Improved Vertical Probe Technology for Production Probing on Cu Pillar Bumps

Martin J. Brophy, Chin-Shun Chen, and Keith Quick
Avago Technologies, 4380 Ziegler Rd., Fort Collins, CO, 80525 U.S.A. martin.brophy@avagotech.com

Joe Kuhn
Wentworth Laboratories, 2000 Wyatt Dr., Suite 1, Santa Clara, CA, 95054 U.S.A

Keywords: Cu Pillar Bump, Probe Test, Diesort

Abstract

We describe an improved method for production die probing on the Sn bumps of Cu pillar bump flip chip die. Large area vertical Tungsten hairpin probes were replaced with smaller hardened BeCu vertical probe tips. Much better probe consistency and a reduction in badly probed die were seen.

INTRODUCTION

I charge you by the law,
Whereof you are a well-deserving pillar,
Proceed to judgment….
Shakespeare, The Merchant of Venice, Act. IV, Sc.1

Copper pillar bump flip chip assembly is commonly employed in modern GaAs IC's to shrink module size and lower both assembly and overall product cost.

Cu pillar bumps are plated copper pillars in the 50 – 100 µm height and diameter range topped off by 25-50 µm bumps of an attachment material like solder paste or plated Sn. In assembly, they are flipped over and soldered to their substrates upside down much like surface mount components. This shrinks the module laminate substrate size while allowing very efficient thermal conduction from the wafer top side. That happens through high thermal conductivity Cu rather than along a backside via through a 100 µm thick wafer to plated backside Au metal as commonly done in wirebond GaAs IC's.

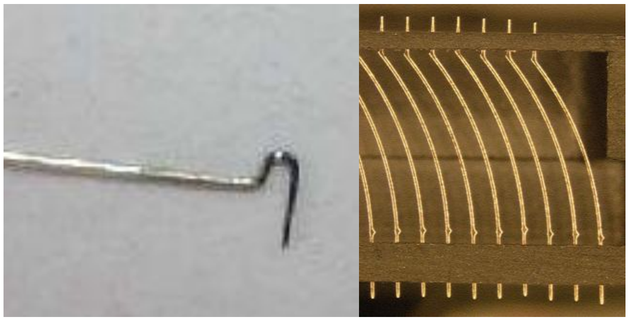

Fig. 1 A single "Hairpin" W probe tip (L) and an array of Wentworth fabricated Accumax® Saber®Probes (R)

Judgment of how "well-deserving" our pillar bumps are comes from diesort probe on those bumps to verify sound electrical connections (and good underlying circuits). That has proven to be not easily done with normal PCM-type cantilever probe cards with BeCu tips which are designed to land and "skate" across Au probe pads to make good contact. The concern is that the top Sn is soft and could be displaced by the horizontal skating of the tip.

Avago had been using "fat" (100 µm diameter) vertical Tungsten hairpin probe tips (see Fig. 1, Left) but using those in production proved to be difficult, so we turned to Wentworth's vertical probe card technology. That uses 75 µm square BeCu fabricated Saber®Probe tips (Fig. 1, Right), with much better probe results as documented below.

CHALLENGES OF DIESORT ON BUMPS

Routine diesort test on these parts would best be done after pillar bump formation so that we can verify all went well with the pillar bump process as well as with the frontside process. But the 1 mil (25 um) angled BeCu probe tips in a cantilever probe card usually used for Au bondpad probing for PCM or diesort test of wirebond HBT parts are not well suited for that. Those tips leave damaged solder where the tip skated across the bump and can potentially tear the bump off the pillar. Vertical probe tip geometries do not have that "skate" and are thought to be a better approach.

As mentioned, our first solution (and the one we still use for quick-turn probecards for test development) involved 100 µm diameter W vertical flat-bottomed probes. Tests of probe contact resistance showed a few Ohms as typical with high variability (compared to a quiet 0.15 Ohms for PCM test[1]). This translated into high false failure rates in production test, often showing a probe pattern in single-site diesort test (Fig. 2). Only with very frequent probe tip cleaning, as much as every 50 touchdowns, did we see satisfactory results.

Wentworth vertical probe cards were seen as a possible better alternative to this probe approach. They use a hardened BeCu 75 µm diameter Saber®Probe tip to

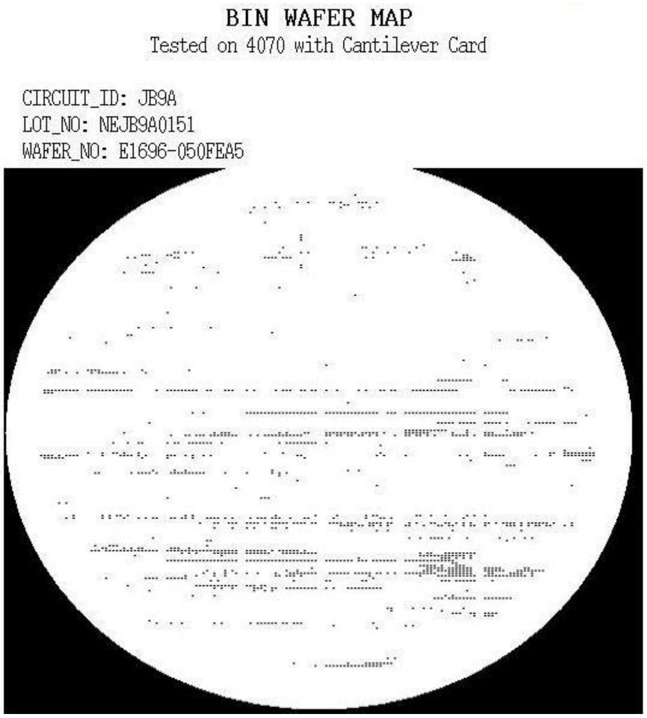

Fig. 2 Probe Pattern False Fails with Old Style Card, single site test. Failing die shown as black spots – in linear array as card picks up temporary debris from probing.

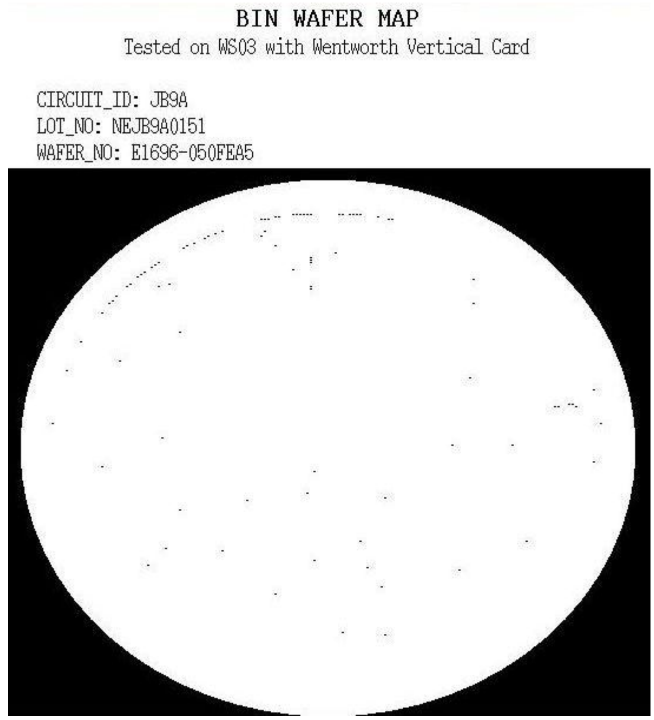

Fig. 3 Same Wafer as Fig. 2 quad-site Tested with New Style Card – no probe card pattern of false fails seen.

vertically contact the bumps. The probes are micro-fabricated rather than stamped for higher precision. The probe head is directly mounted to the Probe Card PCB allowing the Saber®Probe to make direct contact to the PCB trace. This provides a very low resistance path from tester to device.

These tips appear to not get dirtied and cause poor contact as quickly as the W vertical probe tips. This was probably related to the different probe material and to the difference in required overtravel. The old tips needed about 120 um overtravel whereas the new ones only used about 75 um for reasonable probe contact resistance. The new tips yield much cleaner quad-site diesort maps as shown in Fig. 3 below on the same wafer tested the old way in Fig. 2.

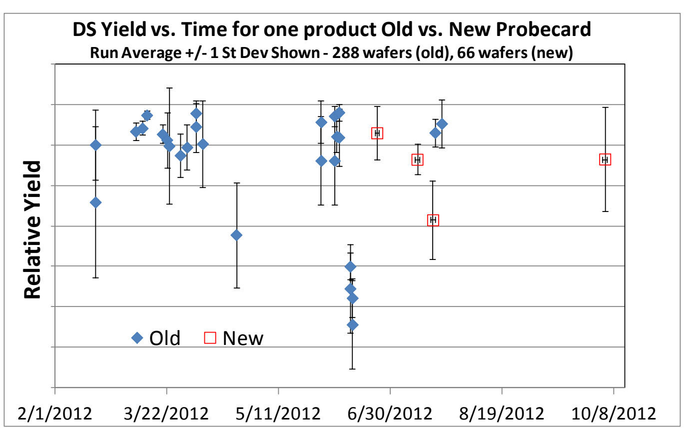

Fig. 4 Relative Diesort Yield Trend for an HBT PA over the transition period to new probecards.

NEW CARDS IN PRODUCTION

In production, throughput as well as test reliability is considerably better with the new cards. Quad site test with probe cleaning every 750 touchdowns was seen to be sufficient compared to a nominal clean frequency of once every 100 touchdowns for the W hairpin cards (and often more frequent than that because we use adaptive cleaning after more than 5 die fails in a row).

Relative diesort yield over several months straddling the probe card change is shown in Fig. 4. The improvement in both yield and consistency of yield is clear in the decrease in very poor yielding lots. The worst yielding runs with the old card are believed to be probing errors. We learned that it is possible to get better behavior from the old cards, as seen in the improved later points for the old probe cards in Fig. 4, but that requires very frequent tip cleans – as often as every 50 touchdowns. That is a very uneconomical approach because of much higher test times. We continue testing with the new approach to date with stable improved results on several products. Retest rates were also reduced.

The new probe cards are more complicated to design and fabricate and thus are more expensive. They also have longer lead times than simple cantilever cards, so they are best for production testing rather than for development of diesort tests. In production, the probe tips are expected to have lifetimes of more than 4 million touches. The probe head can be repeatedly rebuilt, and is expected to last 8 – 16 million touches. This can be compared to typical lives of 1 million touches for the W hairpin cards. We believe the excellent longevity and better contact reliability of the new probe cards overcomes initial higher cost to give a lower cost per yielded die.

PHYSICAL BUMP DISTORTION FROM PROBE

One can probe Cu Pillar Bumps before or after reflowing (and thus rounding) the solder bumps as happens during die mount. Probing the un-reflowed bumps would allow for test of 130 um minimum pitch bumps using spade tip Saber®Probes (vs. 150 um pitch for the square tips). However, by doing that one would lose the ability to assess the final pillar bump coplanarity, which includes a contribution from reflow, right after pillar bump formation. For that reason, we have adopted the convention of probing reflowed bumps with flat tip probes. That will be revisited as we require tighter pitch pillar bumps.

Questions that arise are how much the bump gets physically distorted by probing, and whether that affects the quality and ease of assembly. To assess the first question, we measured bump heights before and after probing with our Camtek[2] bump height mapping tool. Our diesort test does not use two of the round bumps, so knowing relative heights before test (not probed bumps statistically are about 0.4 um lower) and comparing their heights after test with the heights of the other round bumps which are probed shows how much the probe tips flattened the bumps.

Typical results in Fig. 5 show that the bumps are squashed down only about 3-4 microns (and made more uniform, see reduced standard deviation) from probing with the old W probes. Tests of the new probe cards with more than 640,000 probed bumps vs. more than 210,000 not-probed bumps show that the new probe tips squash down the bumps only about 1 micron.

Side by side tests of assembly of probed and un-probed Cu pillar bump parts have shown no discernible difference in assembly quality or module reliability related to having probed the bumps on the die.

CONCLUSIONS

Vertical Accumax® Saber®Probe technology was seen to be a superior way to do production GaAs diesort test of Cu Pillar Bump wafers. Simple W hairpin vertical cards are better for limited time use in test development, but do require very frequent probe cleans. In either case, vertical probe contact is important to minimize damage to the soft top bumps.

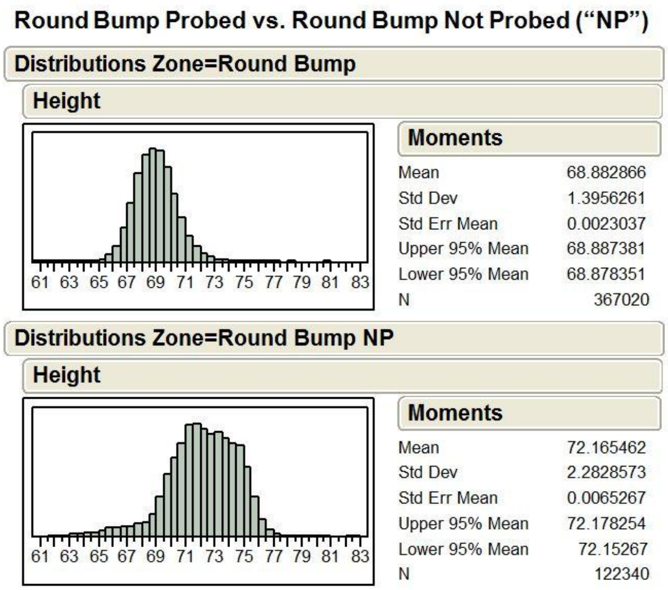

Fig. 5 Bump height distributions before and after probing with W Hairpin probes.

6b

ACKNOWLEDGEMENTS

The authors would like to thank Judy Huggenberger and Susan Shore for their help taking some of the measurements shown, Mark Madrid for Product Engineering help, and Andrew Nott of Alpha Probes, Colorado Springs, for the left picture in Fig. 1.

REFERENCES

1. "Real-time Validation of Probe Contact Quality in GaAs PCM Testing", Brophy et al, 2013 CS Mantech Conference Proceedings
2. That tool is a Camtek Condor 302M. See http://www.camtekusa.com/ for more information.

ACRONYMS

PCB – Printed Circuit Board
PCM – Process Control Monitor