of the invention. In addition, modifications may be made without departing from the essential teachings of the invention.

What is claimed is:

1. A tip having a dissipative material for use in wire bonding machines for connecting leads on integrated circuit bonding pads, wherein said dissipative material has a resistance low enough to prevent a discharge of charge to a device being bonded and high enough to avoid current flow large enough to damage said device being bonded.

2. A tip as in claim 1, having a resistance in the range of 10^5 to 10^{12} ohms.

3. A tip as in claim 1, having a high enough stiffness to resist bending when hot and a high enough abrasiveness so as to function for at least two uses.

4. A tip as in claim 1, wherein said material is an extrinsic semiconducting material which has dopant atoms in the appropriate concentration and valence states to produce said resistance.

5. A tip as in claim 4 wherein said material comprises a polycrystalline silicon carbide uniformly doped with boron.

6. A tip as in claim 1 wherein said dissipative material comprises a doped semiconductor formed on an insulating core.

7. A tip as in claim 6, wherein said insulating core is diamond and said doped semiconductor is an outer surface of said diamond that is ion implanted with boron.

8. A tip as in claim 1 wherein said material is a doped semiconductor formed on a conducting core.

9. A tip having

a dissipative material for use in wire bonding machines for connecting leads on integrated circuit bonding pads, wherein

said dissipative material is a doped semiconductor which is titanium nitride carbide, has a resistance low enough to prevent a discharge of charge to a device being bonded and high enough to avoid current flow large enough to damage said device being bonded, and is formed on a conducting core of cobalt bonded tungsten carbide.

10. A dissipative ceramic for use in capillary wedge-type wire bonding machines for connecting leads on integrated circuit bonding pads, wherein said dissipative ceramic is electrically dissipative.

11. The dissipative ceramic of claim 10, wherein said electrically dissipative ceramic comprises alumina (Al_2O_3).

12. The dissipative ceramic of claim 10, comprising zirconia (ZrO_2).

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13. The dissipative ceramic of claim 10, comprising alumina (Al_2O_3) and zirconia (ZrO_2).

14. The dissipative ceramic of claim 13, wherein the range of alumina is from 15% to 85% and the range of zirconia is from 15% to 85%.

15. The dissipative ceramic of claim 13, having 40 percent alumina and 60 percent zirconia with other additives.

16. A dissipative ceramic comprising aluminum oxide (Al_2O_3) zirconium oxide (ZrO_2).

17. The dissipative ceramic of claim 16, wherein the range aluminum oxide is from 15% to 85% and the range of zirconium oxide is from 15% to 85%.

18. The dissipative ceramic of claim 16, having of about 40 percent aluminum oxide and about 60 percent zirconium with other additives.

19. A method of manufacturing a dissipative bonding tip comprising:

forming a dissipative material as a bonding tip that has a resistance low enough to prevent a discharge of charge to a device being bonded and high enough to avoid current flow large enough to damage said device being bonded.

20. The method of claim 19 wherein the step of forming includes mixing, molding and sintering reactive powders.

21. The method of claim 19 wherein the step of forming includes hot pressing reactive powders.

22. The method of claim 19 wherein the step of forming includes fusion casting.

23. The method of claim 19, wherein said dissipative material has a resistance in the range of 10^5 to 10^{12} ohms.

24. The method of claim 19, wherein said dissipative material has a high enough stiffness to resist bending when hot, and has a high enough abrasiveness to function for at least two uses.

25. The method of claim 19, wherein said dissipative material is an extrinsic semiconducting material which has dopant atoms in the appropriate concentration and valence states to produce said resistance.

26. The method of claim 19, wherein said dissipative material comprises a polycrystalline silicon carbide uniformly doped with boron.

27. The method of claim 19, wherein said dissipative material comprises a doped semiconductor, and said step of forming includes forming said doped semiconductor on an insulating core.

28. The method of claim 27, wherein said insulating core is diamond and said doped semiconductor is an outer surface of said diamond that is ion implanted with boron.

29. The method of claim 19, wherein said dissipative material comprises a doped semiconductor, and said step of forming includes forming said doped semiconductor on a conducting core.

30. A method of manufacturing a dissipative bonding tip comprising:

forming a dissipative material having at least a doped semiconductor that is titanium nitride carbide, as a bonding tip that has a resistance low enough to prevent a discharge of charge to a device being bonded and high enough to avoid current flow large enough to damage said device being bonded,

wherein said step of forming includes forming said doped semiconductor on a conducting core of cobalt bonded tungsten carbide.

31. The method of claim 19 wherein the step of forming comprises:

mixing fine particles of a composition appropriate for forming said dissipative material with a solvent, a dispersant, a binder, and a sintering aid to form a mixture;

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molding the mixture into at least one wedge;

drying the at least one wedge;

providing a heat-treating atmosphere that facilitates removal of the binder at a low temperature and that controls the valence of the dopant atoms;

heating the at least one wedge at a temperature appropriate to remove the binder and the dispersant;

heating the at least one wedge to a high enough temperature to sinter the particles together into a solid structure having low porosity; and

cooling the solid structure.

32. The method of claim 19 wherein the step of forming comprises:

forming a solid structure; and

machining the solid structure to achieve a required size and shape within a required tolerance.

33. The method of claim 19 wherein the step of forming comprises:

forming a solid structure; and

treating the solid structure by ion implantation, vapor deposition, chemical vapor deposition, physical deposition, electro-plating deposition, or neutron bombardment to produce a surface layer.

34. The method of claim 33 wherein the step of forming further comprises:

producing the desired layer properties within said surface layer by heating the solid structure in a controlled atmosphere to induce diffusion, recrystallization, dopant activation, or valence changes of metallic ions.

35. The method of claim 19 wherein the step of forming comprises:

mixing fine particles of a composition appropriate for forming said dissipative material with binders and sintering aids into a mixture;

choosing a hot pressing atmosphere to control a valence of dopant atoms;

pressing the mixture in a mold at a temperature high enough to cause consolidation and binding of the particles into a solid structure having low porosity; and cooling and removing the solid structure from the mold.

36. The method of claim 19 wherein the step of forming comprises:

melting metals of a composition appropriate for forming said dissipative material in a non-reactive crucible;

casting the melted metals into an ingot;

rolling the ingot into a rolled ingot;

extruding the rolled ingot into an extruded material;

drawing the extruded material into a drawn material;

pressing the drawn material in a pressed material; and

heating the pressed material.

37. A method of using a bonding tip, comprising:

bonding a device using a bonding tip made with a dissipative material that has a resistance low enough to prevent a discharge of charge to said device and high enough to avoid current flow large enough to damage said device.

38. The method of claim 37, wherein said dissipative material has a resistance in the range of 10^5 to 10^{12} ohms.

39. The method of claim 37, wherein said dissipative material has a high enough stiffness to resist bending when hot and has a high enough abrasiveness to function for at least two uses.

40. The method of claim 37, wherein said dissipative material is an extrinsic semiconducting material which has

dopant atoms in appropriate concentration and valence states to produce said resistance.

41. The method of claim 37 wherein said dissipative material comprises a polycrystalline silicon carbide uniformly doped with boron.

42. The method of claim 37, wherein said dissipative material comprises a doped semiconductor formed on an insulating core.

43. The method of claim 42, wherein said insulating core is diamond and said doped semiconductor is an outer surface of said diamond that is ion implanted with boron.

44. The method of claim 37 wherein said dissipative material is a doped semiconductor formed on a conducting core.

45. A method of using a bonding tip, comprising:

bonding a device using a bonding tip made with a dissipative material that is a doped semiconductor of titanium nitride carbide and has a resistance low enough to prevent a discharge of charge to said device and high enough to avoid current flow large enough to damage said device, wherein said dissipative material is formed on a conducting core of cobalt bonded tungsten carbide.

46. A device comprising:

a bonding tip having a dissipative material that is positioned to come in contact with a device being bonded during bonding, in which a current is allowed to flow that is produced by static charge generated during bonding, and that has a resistance low enough to prevent a discharge of charge to a device being bonded and high enough so that the current flow is not large enough to damage said device being bonded.

47. The device of claim 46 wherein the current flow allowed is no more than 3 milliamps.

48. A method of manufacturing a dissipative bonding tip comprising:

forming a bonding tip having a dissipative material that is positioned to come in contact with a device being bonded during bonding,

in which a current is allowed to flow that is produced by static charge generated during bonding, and

that has a resistance low enough to prevent a discharge of charge to a device being bonded and high enough so that the current flow is not large enough to damage said device being bonded.

49. The method of claim 46 wherein the current flow allowed is no more than 3 milliamps.

50. A method of bonding using a dissipative bonding tip comprising:

providing a bonding tip having a dissipative material that has a resistance low enough to prevent a discharge of charge to a device being bonded and high enough so that the current flow is not large enough to damage a device being bonded,

positioning the bonding tip so that the dissipative material electrically couples with the device being bonded during bonding,

forming a bond on the device being bonded, and allowing a current flow that is produced by static charge generated by the bonding.

51. The method of claim 46 wherein the current flow allowed is no more than 3 milliamps.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,354,479 B1
DATED : March 12, 2002
INVENTOR(S) : Steven Frederick Reiber and Mary Louise Reiber

Page 1 of 1

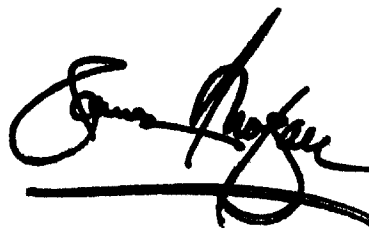
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page.

Delete [73] Assignee: **SJM Technologies**, Mountain View, CA (US).”

Signed and Sealed this

Twenty-seventh Day of May, 2003

A handwritten signature in black ink, appearing to read "James E. Rogan", written over a horizontal line.

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

EXHIBIT B

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

(10) **Patent No.:** **US 6,651,864 B2**
 (45) **Date of Patent:** **Nov. 25, 2003**

(54) **DISSIPATIVE CERAMIC BONDING TOOL TIP**

(76) Inventors: **Steven Frederick Reiber**, 4409 Vivien Way, Rocklin, CA (US) 95677; **Mary Louise Reiber**, 867 Mossy Ridge, Linclon, CA (US) 95648

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/036,579**

(22) Filed: **Dec. 31, 2001**

(65) **Prior Publication Data**

US 2002/0096551 A1 Jul. 25, 2002

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/514,454, filed on Feb. 25, 2000, now Pat. No. 6,354,479.

(60) Provisional application No. 60/288,203, filed on May 1, 2001, and provisional application No. 60/121,694, filed on Feb. 25, 1999.

(51) **Int. Cl.**⁷ **B23K 37/00**; B23K 31/00; B23K 1/00; B23K 5/00

(52) **U.S. Cl.** **228/4.5**; 228/180.5; 228/6.1; 228/6.2; 219/56.4; 219/56.22

(58) **Field of Search** 228/4.5, 180.5, 228/6.1, 6.2; 219/56.21, 56.22

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Primary Examiner—Tom Dunn

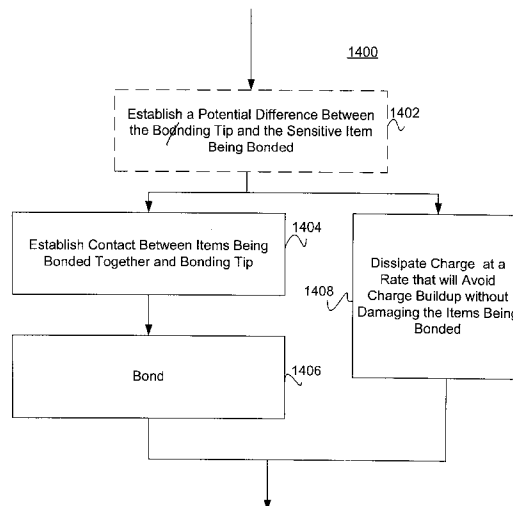
Assistant Examiner—Lynne Edmondson

(74) *Attorney, Agent, or Firm*—Carr & Ferrell LLP

(57) **ABSTRACT**

Methods for making and using dissipative ceramic bonding tool tips for wire bonding electrical connections to bonding pads on integrated circuit chips and packages. The method of using the dissipative ceramic bonding tool tip includes dissipating charge while bonding to avoid damaging delicate electronic devices by a sudden surge of accumulated charge. The method of making the tool tip includes affecting its conductivity so that it conducts electricity at a rate sufficient to prevent charge buildup, but not sufficient to overload the device being bonded. For best results, a resistance in the tip assembly itself should range from 5×10^4 or 10^5 to 10^{12} ohms. In addition, the tips must also have specific mechanical properties to function satisfactorily.

78 Claims, 15 Drawing Sheets



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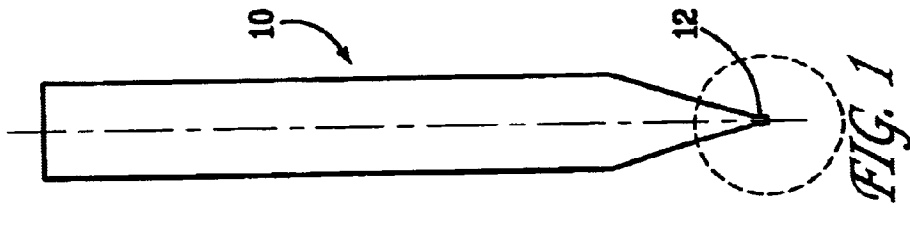
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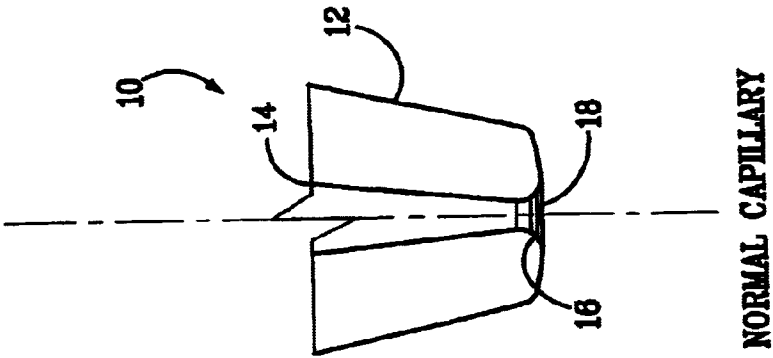
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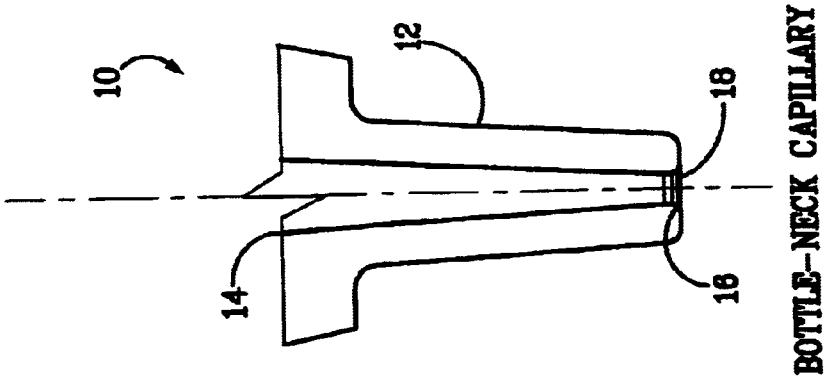
PRIOR ART



NORMAL CAPILLARY

FIG. 2

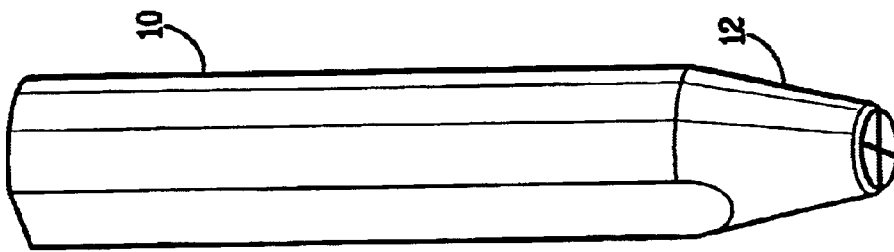
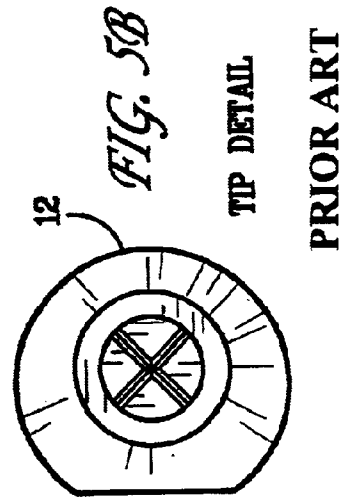
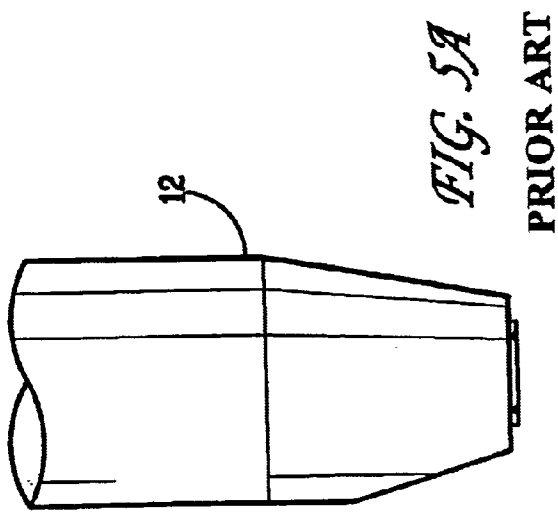
PRIOR ART

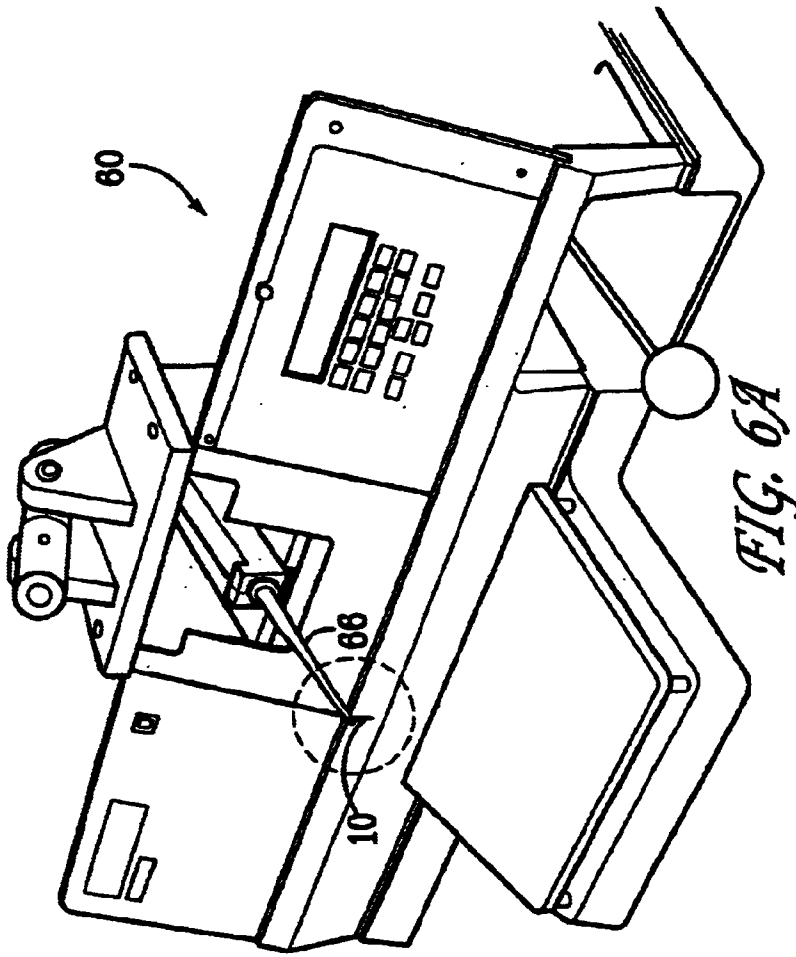


BOTTLE-NECK CAPILLARY

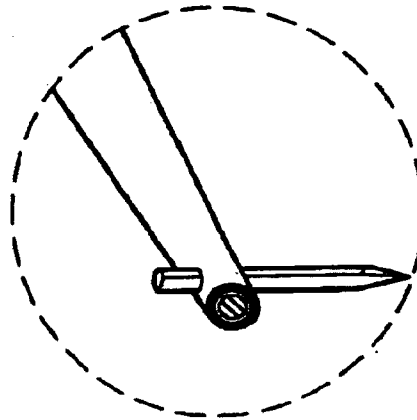
FIG. 3

PRIOR ART



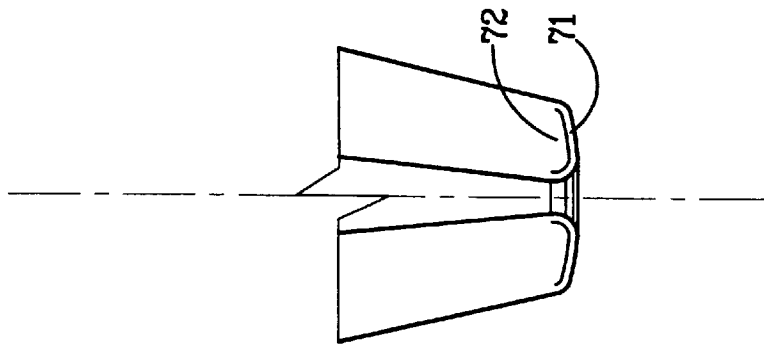


PRIOR ART



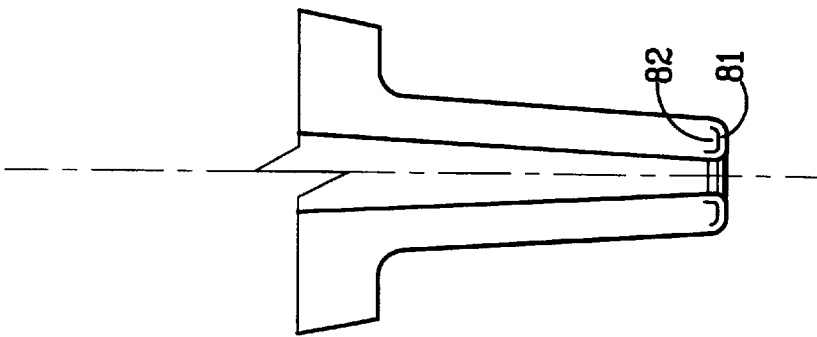
Transducer Horn Tip and Wedge Detail

PRIOR ART



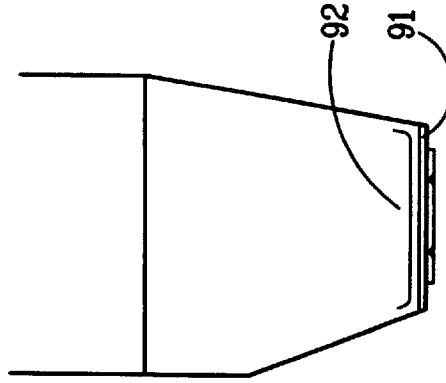
NORMAL CAPILLARY

FIG. 7



BOTTLE-NECK CAPILLARY

FIG. 8



TIP DETAIL

FIG. 9

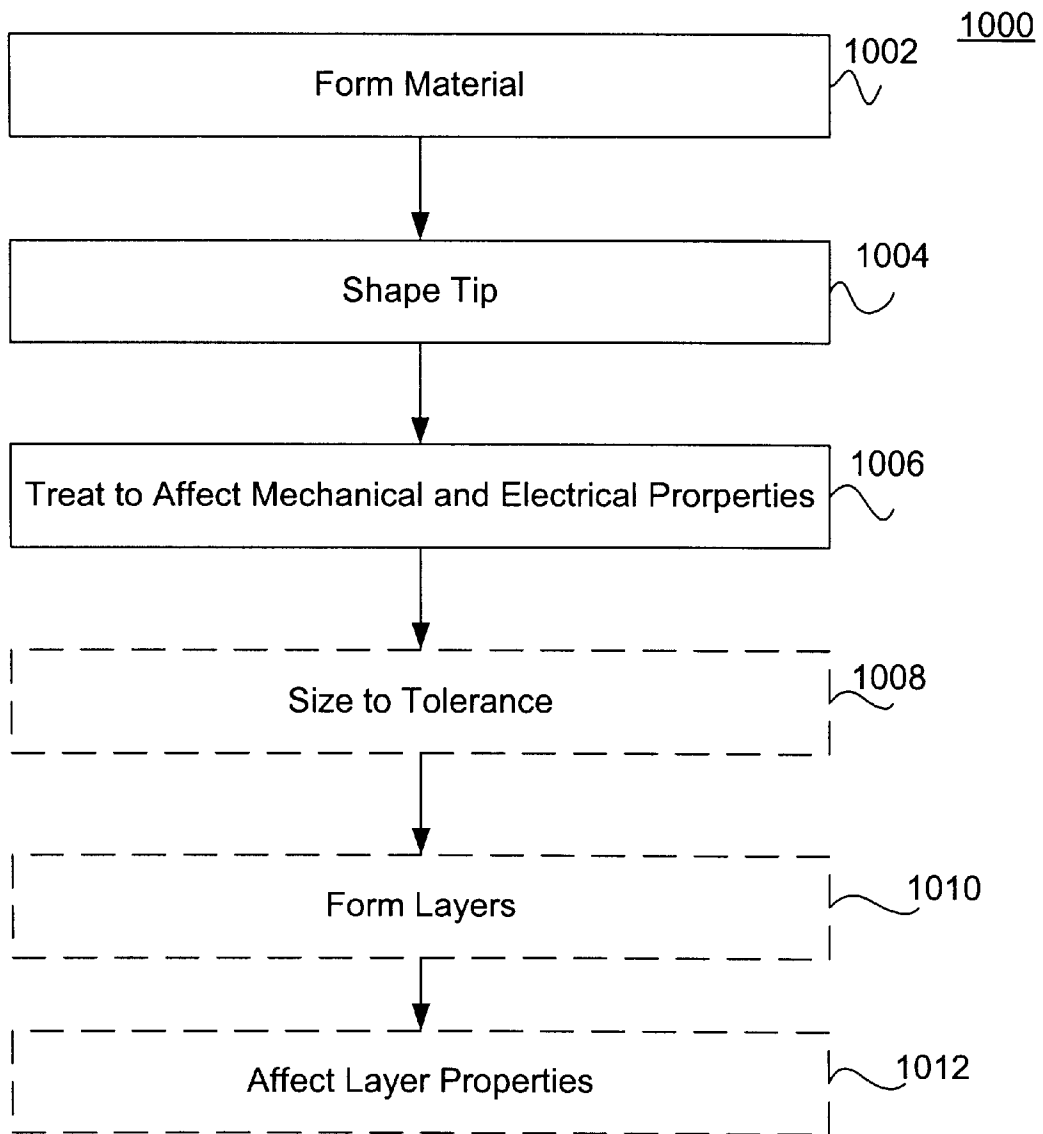


FIG. 10

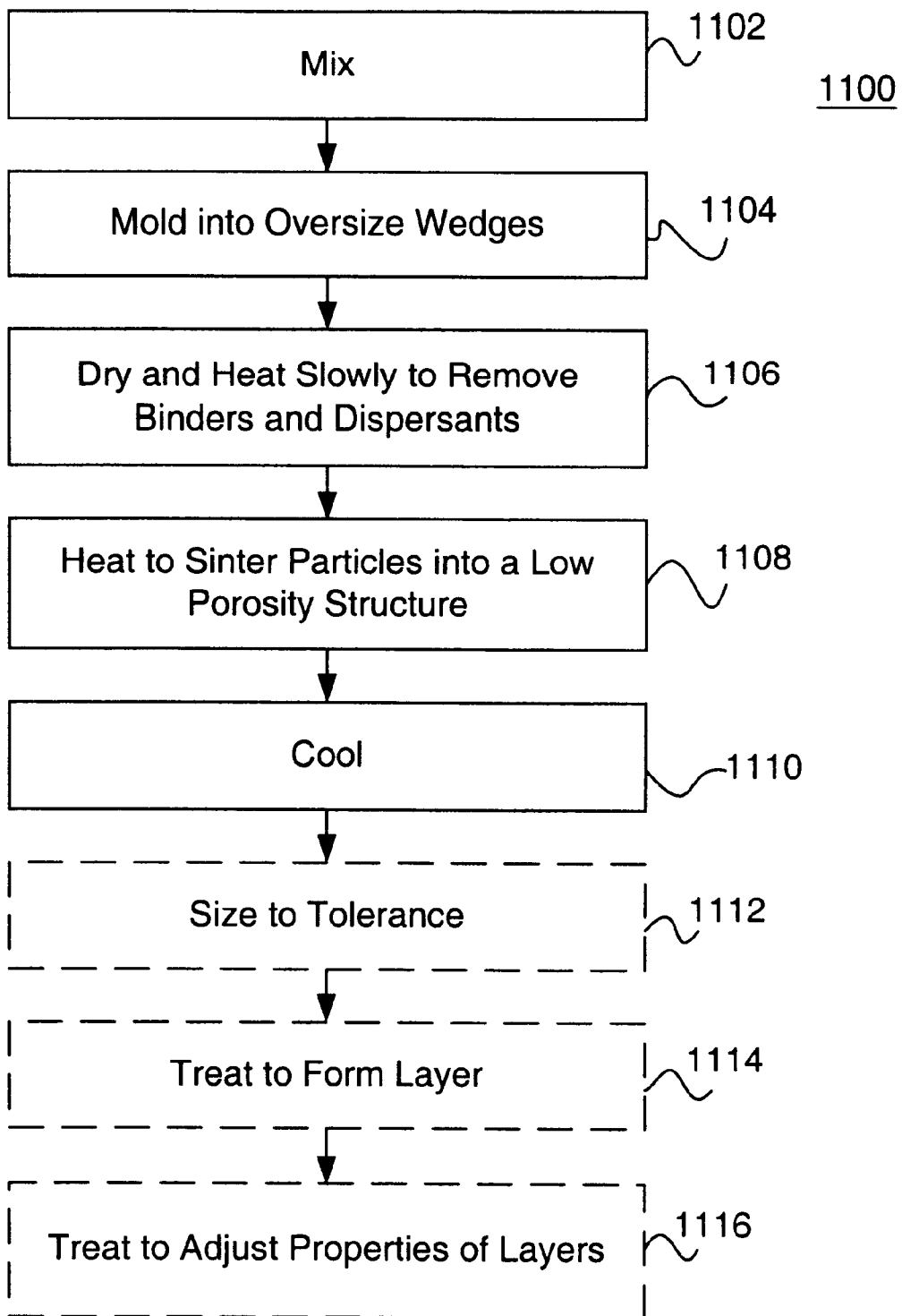


FIG. 11

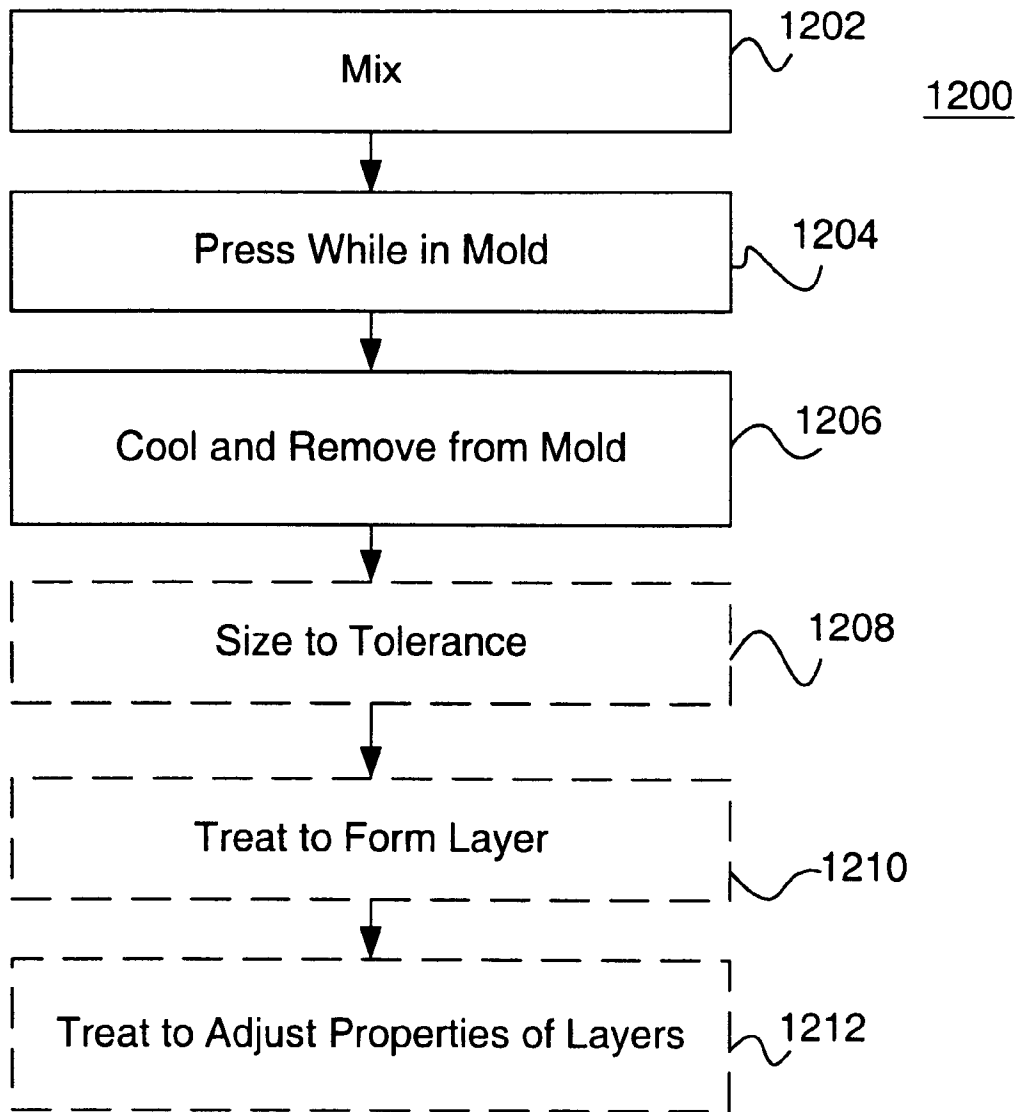


FIG. 12

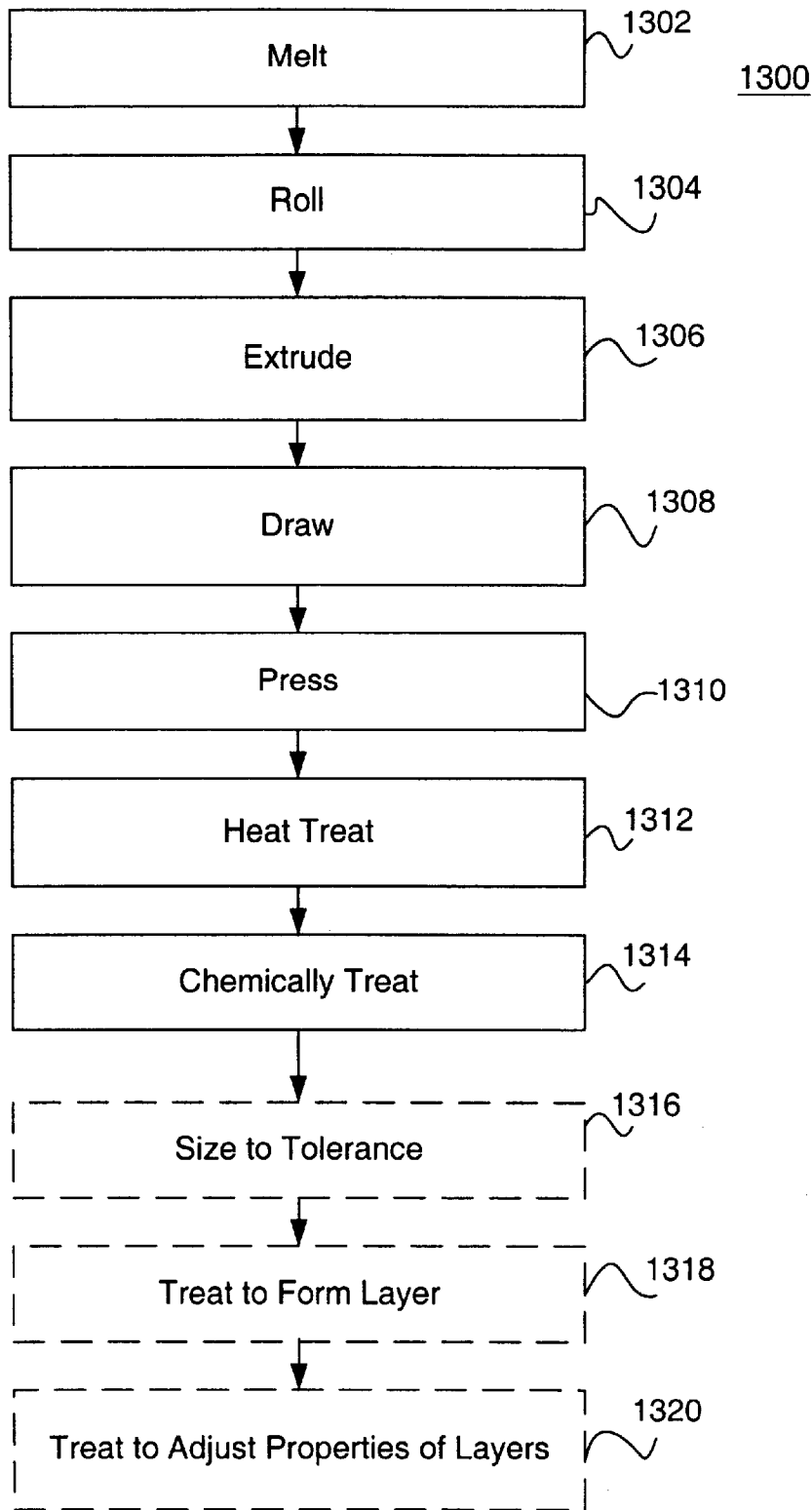


FIG. 13

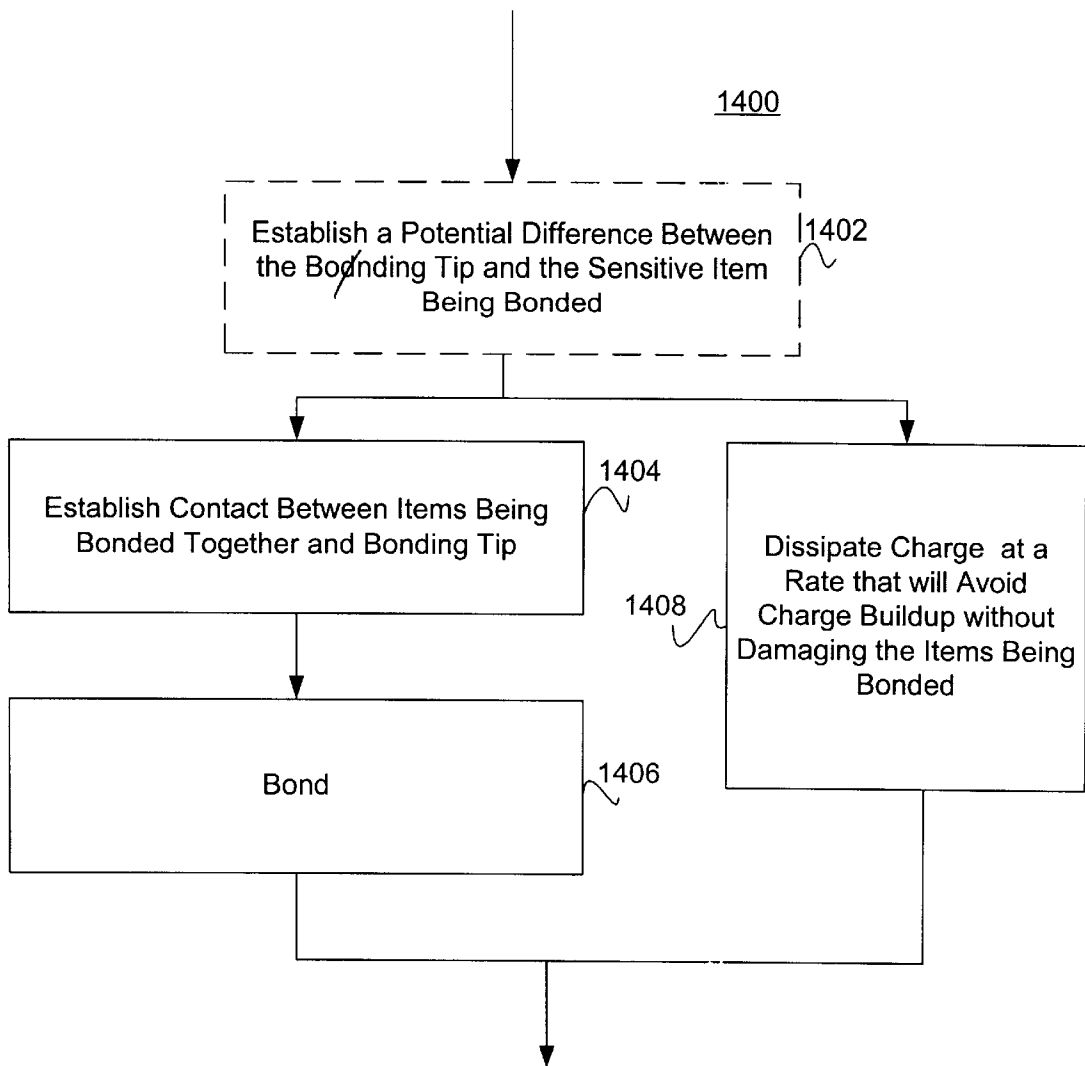


FIG. 14

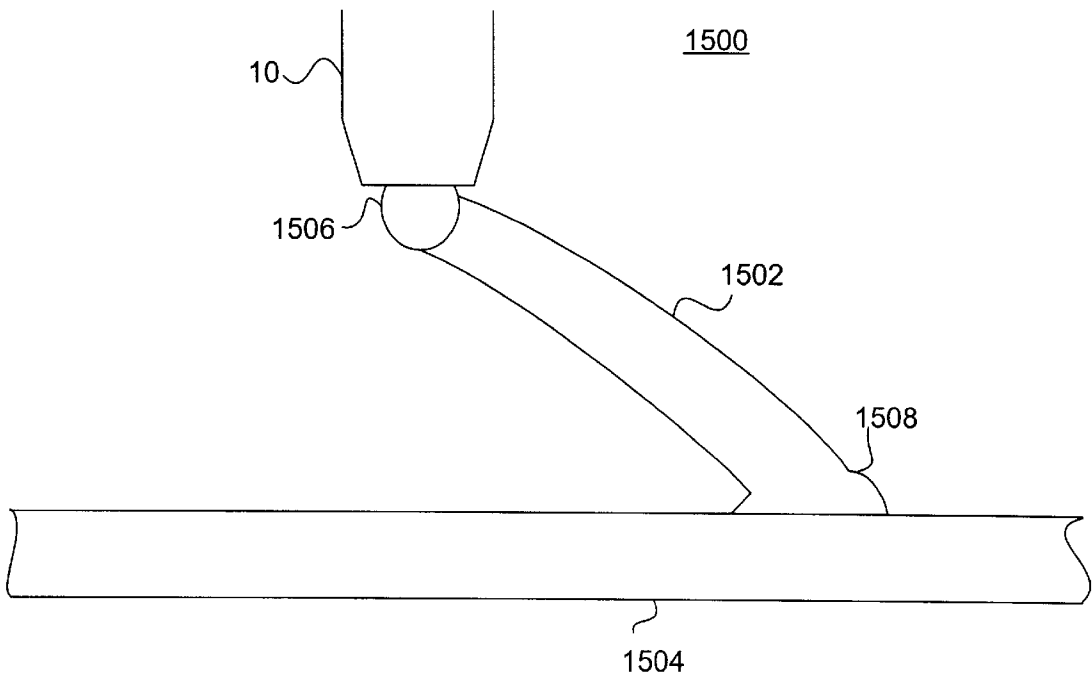


FIG. 15

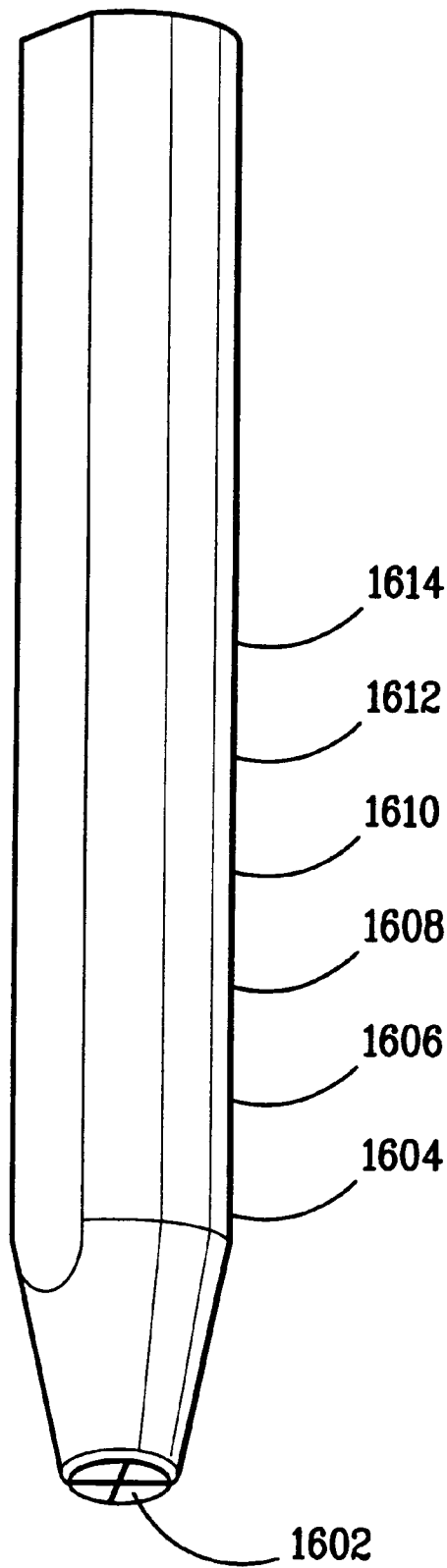
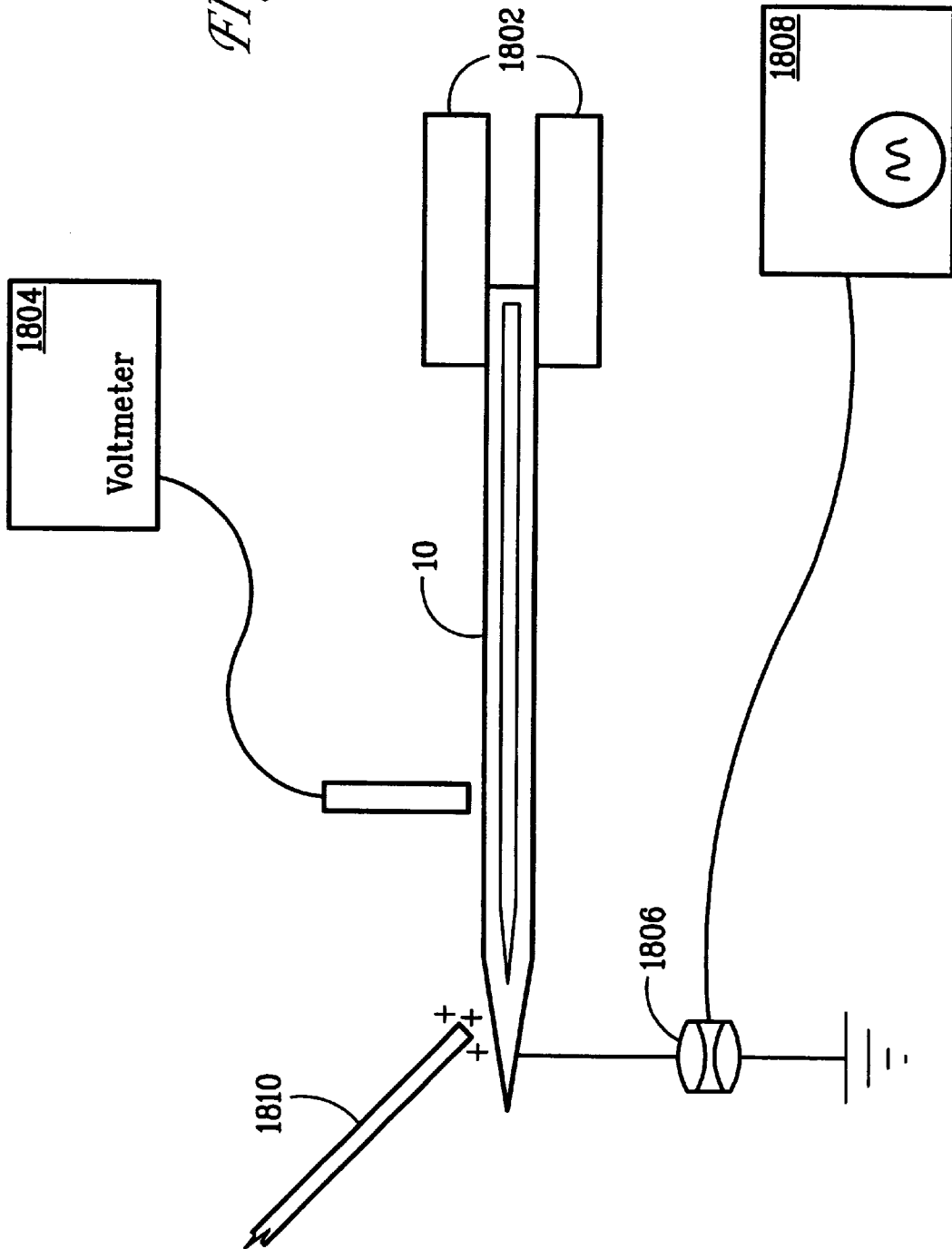


FIG. 16

Reading @	Rod #1		Rod #2	
	10V	100V	10V	100V
1"	$2.11 \times 10^8 \Omega$	$1.80 \times 10^8 \Omega$	$2.38 \times 10^8 \Omega$	$1.89 \times 10^9 \Omega$
2"	$2.78 \times 10^8 \Omega$	$2.42 \times 10^8 \Omega$	$4.13 \times 10^8 \Omega$	$3.63 \times 10^8 \Omega$
3"	$3.34 \times 10^8 \Omega$	$3.03 \times 10^8 \Omega$	$5.49 \times 10^8 \Omega$	$5.17 \times 10^8 \Omega$
4"	$4.35 \times 10^8 \Omega$	$4.09 \times 10^8 \Omega$	$8.52 \times 10^8 \Omega$	$8.25 \times 10^8 \Omega$
5"	$5.67 \times 10^8 \Omega$	$5.46 \times 10^8 \Omega$	$1.27 \times 10^9 \Omega$	$1.22 \times 10^9 \Omega$
6"	$7.05 \times 10^8 \Omega$	$6.93 \times 10^8 \Omega$	$1.26 \times 10^9 \Omega$	$1.23 \times 10^9 \Omega$
Average	$4.22 \times 10^8 \Omega$	$3.96 \times 10^8 \Omega$	$7.64 \times 10^8 \Omega$	$1.01 \times 10^9 \Omega$
Minimum	$2.11 \times 10^8 \Omega$	$1.80 \times 10^8 \Omega$	$2.38 \times 10^8 \Omega$	$3.63 \times 10^8 \Omega$
Maximum	$7.05 \times 10^8 \Omega$	$6.93 \times 10^8 \Omega$	$1.27 \times 10^9 \Omega$	$1.89 \times 10^9 \Omega$

FIG. 17

FIG. 18



Reading #	Small Diameter Rod #1	Small Diameter Rod #2
1	0.16 sec.	0.48 sec.
2	0.16 sec.	0.21 sec.
3	0.20 sec.	0.12 sec.
4	0.21 sec.	0.22 sec.
5	0.21 sec.	0.23 sec.
6	0.15 sec.	0.22 sec.
Average	0.18 sec.	0.25 sec.
Minimum	0.15 sec.	0.12 sec.
Maximum	0.21 sec.	0.48 sec.

FIG. 19

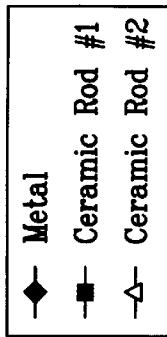
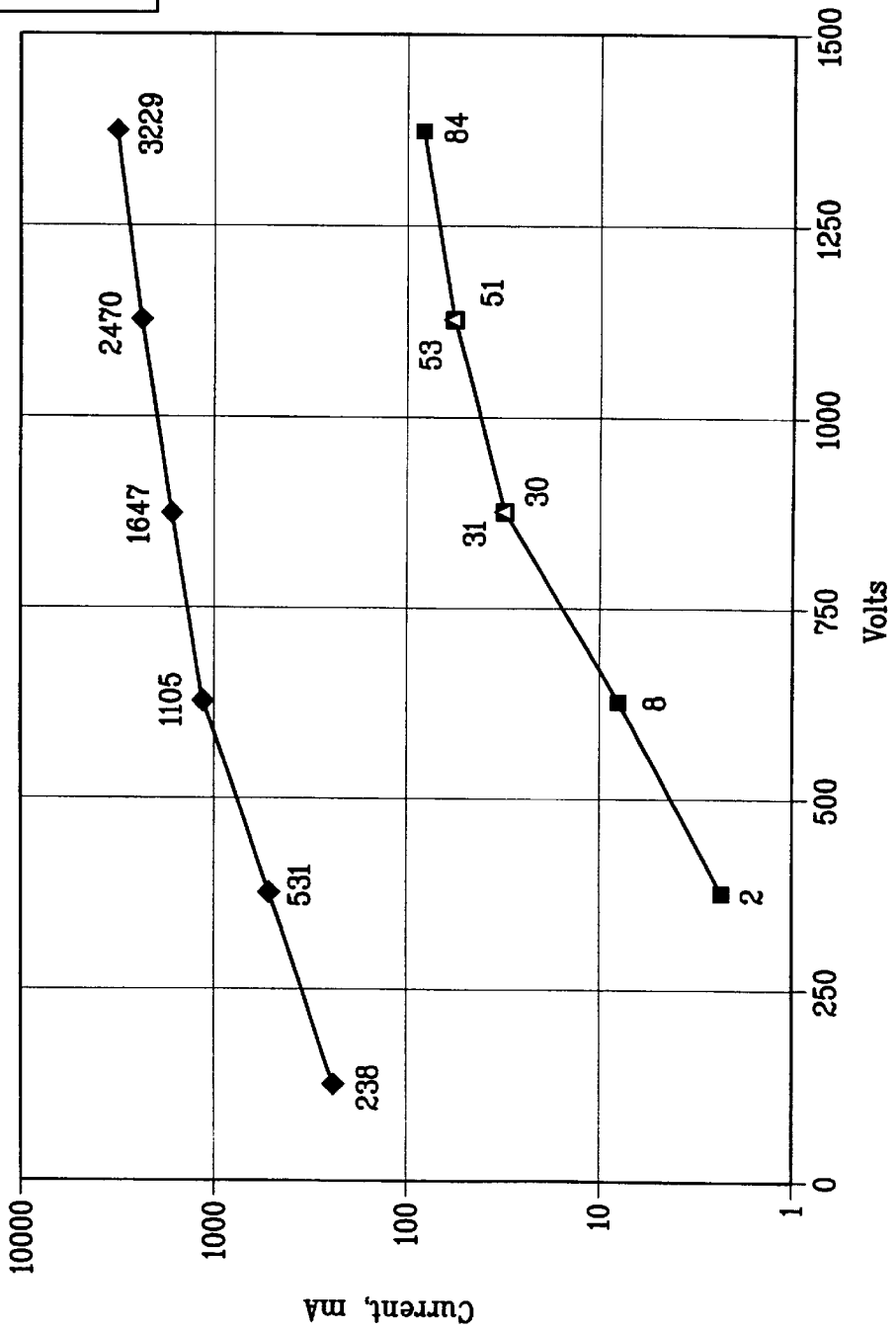


FIG. 20



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DISSIPATIVE CERAMIC BONDING TOOL TIP

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 09/514,454, filed Feb. 25, 2000, now U.S. Pat. No. 6,354,479 entitled, "Dissipative Ceramic Bonding Tool Tip," which claims benefits of Provisional Patent Application Ser. No. 60/121,694, filed Feb. 25, 1999, also entitled, "Dissipative Ceramic Bonding Tool Tip." This application also claims benefit of Provisional Application 60/288,203 filed May 1, 2001. The contents of the above applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to bonding tool tips in general and more particularly to ceramic tool tips for bonding electrical connections.

2. Description of the Prior Art

Integrated circuits are typically attached to a lead frame, and individual leads are connected with wire to individual bond pads on the integrated circuit. The wire is fed through a tubular bonding tool tip having a bonding pad at the output end. These tips are called capillary tips. An electrical discharge at the bonding tool tip supplied by a separate Electronic Flame Off (EFO) device melts a bit of the wire, forming a bonding ball. Other bonding tools do not have the center tube, but have a feed hole or other feature for feeding the wire along, as needed. Some bonding tool tips have no such arrangement for feeding wire, such as bonding tool tips for magnetic disk recording devices, where the wire is insulated and bonded to a magnetic head and then to a flexible wire circuit.

When the bonding tool tip is on the integrated circuit die side of the wire connection, the wire will have a ball formed on the end of the wire, as above, before reaching the next die bonding pad. The ball then contacts the film formed on the die pad on the integrated circuit. The bonding tool tip is then moved from the integrated circuit die pad, feeding out gold wire as the tool is moved, onto the bond pad on the lead frame, and then scrubbed laterally by an ultrasonic transducer. Pressure from the bonding tool tip and the transducer, and capillary action, causes the wire to "flow" onto the bonding pad where molecular bonds produce a reliable electrical and mechanical connection.

Bonding tool tips must be sufficiently hard to prevent deformation under pressure, and mechanically durable so that many bonds can be made before replacement. Prior art bonding tool tips were made of aluminum oxide, which is an insulator that is durable enough to form thousands of bonding connections. Bonding tool tips must also be designed to produce a reliable electrical contact, yet prevent electrostatic discharge damage to the part being bonded. Certain prior art devices emit one or more volts when the tip makes bonding contact. This could present a problem, as a one volt static discharge could cause a 20 milliamp current to flow, which, in certain instances, could damage the integrated circuit or magnetic recording head.

U.S. Pat. No. 5,816,472 to Linn describes a durable alumina bonding tool "without electrically conductive metallic binders" that is therefore an insulator. U.S. Pat. No. 5,616,257 to Harada describes covering a bonding tool electrode with an insulating cap or covering "made of a

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ceramic material" to produce a large electrostatic discharge that creates bonding balls of stable diameter. U.S. Pat. No. 5,280,979 to Poli describes a vacuum wafer-handling tool having a ceramic coating "made with a controlled conductivity" to prevent a large electrostatic discharge.

SUMMARY OF THE INVENTION

The present invention may provide electrically dissipative ceramic bonding tool tips for bonding electrical connections to bonding pads on electrical devices. In accordance with principles of the present invention, the method of using the invention involves an added step of dissipating electrical charge at a rate sufficiently high to prevent charge buildup, but not high enough to overload the device being bonded. This added step is at least partially counter-intuitive because ordinarily charge dissipation is avoided so as not to overload the circuit. Consequently, to avoid damaging delicate electronic devices by any electrostatic discharge, the bonding tool tip is made to conduct electricity at a rate sufficiently high to prevent charge buildup, but not high enough to overload the device being bonded. In other words, it is desirable for the bonding tool tip to discharge slowly. The tip needs to discharge to avoid a sudden surge of current that could damage the part being bonded. For best results, a resistance in the tip assembly itself should range from about 5×10^4 or 10^5 to 10^{12} ohms. This range of resistances is adequate no matter the method of characterizing the resistance. The tools may also have a high stiffness and high abrasion resistance so that the tools have a long lifetime. However, bonding tool tips having a low stiffness and low abrasion resistance may also be made, except that they would have a short lifetime. Possible materials that can be used for the bonding tool tips that have a high abrasion resistance and high stiffness include ceramics (electrical non-conductors) or metals, such as tungsten carbide (an electrical conductor).

In the present invention, bonding tool tips with the desired electrical conduction can be made in at least three different configurations.

First, the tools can be made from a uniform extrinsic semiconducting material that has dopant atoms in the appropriate concentration and valence states to produce sufficient mobile charge carrier densities (unbound electrons or holes) that will result in electrical conduction in the desired range. For example, the tools can be made from polycrystalline silicon carbide uniformly doped with boron.

Second, the tools can be made with a thin layer of a highly doped semiconductor on an insulating core. In this case, the core provides the mechanical stiffness and the semiconductor surface layer provides abrasion resistance and provides a charge carrier path from the tip to the mount that will permit dissipation of electrostatic charge at an acceptable rate. For example, the tools can be made from a diamond tip wedge that has a surface that is ion implanted with boron.

Third, the tools can be made with a lightly doped semiconductor layer on a conducting core. The conducting core provides the mechanical stiffness and the semiconductor layer provides abrasion resistance and provides a charge carrier path from the tip to the conducting core, which is electrically connected to the mount. The doping level is chosen to produce a conductance through the layer that will permit dissipation of electrostatic charge at an acceptable rate. For example, the tools can be made from a cobalt-bonded tungsten carbide coated with titanium nitride carbide.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vastly enlarged cross-sectional view of a capillary bonding tool tip;

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FIG. 2 is a vastly enlarged cross-sectional view of a capillary-type construction of the operating end or tip of a bonding tool;

FIG. 3 is a cross-sectional view of a bottle-neck capillary bonding tool tip;

FIG. 4 is an isometric view of a wedge bonding tool tip;

FIGS. 5a and 5b are side and end views, respectively, of the wedge design bonding tool tip shown in FIG. 4;

FIGS. 6a and 6b are an isometric view and a detailed close-up, respectively, of an apparatus utilized in the wire bonding of a semiconductor integrated circuit chip or other apparatus;

FIG. 7 is a cross-section of an embodiment of FIG. 2 having two layers;

FIG. 8 is a cross-section of an embodiment of FIG. 3 having two layers;

FIG. 9 is a cross-section of an embodiment of FIG. 5 having two layers;

FIG. 10 is a flowchart of a generic method for making a dissipative tool;

FIG. 11 is a flowchart of a first exemplary embodiment of the method of FIG. 10;

FIG. 12 is a flowchart of a second exemplary embodiment of the method of FIG. 10;

FIG. 13 is a flowchart of a third exemplary embodiment of the method of FIG. 10;

FIG. 14 is a flowchart for a method of using the bonding tool tip according to the invention;

FIG. 15 is an illustration showing the method of use of a capillary bonding tool tip according to the invention;

FIG. 16 shows sections of the bonding tool whose resistances were measured;

FIG. 17 is a table of resistances for two ceramic bonding tools measured at the points shown in FIG. 16;

FIG. 18 is a schematic representation of the experimental setup used for measuring the static discharge;

FIG. 19 is a table showing the static decay times measured using the experimental setup of FIG. 18; and

FIG. 20 is a plot comparing the discharge current at various voltages of the ceramic bonding tools to a metal rod.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a typical capillary bonding tool 10 according to the invention. Such bonding tools 10 can be about one-half inch (12–13 mm) long and about one-sixteenth inch (1.6 mm) in diameter. The bonding tool tip 12 can be from 1 to 8 mils, 2 to 6 mils, or 3 to 10 mils (0.08 to 0.25 mm) long. Running the length of the tool itself, but not viewable in FIG. 1, is a tool hole that accommodates a continuously fed length of gold wire (not shown).

FIG. 2 is a highly enlarged, cross-sectional view of the capillary bonding tool 10 10 shown in FIG. 1. Only the portion of the bonding tool 10 that is shown within the dotted circle in FIG. 1 is shown in FIG. 2. Tool tip 12 has a tool hole 14 which may run the entire length of bonding tool 10. The wire (not shown) exits the tool tip 12 through an exit hole 18. If a ball is formed on the wire, the ball is seen immediately adjacent the exit hole 18. The wire may be gold, for example, but could be made from other conductive metals or mixtures of conductive metals. The chamfer 16 at the exit hole 18 has at least two purposes. First, the chamfer 16 accommodates a ball that has been formed at the end of

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the wire. Second, the chamfer surface 16 allows a smoother looping of the wire as the bonding tool 10 is moved from the bonding pad on an integrated circuit (not shown) to a bonding pad (not shown) on a lead frame (not shown) of an integrated circuit assembly (not shown). The inner diameter of the bonding tool tip 10 may be about 1.5 times the width of the wire being fed through it. For example the inner diameter may be 1.3 or 1.4 to 1.6 microns.

Although the size of the bonding tool 10 may change according to the size of the component being manufactured, the diameter of the tool tip 12 may remain essentially the same.

FIG. 3 shows an alternative embodiment of a bonding tool 10 having similar features, such as the tool hole 14, chamfer surface 16, and exit hole 18. This bonding tool tip, named a bottle-neck capillary tip, is provided for narrower bond situations where the bonding pitch (distance between the centers of the bonding pads) is small. Bonding tool tips and the bonding pitch tend to get smaller as the dimensions of integrated circuits get smaller, or as the number of circuits on a chip gets larger, while the die area remains more or less constant.

FIG. 4 shows still another type of bonding tool 10, called a wedge tool, having end 14, raised portion 16, and grooves 18. The FIG. 4 embodiment of bonding tool 10 can be used for disk drive bonding where it is used to capture the insulated wire, lay it on the head of bonding tip 12 and ultrasonically bond it to a part of the disk drive system, for example, or other device being bonded. Bonding tool 10 may also be used with an integrated circuit die mounted on a lead frame (not shown). When bonding a magnetic recording head or integrated circuit dies the wires from the magnetic recording head or integrated circuit die may not be connected from the die directly to connections in an integrated circuit package, but from the magnetic recording head or integrated circuit die to a lead frame, as is well-known to skilled practitioners in the art. The composition of the lead frame may be different than the composition of the integrated circuit package. The tip 12 of the bonding tool 10 of FIGS. 5a and 5b accommodates the different physical attributes of different integrated circuit lead frames. The grooves 18 in FIGS. 4, 5a and 5b frictionally hold the pad being bonded in place during ultrasonic bonding. The grooves 18 are typically “v” shaped but other shapes such as cylindrical also work. The size of the grooves 18 and/or die area may be kept essentially constant despite differences in size of the component being worked on. The width of the grooves 18 may be approximately the same or slightly smaller than the diameter of the wire being bonded. In an embodiment, the grooves 18 are 1 to 30 microns wide and 1 to 30 microns deep. The grooves 18 may cut through the entire depth of the raised portion 16, which may also be 1 to 30 microns deep. In an embodiment, raised portion 16 is 6 to 7 microns deep, grooves 18 are 2.5 to 4.5 microns deep, raised portion 16 is 100 to 150 microns wide. Raised portion 16 and end 14 may be 8 to 35 or 40 microns wide. Although FIGS. 4, 5a, and 5b show two grooves 18 forming a cross the bonding tool tip 12 may have just one groove or a mesh of intersecting and/or parallel grooves. Although the grooves 18 are illustrated as being perpendicular they may be at any angle with respect to one another.

FIG. 6a illustrates a typical wire bonding machine 60 for use in bonding wire leads in magnetic disk drive units. Shown within the dotted circle is the bonding tool 10. The bonding tool 10 is mounted to an arm 66 that can be moved in the desired directions by the apparatus of wire bonding machine 60. Such a machine is available as Model 7400 from the West Bond Company in Anaheim, Calif.

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Typical bonding tool tips available on the market today are made of an insulator of alumina (Al_2O_3), sometimes termed aluminum oxide, ruby, or sapphire, which are very hard compounds that have been used successfully on commercial machines. Wire bonding tool tips made of alumina, ruby, or sapphire have a reasonably long lifetime. In the prior art, to ensure that the tool tip is an insulator, no conductive binders are used in these bonding tool tips. However, as stated previously, a problem has existed that an electrostatic discharge from the bonding tool making contact with the bonding pad of the circuit can damage the very circuit it is wiring.

In accordance with principles of the present invention, to avoid damaging delicate electronic devices by this electrostatic discharge, bonding tool tip **12** should conduct electricity at a rate sufficiently high to prevent charge buildup, but not high enough to overload the device being bonded. It has been determined that the bonding tool **10** may have an electrical conductance greater than one ten-billionth of a mho (i.e. $>1 \times 10^{-12}$ reciprocal ohms (Ω^{-1}) of power) and its electrical conductivity may be less than one one-hundred thousandth of a mho (i.e. $<1 \times 10^{-5} \Omega^{-1}$). The resistance should be low enough that the material is not an insulator that does not allow charge dissipation, and high enough that it is not a conductor allowing a current flow that is damaging to the device being bonded. For best results, a resistance in the tip assembly itself should range from 5×10^4 or 10^5 to 10^{12} ohms. For example, today's magnetic recording heads are damaged by 5 milliamps of current. In an embodiment that may be used with magnetic recording heads, no more than 2 to 3 milliamps of current should be allowed to pass through the bonding tool tip **12** to the head.

In an embodiment, to achieve high stiffness and high abrasion resistance, ceramics (electrical non-conductors) or metals, such as tungsten carbide (an electrical conductor) are used. The bonding tool tip of this embodiment may have a Rockwell hardness of about 25 or above, preferably of about 32 or above. The tip needs to be able to last for at least two bondings.

In the present invention, bonding tool tips with the desired electrical conduction can be made in at least three different configurations.

First, the tools can be made from a uniform extrinsic semiconducting material that has dopant atoms in the appropriate concentration and valence states to produce sufficient mobile charge carrier densities (unbound electrons or holes) that will result in electrical conduction in the desired range. For example, polycrystalline silicon carbide uniformly doped with boron can give the desired range of conductivity. Preferably the amount of boron used is 5–7% by weight of the polycrystalline silicon carbide.

Second, the tools can be made by forming a thin layer of a highly doped semiconductor on an insulating core. For example, a diamond tip wedge may have a surface that is ion implanted with boron or have a surface that is a doped ceramic. In this case the core provides the mechanical stiffness and the semiconductor surface layer provides abrasion resistance and provides a charge carrier path from the tool tip **12** to the mount (not shown), which will permit dissipation of electrostatic charge at an acceptable rate. The conductance of the semiconductor surface layer should be about $10^{8-109} \Omega^{-1}$.

Third, the tools can be made by forming a lightly doped semiconductor layer on a conducting core, for example, a cobalt bonded tungsten carbide core coated with titanium nitride carbide. The conducting core provides the mechani-

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cal stiffness and the semiconductor layer provides abrasion resistance and provides a charge carrier path from the device being bonded to the conducting core, which is electrically connected to the mount. The doping level is chosen to produce a conductance through the layer that will permit dissipation of electrostatic charge at an acceptable rate. The conductivity of the semiconductor surface layer should be about $10^{7-108} \Omega^{-1}$.

FIGS. **7**, **8** and **9** illustrate the two-layered structure of the last two configurations. This structure is not intended to be specific to the type of tool tip. Rather, it could be used for any bonding tool tip. Layers **71**, **81**, and **91** could be 100–1000 Angstroms thick, for example. In the second and third configurations, the outer layers are labeled **71**, **81**, and **91** and the cores are labeled **72**, **82**, and **92**. In the second configuration, mentioned above, layers **71**, **81**, and **91** are highly doped semiconductor and the cores **72**, **82**, and **92** are insulators. In the third configuration, mentioned above, layers **71**, **81**, and **91** are lightly doped semiconductor and the cores **72**, **82**, and **92** are conductors. No significance should be attached to the relative thickness or scale of the portions of the layer **71**, **81**, and **91**, which may or may not have a uniform thickness.

Dissipative tools can be manufactured by any of several methods.

FIG. **10** illustrates a generic method **1000** for manufacturing dissipative tools. The process of creating a ceramic part may start with a powder having the same or a similar composition as desired in the ceramic part to be created. The quality of the ceramic component may be influenced by the quality of the ceramic powder used. To ensure quality, the ceramic powder may be tested and processed multiple times. The purity, concentration of agglomerations, and particle size of the ceramic powder may be monitored. The powder may be milled (e.g., attrition milled, balled milled, or turbo milled). The milling operation refines the particle size of the ceramic powder before process **1000** begins. In step **1002** a material, which may initially be a powder, is formed having the desired composition. The material is next shaped and sized in step **1004** into a form appropriate for the tool. The material may be further treated in step **1006** to affect or impart desired mechanical, chemical and/or electrical properties. Depending upon the embodiment, steps **1002**, **1004**, and **1006** may be performed simultaneously as part of one process. Since the properties of the material depend upon the process of making and the materials used for making the composition, parts or all of step **1006** may be performed before step **1004**. In optional step **1008** the material is sized to tolerance. In optional step **1010** the layering is formed. In optional step **1012** the material is further treated to impart desired properties to the layers or affect the desired properties of the layers.

FIGS. **11–13** show three examples of the method of FIG. **10**.

FIG. **11** shows method **1100**, which includes mixing, molding and sintering reactive powders of, for example, alumina (Al_2O_3), zirconia (Zr_2O_3), iron oxide (FeO_2), or titanium oxide (Ti_2O_3).

In general, sintering may involve the densification of powder compacts at a temperature below the melting point of the powder. The shrinkage occurs as the pores between the particles decrease in size until they are eliminated. The driving force of the sintering process is the reduction of surface energy. During the sintering of two spherical particles, for example, the inter-particle contact areas will increase as the growth into a neck between the particles

increases. There are three basic stages involved with the sintering process. In the first stage, the material between the particles moves outward by viscous flow, plastic flow or volume diffusion and is deposited on the neck area. The distance between the particle centers decreases and shrinkage occurs. If the material is transported from the circumference into the neck by evaporation-condensation or surface diffusion then there is no shrinkage. In the second stage, the growing necks merge, the original particle structures disappear and are replaced by polycrystalline bodies with an inter-granular pore network along grain boundary edges. The grain growth can occur by the movement of grain boundaries towards their centers of curvature. In the third stage the grain growth continues; pores become closed at grain corners and further densification occurs as the pores shrink. If the grain boundaries are sufficiently curved, they can move over the pores leaving them isolated in the grains. The process of further shrinkage may be slow once the pores are within the grains.

In step **1102** fine particles (e.g., a half of a micron in size) of the desired composition are mixed with organic and inorganic solvents, dispersants, binders, and sintering aids. The solvents could be Yttrium or H_2O , for example. The binder and/or the sintering aids could be any of, any combination of, or all of ceria, magnesia, yttria, boron, carbon colloidal silica, alumina solvents, ethyl silicate, any phosphates, any rare earth metal oxide, or yttrium, for example. In step **1104** the mix is molded into oversize wedges. The pieces are carefully dried, and heated slowly in step **1106** to remove the binders and dispersants and then heated in step **1108** to a high enough temperature so that the individual particles sinter together into a solid structure with low porosity. The slow heating can be done over three to eight hours at a rate of $50^\circ C.$ to $200^\circ C.$ every 15 minutes, for example, in an atmosphere of $500^\circ C.$ or $1000^\circ C.$ to $2500^\circ C.$ for 3 to 24 hours, so as to obtain low porosity, and to obtain homogeneity. The sintering can occur at $4000^\circ C.$, for example. The heat-treating atmosphere is chosen to facilitate the removal of the binder at a low temperature and to control the valence of the dopant atoms at the higher temperature and while cooling. The low porosity can be ensured by keeping the grain size less than about half a micron. Next, in step **1110**, the solid structures are allowed to cool preferably over a period of one to two hours. After cooling, in optional step **1112**, the pieces may be machined or otherwise sized to achieve the required tolerances. In optional step **1114** the pieces may then be treated to produce the desired surface layer by ion implementation, vapor deposition, chemical vapor deposition, physical deposition, electro-plating deposition, neutron bombardment, or combinations of the above. The pieces may be subsequently heat treated in optional step **1116** in a controlled atmosphere to produce desired layer properties (e.g., the desired hardness and resistivity) through diffusion, recrystallization, dopant activation, or valence changes of metallic ions.

In an example, in step **1104** silicon nitride or zirconia ceramic materials could be fabricated by firing a powder compact at a suitable temperature until agglomeration of the particles occurs with a decrease in the surface area and porosity of the compact. This process may involve chemical reactions, crystal growth and/or the formation of liquid phases and solid state diffusion. An untreated silicon nitride ceramic powder is typically in the alpha phase. The sintering process of step **1106** involves heating the ceramic powder to $+2000^\circ C.$ to convert the powder to the preferred beta- Si_3N_4 state. The beta- Si_3N_4 state has the high thermo-mechanical properties suitable for high temperature applications such as

resistive heating. Silicon nitride is very difficult to sinter because it has very strong directional covalent bonds. Although silicon nitride may be at least partially sintered without adding sintering aids, the ceramic powder may not completely turn from the alpha phase to the beta- Si_3N_4 phase during the heating process without the sintering aids. Sintering aids of rare earth oxides and other oxides may act as nucleating agents for the Si_3N_4 powders to nucleate the formation of grains. Yttria (Y_2O_3) and Aluminum Oxide (Al_2O_3) may be used as the sintering aids although other sintering aids will also work.

In another example, silicon carbide, zirconia, or silicon nitride could be used for the bonding tip **12**. Although silicon nitride does not need much preparation before it enters the sintering stage of step **1106**, silicon carbide and zirconia have two phases that can exist that may affect the quality of the finished product. Silicon nitride has two phases, alpha and beta- Si_3N_4 , a hexagonal structure, and can be used to make a polycrystalline ceramic. Similarly, zirconia exists as a monoclinic crystal at room temperature and inverts to a tetragonal phase above $1200^\circ C.$ In other words, zirconia has a low temperature monoclinic state and a high temperature tetragonal state. The silicon nitride beta phase and the tetragonal zirconia crystal have the higher strength properties of their two respective phases but some stabilizers should be added in step **1102** in order to induce silicon nitride and zirconia to remain in their beta phase and tetragonal phase, respectively, during the cooling step **1110**. For example, a stabilizer such as magnesium oxide may be added in step **1102** to prevent the transformation upon cooling in step **1110**. The addition of yttria in step **1102** yields an extremely fine grained (less than 1 micron) microstructure known as tetragonal zirconia polycrystal (TZP).

The process of mixing in the additives during step **1102** to achieve the higher strength phase is called forming the green body.

There are several other types of sintering processes that can be used to manufacture the bonding tool tip. In reaction bonding sintering, in step **1106** the green body is placed in a chamber where it is heated and infiltrated with a reacting gas to form a compound. The process of reaction bonding silicon nitride to form a silicon nitride bonding tool tip involves taking a silicon green body between steps **1106** and **1108** and reacting the body to a gas of hydrogen and nitrogen to form Si_3N_4 . Exposing the green body to the hydrogen and nitrogen gas is commonly known as nitriding. The body is nitrided in the gas starting at $1150^\circ C.$ and slowly increasing the temperature to $1420^\circ C.$ The resulting product is a mixture of alpha and beta silicon nitrides with 18 to 25% porosity. The original dimensions of the silicon compact remain virtually unchanged during the nitriding. The bonding tool tip can be machined after partial nitriding in step **1112**. Reaction bonding can be relatively cheap.

When using hot press sintering to form a bonding tool tip, a ceramic powder is placed in a die and then it is compressed at a high pressure while the powder is heated in step **1104**. When working with silicon nitride powders, the powder is hot pressed with a suitable oxide additive in a graphite die and it may be heated by induction, for example, to $1700^\circ C.$ to $1800^\circ C.$ to give a fully dense high strength beta-silicon nitride. Diamond machining follows the hot pressing.

When using Hot Isostatic Pressing (HIP) to form the bonding tool tip, in step **1104** the powder is placed in an evacuated pressure vessel. The vessel will simultaneously heat and isostatically press the material with an inert gas with pressures as high as 310 MPa (45,000 psi) and tem-

peratures up to 2000° C. The powder is simultaneously heated and isostatically pressed by inert gas pressure until densified.

FIG. 12 illustrates method 1200 of hot pressing reactive powders. Fine particles (e.g., a half of a micron in size) of the desired composition are mixed in step 1202 with binders and sintering aids and then pressed in a mold in step 1204 at a high enough temperature to cause consolidation and binding of the individual particles into a solid structure (e.g., 1000° C. to 4000° C., preferably 2000° C.) with low porosity (e.g., having grain size of less than half a micron in size). The hot pressing atmosphere is chosen to control the valence of the dopant atoms. After cooling and removal from the hot press in step 1206, the pieces may be machined or otherwise sized to achieve the required tolerances in step 1208. The pieces may then be treated in optional step 1210 to produce the desired surface layer (e.g., 100 to 1000 Angstroms thick) by ion implantation, vapor deposition, chemical vapor deposition, physical deposition, electro-plating deposition, neutron bombardment or combinations of the above. In optional step 1212 the pieces may subsequently be heat treated (e.g., 2000° C. to 2500° C. for 3 to 5 minutes) in a controlled atmosphere to produce the desired layer properties through diffusion, recrystallization, dopant activation, and/or valence changes of metallic ions.

FIG. 13 illustrates method 1300 of fusion casting. Metals of the desired composition are melted in step 1302 in a non-reactive crucible then cast into an ingot. The ingot is then rolled in step 1304, extruded in step 1306, drawn in step 1308, pressed in step 1310, heat treated (e.g., at 1000° C. or 500° C. to 2500° C. for one to two hours) in step 1312 in a suitable atmosphere, and chemically treated in step 1314. The rolling 1304, extruding 1306, drawing 1308 and pressing 1310 steps shape the tip and the heat treatment 1312 and chemical treatment 1314 steps are for affecting or imparting the mechanical and electrical properties such as the hardness and resistivity. The pieces are then optionally machined or otherwise sized to achieve the required tolerances in step 1316. The metallic pieces are then optionally heat treated to produce the desired surface layer by vapor deposition, chemical vapor deposition, physical deposition, electro-plating deposition, or combinations of the above in step 1318. The pieces may be subsequently heat treated (e.g., at 4000° C. for three to four hours) in a controlled atmosphere to produce the desired layer properties through diffusion, recrystallization, dopant activation, or valence changes of metallic ions in step 1320.

Although steps 1008, 1112, 1208, and 1316; 1010, 1114, 1210, and 1318; and 1012, 1116, 1212 and 1320 share similar descriptions they are given different labels because the details of how to best carry out these steps may be partly dependent upon the details of the preceding steps.

In the three methods above the heat-treating, hot pressing, and controlled atmospheres are preferably primarily an inert gas such as nitrogen using a nitrogen-based furnace.

The green body for the bonding tool tip can be formed by using a variety of other methods of casting high temperature ceramics such as injecting molding, cold isostatic, extrusion, slip casting, Hot Isostatic Pressing (HIP), and gelcasting

Injection molding can be used with all types of ceramics. The features basic to injection molding are that the powder is placed in a thermosetting polymeric binder, is injected into a mold where it hardens with time, and then is ejected from the mold. A concern with injection molding is that the de-waxing or removing the resin should be done without degrading the surface of the green body.

When using slip casting, a slip may be made of water and the ceramic powder. The slip is cast into an absorbent mold. The casting rate is dependant on the pressure applied to the slip cast and the cast thickness. The geometry of the casting surface may also affect the casting time.

In extrusion, a feedrod for coextrusion is formed from the compounded material, which may have of a silicon nitride-filled core with a cladding of boron nitride-filled material. The feedrod is then extruded through a heated die to form fine filaments.

In dipcoating a single component filament (such as a silicon nitride-filled polymer) is pulled through a slurry of boron nitride which dries to form the cell boundary material. Gelcasting is a ceramic-forming process for making high-quality, complex-shaped ceramic parts. Gelcasting can be used for making bonding tool tips 12 with any of the ceramic powders mentioned in this specification. Gelcasting involves mixing ceramic powders in a polymerizable aqueous monomer solution that is then gelled in a mold. The cast body will be both homogeneous in its chemistry and have a certain density, resulting in the material properties (e.g., hardness and resistivity) being constant throughout the body and the drying and sintering processes having uniform volume changes. Using Gelcasting, the casting time from design to final fired part can be one week.

Layers 71, 81, and 91 of bonding tool tip 12 may be made from several compositions of matter. A formula for dissipated ceramic may include alumina and zirconia and/or other elements. This mixture is both somewhat electrically conductive and mechanically durable. The tip of a bonding tool is coated with this material or can be made completely out of this material. The tip may be wedge-shaped or circular-shaped as shown and described in the earlier FIGS. 1 to 5, for example.

One actual sample was constructed with the following elements:

ELEMENT

Iron
Oxygen
Sodium
Carbon
Zirconium
Silicon
Aluminum
Yttrium

While the range of alumina could extend from 15% to 85% and the range of zirconia from 15% to 85%, in one embodiment the sample included alumina at 40% and zirconia at 60%.

FIG. 14 is a flowchart for a method of using the invention. In optional step 1402 an initial potential is established between the bonding tool tip and the item being bonded that is sensitive to electrical discharge. Although not necessary, establishing a potential may give the user some additional control over how the tip discharges. Establishing a potential may involve establishing an electrical connection or grounding the lead frame, individual leads on the integrated circuit and/or the individual bond pads on the integrated circuit. In step 1404 the bonding tool tip is placed in contact with the items being bonded together to hold them in place. In step 1406 the bond is formed. Steps 1404 and 1406 may be performed simultaneously as part of the same step. In step 1408 the charge is dissipated. This step may be performed simultaneously with steps 1404 and 1406. It is important that

this step be performed whenever the tip and the electrostatic discharge sensitive component are in contact to prevent a discharge.

For example, in the case of a capillary tip the wire is fed through the tubular bonding tool tip prior to placing it in contact with the items being bonded. Then an electrical discharge at the bonding tool tip is supplied by a separate EFO device to melt a bit of the wire, forming a bonding ball. The ball then makes intimate contact with the film formed on the die pad on the integrated circuit, initiating the dissipation of charge. The bonding tool tip is then moved from the integrated circuit die pad, with gold wire being fed out as the tool is moved, onto the bond pad on the lead frame, and then scrubbed laterally by an ultrasonic transducer. Pressure from the bonding tool tip and the transducer, and capillary action, 'flows' the wire onto the bonding pad where molecular bonds produce a reliable electrical and mechanical connection while still dissipating charge. In this example the bonding, the contact between the bonding tool tip and the electrostatic discharge sensitive integrated circuit, and the dissipation all occur essentially simultaneously.

FIG. 15 shows a capillary bonding tool **10** being used to bond wire **1502** to pad **1504**. Ball **1506** will be used to bond wire **1502** to the next point. The bonding joint **1508** was formed with a ball similar to **1506**. The difference between this method of use and the prior art is primarily in the dissipation of charge from the bonding tool **10**.

The bonding tool tip **12** of the present invention could be used for any number of different types of bonding. Two examples are ultrasonic and thermal bonding.

FIG. 16 shows sections of the bonding tool **10** having end **1602** and points **1604**–**1614**. Point **1604** is 1 inch from end **1602** whose resistances were measured. Points **1604**–**1614** are each one inch apart.

Two ceramic rods **#1** and **#2** (not shown), were used as the base material for ceramic wire bonding tool tips **12** to form bonding tools **10** according to the invention. The two rods each had a diameter of approximately 0.07 inches. The point-to-point resistances along both of the rods were measured from the end of the bonding tool tip to various points along the tool tip at 10 and 100 volts. The resistance at each voltage was measured six times, each time from end **1602** to a different one of points **1604**–**1614** to obtain measurements of a 1, 2, 3, 4, 5, and 6 inch section, respectively, that starts at end **1602**.

FIG. 17 is a table of resistances for two ceramic bonding tools measured at the points shown in FIG. 16. As shown in the table and as discussed in the preceding paragraph, the resistances were measured at 1, 2, 3, 4, 5, and 6 inches at 10V and 100V. The two bonding tools had point-to-point resistances that varied between $1.8 \times 10^8 \Omega$ and $1.9 \times 10^9 \Omega$. After measuring the resistances according to FIG. 16 the static discharge was measured.

FIG. 18 is a schematic representation of the experimental setup used for measuring the static discharge having bonding tool **10**, clamp **1802**, voltmeter **1804**, current probe **1806**, oscilloscope **1808**, and ElectroStatic Discharge (ESD) simulator **1810**.

The static discharge was measured by charging bonding tool **10** and measuring the time required for the charge to dissipate. The charge was assumed to have dissipated once the current from the bonding tool **10** to ground dropped off significantly from its initial value (e.g., the current was less than 10% of its initial value). The current was measured from the bonding tool **10** when it was charged and grounded. The bonding tool **10** was held in insulative clamp **1802** on a ring stand (not shown), charged to a known voltage with

ESD simulator **1810**. The voltage was verified using voltmeter **1804**, and then the bonding tool **10** was grounded. The current moving through the ground wire was measured with current probe **1806** connected to oscilloscope **1808**. Ten measurements were made at each voltage level on the bonding tool **10**. Using the setup of FIG. 18 the bonding tool **10** can be charged and discharged successively. The rise and fall of the current is plotted by the trace on oscilloscope **1808** which allows the discharge time of several successive cycles of discharging to be viewed and measured graphically.

The voltmeter **1804** could be, but is not limited to, a TREK model **341** non-contact voltmeter. The current probe **1806** could be, but is not limited to, a CT-1 current probe. Oscilloscope **1808** could be, but is not limited to, a Tektronics TDS 520A Digital Oscilloscope. The ESD simulator **1810** could be, but is not limited to, a KeyTech MZ-15.

FIG. 19 is a table showing the static decay times measured using the experimental setup of FIG. 18. The static decay from **1000** volts to **10** volts was also measured on both rods, **#1** and **#2**. The static decay times varied between 0.1 and 0.5 seconds, or more precisely between 0.12 and 0.48 seconds, indicating how quickly the charge dissipate. The decay time is the product of the resistance times the capacitance. Using the data of the tables of FIGS. 17 and 19 an estimate of the capacitance as a function of position associated with the bonding tool **10** can be made, indicating how much charge may build up in bonding tool **10**.

FIG. 20 is a plot comparing the discharge current at various voltages of the ceramic bonding tools to a metal rod. The averages of the current at each voltage level are plotted in FIG. 20. One of the bonding tools (**#1**) was measured at five different voltages, and the other bonding tool (**#2**) was measured at two voltage levels to verify the discharge currents. The data points representing the two bonding tool tips are marked using squares for one tool tip and triangles for the other. The data points representing the metal rod are marked with diamonds. The resistance associated with this measurement is around $1 \times 10^5 \Omega$ or more precisely between about $7.5 \times 10^4 \Omega$ and $2.8 \times 10^5 \Omega$. The current represents the discharge rate. Clearly the bonding tools discharge at a slower rate than the metal rod.

While the invention has been described with reference to specific embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the true spirit and scope of the invention. In addition, modifications may be made without departing from the essential teachings of the invention.

What is claimed is:

1. A device comprising:

a tip having a dissipative material for use in wire bonding machines for connecting leads to integrated circuit bonding pads, wherein said dissipative material has a resistance in the range of 5×10^4 to 10^{12} ohms.

2. The device of claim 1, wherein the tip has a tube for feeding wire.

3. The device of claim 1, wherein the tip has grooves.

4. A device comprising:

a tip having a dissipative material for use in wire bonding machines for connecting leads to integrated circuit bonding pads, wherein said dissipative material has a resistance low enough to conduct an essentially constant current and high enough to prevent a current equal to or more than 20 milliamps from discharging to a device being bonded.

5. The device of claim 4, wherein the resistance is high enough to prevent a current less than or equal to 5 milliamps.

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6. The device of claim 4, wherein the resistance is high enough to prevent a current less than or equal to 3 milliamps.

7. The device of claim 4, wherein the resistance is high enough so that the current dissipated from the tip is less than or equal to 2 milliamps.

8. A method of making a dissipative ceramic bonding tool tip having a resistance in the range of 10^5 to 10^{12} ohms, comprising:

sintering fine particles to form said dissipative ceramic bonding tool tip.

9. The method of claim 8, wherein sintering fine particles comprises:

mixing fine particles of a composition appropriate for forming said dissipative material with a solvent, a dispersant, a binder, and a sintering aid to form a mixture;

molding the mixture into at least one wedge;

drying the at least one wedge;

providing a heat-treating atmosphere that facilitates removal of the binder at a low temperature and that controls the valence of the dopant atoms;

heating the at least one wedge in the atmosphere at a temperature appropriate to remove the binder and the dispersant;

heating the at least one wedge to a high enough temperature in the atmosphere to sinter the particles together into a solid structure having low porosity; and

cooling the solid structure.

10. The method of claim 8, wherein the fine particles are heated to a 500–2500 degrees Celsius to remove binders.

11. The method of claim 8, wherein the fine particles are sintered to a 4000 degrees Celsius to remove binders.

12. The method of claim 8, wherein the fine particles are mixed with solvents, dispersants, binders, and sintering aids.

13. The method of claim 8, wherein the fine particles are mixed with a solvent including H_2O .

14. The method of claim 8, wherein the fine particles are mixed with a binder including ceria.

15. The method of claim 8, wherein the fine particles are mixed with a solvent including ceria.

16. The method of claim 8, wherein the dissipative ceramic bonding tool tip has a grain size of less than half a micron.

17. A method of making a dissipative ceramic bonding tool tip having a resistance in the range of 10^5 to 10^{12} ohms, comprising:

hot pressing reactive fine particles to form the dissipative ceramic bonding tool tip.

18. The method of claim 17, wherein the step of hot pressing comprises:

mixing fine particles of a composition appropriate for forming a dissipative material with binders and sintering aids into a mixture;

choosing a hot pressing atmosphere to control a valence of dopant atoms;

pressing the mixture in a mold at a temperature high enough to cause consolidation and binding of the particles into a solid structure having low porosity; and cooling and removing the solid structure from the mold.

19. The method of claim 17, wherein the fine particles are mixed with binders and sintering aids.

20. The method of claim 17, wherein hot pressing is performed at a temperature that is between 1000 and 2500 degrees Celsius.

21. The method of claim 17, wherein the fine particles are mixed with a solvent including H_2O .

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22. The method of claim 17, wherein the fine particles are mixed with a binder including ceria.

23. The method of claim 17, wherein the fine particles are mixed with a solvent including ceria.

24. The method of claim 17, wherein the dissipative ceramic bonding tool tip has a grain size of less than half a micron.

25. A method of making a dissipative ceramic bonding tool tip having a resistance in the range of 10^5 to 10^{12} ohms, comprising:

fusion casting fine particles to form said dissipative ceramic bonding tool tip.

26. The method of claim 25, wherein the fusion casting comprises:

melting metals of a composition appropriate for forming a dissipative material in a non-reactive crucible;

casting the melted metals into an ingot;

rolling the ingot into a rolled ingot;

extruding the rolled ingot into an extruded material;

drawing the extruded material into a drawn material;

pressing the drawn material into a pressed material; and heating the pressed material.

27. The method of claim 25, wherein the dissipative ceramic bonding tool tip as a grain size of less than half a micron.

28. A method of using an electrically dissipative bonding tool tip, having a resistance in the range of 10^5 to 10^{12} ohms, comprising:

providing the electrically dissipative bonding tool tip;

bonding a material to a device;

allowing an essentially smooth current to dissipate to the device, the current being low enough so as not to damage said device being bonded and high enough to avoid a build up of charge that could discharge to the device being bonded and damage the device being bonded.

29. The method of claim 28, wherein the bonding comprises:

heating the electrically dissipative bonding tool tip using electrical resistive heating; and

using the electrically dissipative bonding tool tip to melt a bonding material.

30. The method of claim 28, wherein the bonding comprises scrubbing the material laterally to cause the material to flow.

31. The method of claim 28, further comprising establishing a potential between the electrically dissipative bonding tool tip and the device being bonded.

32. The method of claim 31, wherein the establishing further comprises grounding leads on the device being bonded.

33. The method of claim 28 further comprising placing the electrically dissipative bonding tool tip in electrical contact with the device being bonded.

34. The method of claim 33 further comprising feeding wire through a tubular channel in the electrically dissipative bonding tool tip prior to placing it in contact with the device being bonded.

35. The method of claim 28 further comprising:

providing an electrical discharge at the electrically dissipative bonding tool tip to melt a bit of wire, and forming the bit of wire into a bonding ball.

36. The method of claim 35 further comprising causing the ball to make intimate contact with the device, thereby initiating dissipation of charge.

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37. The method of comprising moving the electrically dissipative ceramic bonding tool tip from the device, with wire being fed as the electrically dissipative bonding tool tip is moved, onto a different point of the device.

38. The device of claim 1, wherein the range of 5×10^4 to 10^{12} Ohms of the resistance is limited to 10^5 to 10^{12} Ohms.

39. The method of claim 8, wherein the fine particles are mixed with dispersants.

40. The method of claim 8, wherein the fine particles are mixed with binders.

41. The method of claim 8, wherein the fine particles are mixed with sintering aids.

42. The method of claim 8, wherein the fine particles are mixed with solvents.

43. The method of claim 8, wherein the fine particles are mixed with a binder including magnesia.

44. The method of claim 8, wherein the fine particles are mixed with a binder including yttria.

45. The method of claim 8, wherein the fine particles are mixed with a binder including boron.

46. The method of claim 8, the fine particles are mixed with a binder including a carbon colloidal silica.

47. The method of claim 8, wherein the fine particles are mixed with a binder including an alumina solvent.

48. The method of claim 8, wherein the fine particles are mixed with a binder including ethyl silicate.

49. The method of claim 8, wherein the fine particles are mixed with a binder including a phosphate.

50. The method of claim 8, wherein the fine particles are mixed with a binder including a rare earth metal oxide.

51. The method of claim 8, wherein the fine particles are mixed with a binder including yttrium.

52. The method of claim 8, wherein the fine particles are mixed with a solvent including magnesia.

53. The method of claim 8, wherein the fine particles are mixed with a solvent including yttria.

54. The method of claim 8, wherein the fine particles are mixed with a solvent including boron.

55. The method of claim 8, wherein the fine particles are mixed with a solvent including a carbon colloidal silica.

56. The method of claim 8, wherein the fine particles are mixed with a solvent including an alumina solvent.

57. The method of claim 8, wherein the fine particles are mixed with a solvent including ethyl silicate.

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58. The method of claim 8, wherein the fine particles are mixed with a solvent including a phosphate.

59. The method of claim 8, wherein the fine particles are mixed with a solvent including a rare earth metal oxide.

60. The method of claim 8, wherein the fine particles are mixed with a solvent including yttrium.

61. The method of claim 17, wherein the fine particles are mixed with a binder including magnesia.

62. The method of claim 17, wherein the fine particles are mixed with a binder including yttria.

63. The method of claim 17, wherein the fine particles are mixed with a binder including boron.

64. The method of claim 17, wherein the fine particles are mixed with a binder including a carbon colloidal silica.

65. The method of claim 17, wherein the fine particles are mixed with a binder including alumina solvents.

66. The method of claim 17, wherein the fine particles are mixed with a binder including ethyl silicate.

67. The method of claim 17, wherein the fine particles are mixed with a binder including a phosphate.

68. The method of claim 17, wherein the fine particles are mixed with a binder including a rare earth metal oxide.

69. The method of claim 17, wherein the fine particles are mixed with a binder including yttrium.

70. The method of claim 17, wherein the fine particles are mixed with a solvent including magnesia.

71. The method of claim 17, wherein the fine particles are mixed with a solvent including yttria.

72. The method of claim 17, wherein the fine particles are mixed with a solvent including boron.

73. The method of claim 17, wherein the fine particles are mixed with a solvent including a carbon colloidal silica.

74. The method of claim 17, wherein the fine particles are mixed with a solvent including alumina solvents.

75. The method of claim 17, wherein the fine particles are mixed with a solvent including ethyl silicate.

76. The method of claim 17, wherein the fine particles are mixed with a solvent including a phosphate.

77. The method of claim 17, wherein the fine particles are mixed with a solvent including a rare earth metal oxide.

78. The method of claim 17, wherein the fine particles are mixed with a solvent including yttrium.

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