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(54) **PROBE BONDING METHOD HAVING IMPROVED CONTROL OF BONDING MATERIAL**

(75) Inventor: **January Kister**, Portola Valley, CA (US)

(73) Assignee: **MicroProbe, Inc.**, Carlsbad, CA (US)

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See application file for complete search history.

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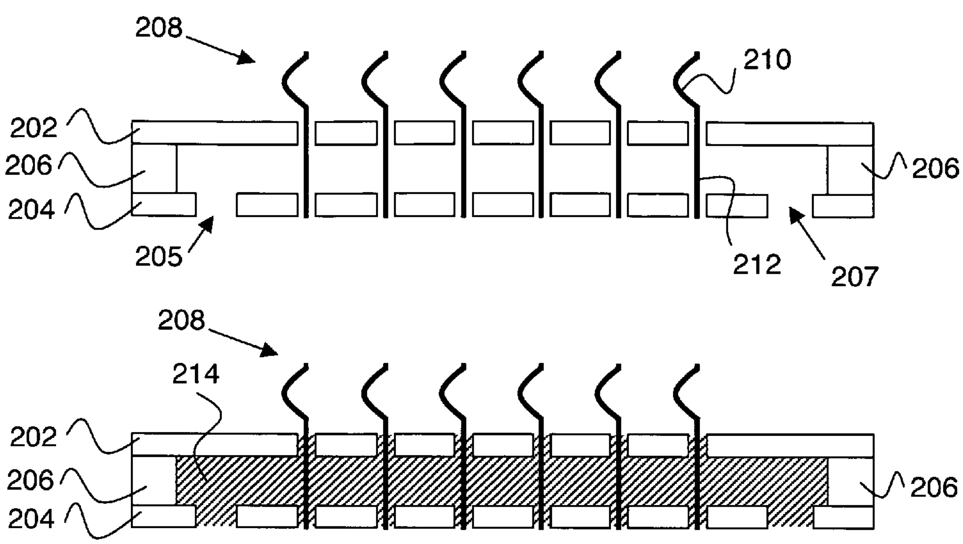
Primary Examiner — Donghai D. Nguyen
(74) *Attorney, Agent, or Firm* — Deborah A. Peacock; Samantha A. Updegraff; Peacock Myers, P.C.

(57) **ABSTRACT**

In assembly of probe arrays for electrical test, a problem can arise where a bonding agent undesirably wicks between probes. According to embodiments of the invention, this wicking problem is alleviated by disposing an anti-wicking agent on a surface of the probe assembly such that wicking of the bonding agent along the probes toward the probe tips is hindered. The anti-wicking agent can be a solid powder, a liquid, or a gel. Once probe assembly fabrication is complete, the anti-wicking agent is removed. In preferred embodiments, a template plate is employed to hold the probe tips in proper position during fabrication. In this manner, undesirable bending of probes caused by introduction or removal of the anti-wicking agent can be reduced or eliminated.

28 Claims, 3 Drawing Sheets



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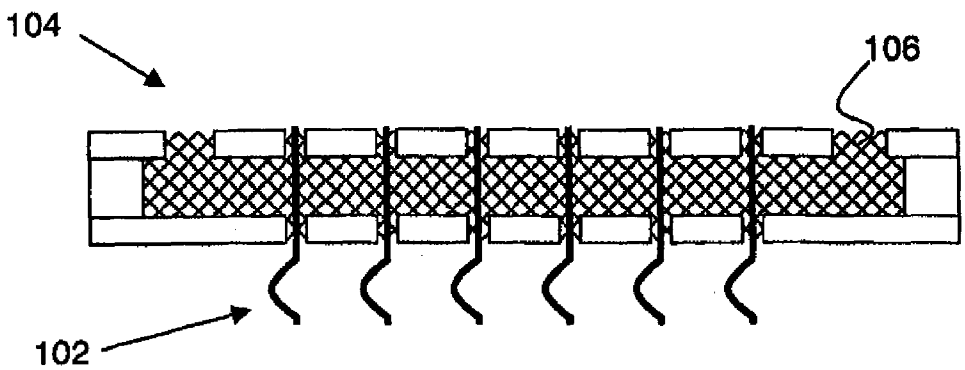

Fig. 1a

Prior Art

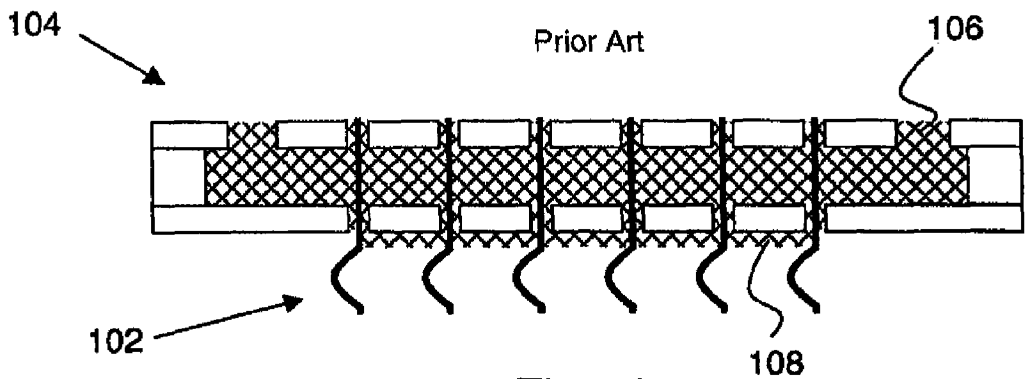

Fig. 1b

Prior Art

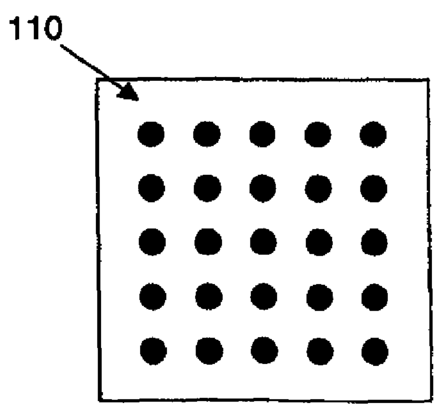

Fig. 1c

Prior Art

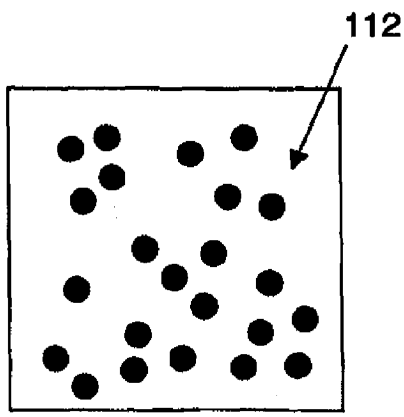

Fig. 1d

Prior Art

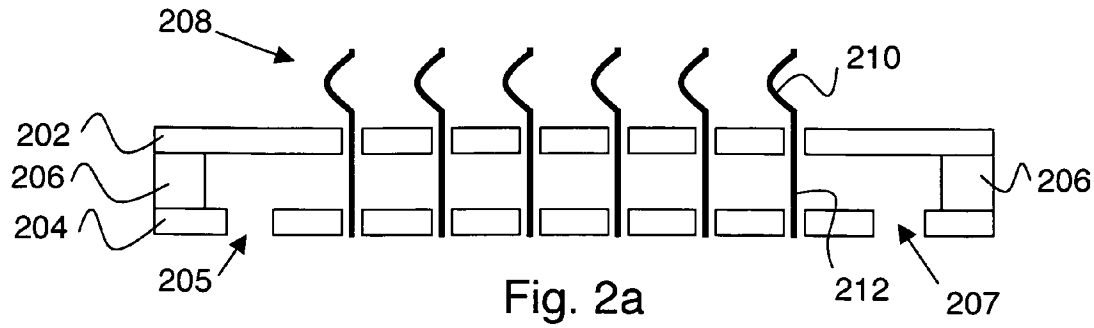

Fig. 2a

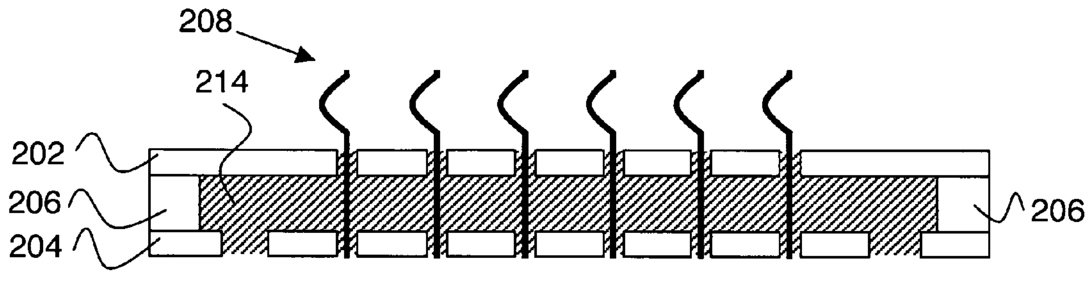

Fig. 2b

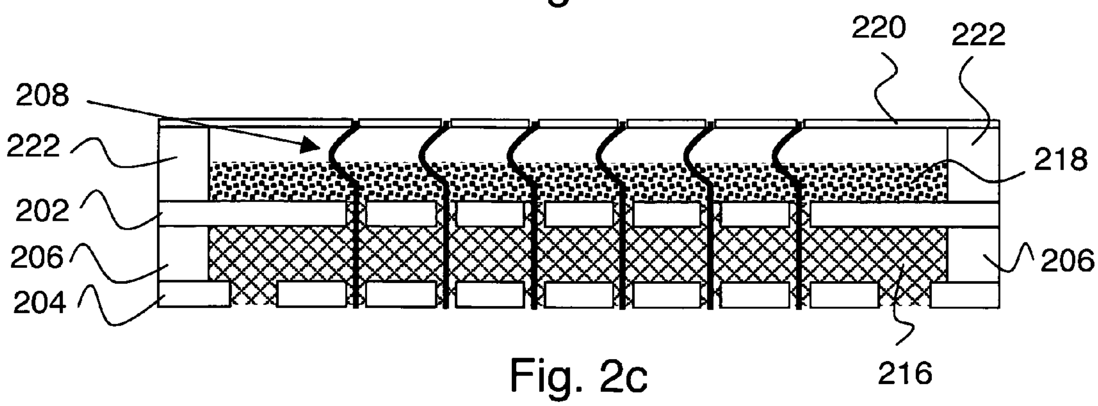

Fig. 2c

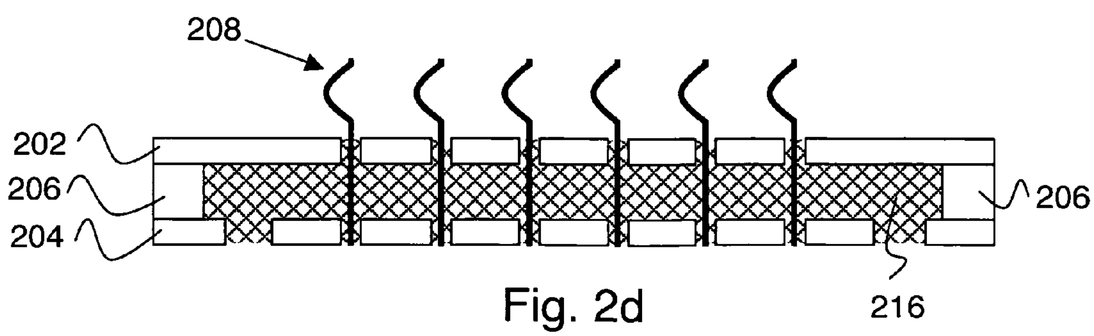

Fig. 2d

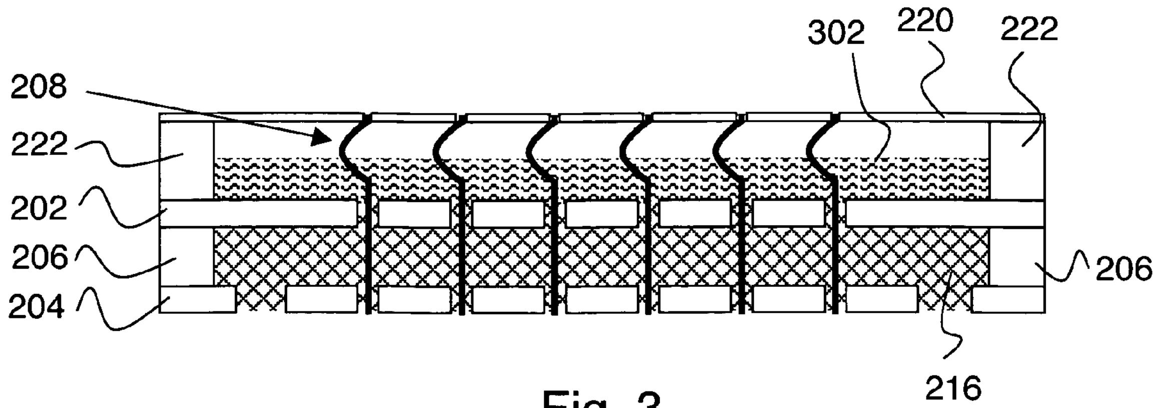

Fig. 3

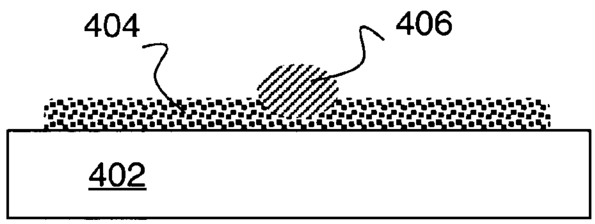

Fig. 4a

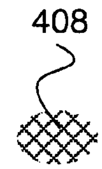

Fig. 4b

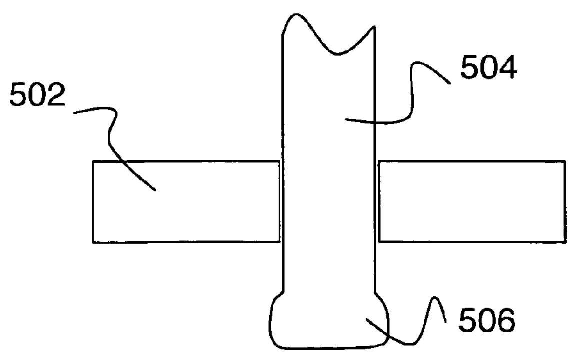

Fig. 5

PROBE BONDING METHOD HAVING IMPROVED CONTROL OF BONDING MATERIAL

FIELD OF THE INVENTION

This invention relates to probe assemblies for making temporary electrical contact to devices or circuits under test.

BACKGROUND

Probes and probe arrangements for making temporary electrical contact to devices or circuits under test have been in widespread use for many years. Accordingly, many aspects of this technology have been developed. Although much of this technological development has focused on details pertaining to the probes, other aspects of probe technology have also been considered. More specifically, probes are typically attached to a probe card, or some other form of substrate, and some work has focused on improvements relating to the probe card/substrate.

For example, in U.S. Pat. No. 6,881,974, a probe card manufacturing approach which starts by forming blind holes in a substrate and filling these holes with an electrically conductive metal is considered. After subsequent processing, part of the metal in the blind holes is exposed to form the probe pins. In U.S. Pat. No. 6,259,261, a probe assembly is considered where a selector card can be employed to determine the pin pattern of the probing card. In U.S. Pat. No. 6,566,898, a multi-layer probe card substrate having an improved thermal expansion match to silicon is considered. In U.S. Pat. No. 6,586,955, a probe assembly having cavities filled with a low melting point metal, which are individually electrically connected to probe tips, is considered. By including a molten or near-molten metal section in each probe, metal fatigue in the probes can be alleviated, and cracking can be avoided or rendered less harmful by self-healing.

However, as integrated circuit technology continues to develop, it is necessary to probe at increasingly fine probe pitch (i.e., reduced probe spacing). This evolution can generate problems that have not apparently arisen in connection with electrical probing before, and which require new solutions.

SUMMARY

One such problem is shown in the example of FIGS. **1***a-d*. FIG. **1***a* shows a probe assembly **104** having probes **102** fixed in position by a bonding material **106** (e.g., epoxy). This kind of probe bonding approach has been considered in U.S. Pat. No. 7,345,492, issued to the present inventor, and incorporated herein by reference in its entirety. It has been found that a wicking problem can arise in connection with this probe bonding approach, as shown on FIG. **1***b*. Throughout this application, "wicking" refers to situations where bonding material ends up being disposed between probes at locations (e.g., **108** on FIG. **1***b*) outside the main bonding cavity of the probe assembly. This wicking is highly undesirable because it typically interferes with proper probe motion during operation.

In investigations to date, wicking has most commonly been observed in irregular probe arrays (e.g., probe array **112** on FIG. **1***d*), where closely spaced probes that are well-separated from other probes in the array tend to experience wicking. In general, probes having relatively large pitch (e.g., lateral spacing 175 μm or more) tend not to exhibit wicking, while regular probe arrays (e.g., probe array **110** on FIG. **1***c*) tend to be relatively well-behaved with respect to wicking (e.g., no wicking seen on a regular probe array having 110 μm probe pitch). However, it is expected that wicking in regular probe arrays is likely to be a problem for pitches of 100 μm or less. It is presently believed that wicking of the epoxies presently used for probe bonding occurs mainly during curing of the epoxy, because the elevated temperature for curing causes a temporary reduction in epoxy viscosity. This reduced viscosity enables the epoxy to more freely flow along the probes, thereby exacerbating the wicking problem.

According to embodiments of the invention, this wicking problem is alleviated by disposing an anti-wicking agent on a surface of the probe assembly such that wicking of the bonding agent along the probes toward the probe tips is hindered. The anti-wicking agent can be a solid powder, a liquid, or a gel. Once probe assembly fabrication is complete, the anti-wicking agent is removed. In preferred embodiments, a template plate is employed to hold the probe tips in proper position during fabrication. In this manner, undesirable bending of probes caused by introduction or removal of the anti-wicking agent can be reduced or eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1***a-b* show a problem that can arise in connection with probe assemblies having closely spaced probes.

FIGS. **1***c-d* show examples of probe arrangements.

FIGS. **2***a-d* show steps of a probe assembly fabrication sequence according to an embodiment of the invention.

FIG. **3** shows an approach for prevention of inter-probe wicking according to an alternate embodiment of the invention.

FIGS. **4***a-b* show steps in a process for evaluating the suitability of anti-wicking materials for practicing embodiments of the invention.

FIG. **5** shows a probe tip template arrangement suitable for use with a preferred embodiment of the invention.

DETAILED DESCRIPTION

FIGS. **2***a-d* show steps of a probe assembly fabrication sequence according to an embodiment of the invention. On FIG. **2***a*, a first guide plate **202** is separated from a second guide plate **204** by a spacer **206**. Guide plates **202** and **204**, in combination with spacer **206**, form a guide plate assembly and define a bonding cavity (i.e., the region between plates **202** and **204** and surrounded by spacer **206**). Guide plates **202** and **204** include holes within which probes are disposed.

More specifically, each of probes **208** has a base section and a tip section. The base and tip sections of one of the probes are shown on FIG. **2***a* as **212** and **210** respectively. The base sections of the probes are disposed in the guide plate holes such that the base sections of the probes pass through the bonding cavity of the guide plate assembly. By way of example, gaps between the probes and the guide plates at the holes are typically between 5 μm and 40 μm, and lateral probe spacing is typically less than about 150 μm.

Typically, the first and second guide plates have corresponding first and second hole patterns that are aligned with each other, so that substantially straight probe base sections fit into the guide plate assembly, as shown. In most cases, all of the probe tip sections face the same way relative to the guide plate assembly, also as shown.

FIG. **2***b* shows the result of filling the bonding cavity with a curable bonding agent **214**. Such filling can be performed by introducing the bonding agent through guide plate holes such as **205** and **207** on FIG. **2***a*. Suitable bonding agents include, but are not limited to: epoxies, thermally set materials, molten plastics and injection molding materials.

FIG. **2***c* shows the result of the following steps:

a) (optional) providing a probe tip template **220** (supported by a frame **222**) and engaging tip sections of probes **208** with the probe tip template (e.g., as shown on FIG. **2***c*) before adding the anti-wicking agent;

b) disposing an anti-wicking agent **218** on a surface of the guide plate assembly facing the tip sections of the probes; and

c) curing the bonding agent after disposing the anti-wicking agent. The cured bonding agent is referenced as **216**. Typically, curing is performed by heating the probe assembly, although other curing processes can also be employed in practicing the invention. The bonding agent and curing process are preferably selected such that the bonding agent viscosity is lower during part of the curing step than before curing is initiated. This combination of properties facilitates elimination of bonding agent wicking according to embodiments of the invention, because wicking is suppressed at points in the process where it would otherwise be most likely to occur (i.e., during curing). Suitable materials for the optional probe tip template include polyimide, ceramics and metals.

FIG. **2***d* shows the result of removing anti-wicking agent **218** after the bonding agent is cured (and of removing the probe tip template in cases where a probe tip template is employed). Anti-wicking agent **218** can be removed by vacuuming, and ultrasonic cleaning can be employed as a final cleaning step.

In the example of FIGS. **2***a-d*, anti-wicking agent **218** is a solid powder. It is important that bonding agent **214** not wick into the solid particles of anti-wicking agent **218**. Various methods can be employed, individually or in combination, to reduce/prevent such wicking. For example, the particles of anti-wicking agent **218** can be compacted during deposition. Another method is to select solid powder materials having surfaces that are not wetted by the bonding agent. For example, talc and starch flour have been found to be suitable anti-wicking agents for an epoxy bonding agent. Fine powders are typically employed for the anti-wicking agent (e.g., particle size about 3 μm). A powder anti-wicking agent having ~3 μm particles has been found to be effective for blocking epoxy wicking through probe to guide plate gaps of about 20 μm. A syringe capable of delivering the solid particles (i.e., having a needle bore substantially larger than the particle size) has been found suitable for delivering and compacting the anti-wicking agent. A commercial programmable epoxy dispenser can be adapted to control the amount of applied anti-wicking powder.

FIG. **3** shows a fabrication step relating to an alternate embodiment of the invention. FIG. **3** corresponds to FIG. **2***c*, except that a gel or liquid anti-wicking agent **302** is used on FIG. **3** instead of the solid powder anti-wicking agent of FIG. **2***c*. In order for a gel or liquid to function properly as an anti-wicking agent, it is preferred that the anti-wicking agent and the bonding agent be immiscible. Suitable gel or liquid anti-wicking agents for practicing embodiments of the invention include silicone based gels and lithography compatible masking fluids. After the bonding agent is cured, the anti-wicking agent can be removed by standard lithographic processes, and accordingly it is preferred for gel or liquid anti-wicking agents to be removable in this manner. In situations where probe assembly fabrication is performed in a clean room environment, it is preferred for the anti-wicking agent to be a gel or a liquid, as opposed to a powder.

FIGS. **4***a-b* show steps in a process for evaluating the suitability of anti-wicking materials for practicing embodiments of the invention. In this method, a drop of uncured bonding agent **406** is disposed on a bed of a candidate material **404** on a substrate **402**. The bonding agent is cured and then separated from the bed to provide a bead **408**. If the surface of bead **408** is smooth and has substantially the same shape as the surface of uncured bonding agent **406** on FIG. **4***a*, then the bonding agent does not significantly wick into candidate material **404** as it cures, and so candidate material **404** may be a suitable anti-wicking agent. If the surface of bead **408** is rough and/or if the shape of bead **408** is substantially different than the shape of bonding agent **406** on FIG. **4***a*, then candidate material **404** (as prepared in this test) is not suitable for practicing embodiments of the invention. This test can be employed to evaluate the suitability of powder, liquid and gel candidate materials for practicing embodiments of the invention. It can also be used to evaluate deposition conditions, such as degree of compaction for a powdered candidate material.

FIG. **5** shows a probe tip template arrangement suitable for use with a preferred embodiment of the invention. More specifically, this figure shows a close-up view of a probe tip section **504** passing through a probe tip template **502** and having a tip **506**. Preferably, tip section **504** is narrower than tip **506**, as shown. The probe can move vertically with respect to the probe tip template, where tip **506** acts as a limit to keep the probe tip template from sliding off during processing. Preferably, all of the probes in the probe array have this feature which prevents the probe tip template from inadvertently sliding off the probes.

One approach for providing such a probe tip template is as follows. A probe template can be made from a polyimide sheet (e.g., 25 μm thick) with rectangular or square holes formed by laser drilling. The hole size is chosen to be slightly larger than the cross section of probe tip section **504** and slightly smaller than the cross section of probe tip **506**, so the probe tip can "click" into the hole with application of a slight insertion force. After assembly and curing of the bonding agent, the template can be removed mechanically by gently pulling it off the probe tips, or chemically or via plasma etch. When mechanical removal is employed, the probe tips sometime mechanically "give" and lose alignment, so the plasma etch removal method is preferred. Plasma etching completely dissolves the polyimide template without changing probe tip alignment.

The invention claimed is

1. A method for fabricating a probe assembly comprising:
forming a bonding cavity;
passing a plurality of probes through the bonding cavity;
filling the bonding cavity with a bonding agent;
disposing an anti-wicking agent on a surface of the bonding agent in the bonding cavity; and
curing the bonding agent in the bonding cavity; and removing the anti-wicking agent.

2. The method of claim **1** further comprising providing a guide plate assembly having a first guide plate separated from a second guide plate by a spacer, the guide plate assembly defining the bonding cavity.

3. The method of claim **2** further comprising disposing holes in the first and second guide plates.

4. The method of claim **3** further comprising disposing the probes in the holes.

5. The method of claim **4** further comprising providing gaps between the probes and the guide plates at the holes between 5 μm and 40 μm.

6. The method of claim **4** comprising lateral spacing of the probes less than about 150 μm.

7. The method of claim **3** further comprising aligning the first and second guide plates using corresponding first and second hole patterns.

8. The method of claim **3** wherein the filling the bonding cavity comprises introducing the bonding agent through the holes.

9. The method of claim **1** further comprising facing probe tip sections the same way relative to the guide plate assembly.

10. The method of claim **1** comprising boding with a material selected from the group consisting of epoxy, thermally set material, molten plastic, and injection molding material.

11. The method of claim **1** further comprising:

providing a probe tip template; and

engaging a tip section of each of the plurality of probes with the probe tip template prior to disposing the anti-wicking agent.

12. The method of claim **11** wherein the probe tip template comprises a material selected from the group consisting of polyimide, ceramic, and metal.

13. The method of claim **1** wherein curing comprises heating.

14. The method of claim **1** wherein removing the anti-wicking agent comprises vacuuming out the anti-wicking agent.

15. The method of claim **1** further comprising cleaning the probe assembly via ultrasonic cleaning.

16. The method of claim **1** wherein the anti-wicking agent comprises a powder.

17. The method of claim **16** wherein the bonding agent does not substantially wick into the powder.

18. The method of claim **1** wherein the anti-wicking agent comprises talc.

19. The method of claim **1** wherein the anti-wicking agent comprises starch flour.

20. The method of claim **1** wherein the anti-wicking agent comprises a powder having a particle size of about 3 μm.

21. The method of claim **1** further comprising compacting the anti-wicking agent.

22. The method of claim **1** wherein the disposing the anti-wicking agent is performed with a syringe capable of delivering the powder.

23. The method of claim **1** wherein the anti-wicking agent comprises a gel.

24. The method of claim **23** wherein the gel comprises a silicone based gel.

25. The method of claim **23** wherein the gel and bonding agent are substantially immiscible.

26. The method of claim **1** wherein the anti-wicking agent comprises a liquid.

27. The method of claim **26** wherein the liquid comprises lithography compatible masking fluid.

28. The method of claim **26** wherein the liquid and bonding agent are substantially immiscible.

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