

A New Technique for Testing Copper Stud Bumps

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Abstract

We describe a technique to evaluate stud bump pull strength where the bumps are made from copper. The method uses a DAGE 4000 bond tester equipped with a CBP100 load cell and customized jaws. Results show that the bond strength can be assessed reliably and reproducibly. Data will be presented showing the bond strength of particular examples and the types of failure mode. Evaluation of these bumps is an essential part of the quality assurance for the flip chip products in which they are used. Previously these stud bumps were made from gold and its softness precluded the use of pull. Only shear testing could be used. Pull would be the preferred technique as a simple tensile load is applied to the bond. The extra resilience of copper permits the use of pull jaws to grip the material and exert a load. It is possible that this technique might be extended to first ball bonds where copper is substituted for gold.

Key words: Copper stud bumps, pull, bond testing

Introduction

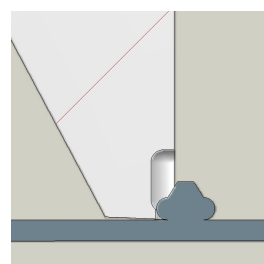
Copper is finding increasing use as an interconnect material; as studs, pillars and also as first ball bonds, replacing the use of gold in these applications. Testing the mechanical integrity of these bonds is an important part of manufacturing quality assurance. For the gold interconnects the traditional means of mechanically testing has been shear testing. This has always been somewhat of a compromise as it is considered that tensile loading would be more representative of the loads to which bonds are subjected. Unfortunately the high compliance of the gold bonds makes it very difficult to grip them and effectively apply the load. But the greater stiffness of copper may allow tensile testing.

The work described here shows that pull testing is indeed feasible on small copper stud bumps. Tiny jaws can be designed to grip the bumps and vertical loads applied with an appropriate load cartridge. Consistent failure forces are measured and reproducible failure modes observed.

Method and Equipment

The sample consisted of a small test coupon with eleven copper studs, approximately 90µm in diameter and 30µm high. These studs have been formed in the normal ball bonding process, but the wires have been flamed off. The bonds appear to be attached to copper pads on bare silicon.

Tensile tests were carried out using a DAGE 4000 bond tester fitted with a CBP/TP100 load cell. The load cell, designed to measure forces up to 100g



was equipped with customized jaws (cavity size approximately 100µm). When closed, the two halves form a cavity approximately the size of the bump. The base of the cavity in each jaw has a very slight lip which facilitates gripping of the base of the bump where it curves towards the pad.

Closing of the jaws is achieved using an air operated collet mechanism. It is important that the clamping pressure is established carefully by incremental increases in the pressure from a low value and testing the ability to pull the bump after each change. The reason for this care is that pulling copper bumps is very different from compliant materials such as gold or solder (both tin-lead and lead-free). In the latter cases, an express function of the clamping pressure is to reform the shape of the bump in order to form a mushroom head which allows the load application of the load through the special shape of the jaws. Too much pressure will crush the bump, but is unlikely to break the jaws, but this is a very real danger with the stiffer copper bumps. A benefit of the current technique is its simplicity compared with that described above for conventional solder bumps. Essentially the clamping pressure here serves to provide a friction fit of the jaws on the bump. With these particular bumps and jaws, the clamping pressure was 1.75bar. This parameter must be ascertained for any particular combination of jaws and bumps.

Other parameters for the testing are the test speed – 500 μ m/s and the landing force – 10g.

The test procedure is very simple. Once the sample has been firmly clamped in a work holder mounted on an XY-stage, the jaws are aligned over the bump (but not touching the substrate) with the aid of a microscope, and the test initiated. The principal output of the test is the failure force, coupled with observation of the failure mode.

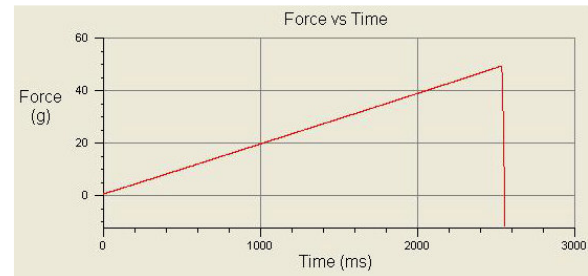
Results

Three sets of readings were collected, with at least 15 tests in each. Each set was done at a different test speed.

Test speed – μ m/s	Force - g	Standard deviation	Range
500	50	11	32-75
1500	52	11	33-70
4000	51	15	32-79

Note the consistency of the failure force across the different test speeds; however the higher speed does increase the variance, so the lower speed would be recommended.

The following force versus time curve shows a typical test; a steady rise in force as the load is applied and an abrupt fall as the bond fails at the peak load.



Graph 1 – Force time curve for a typical test

All the failure modes for this particular sample are similar; the bump is completely removed exposing the substrate underneath. Occasionally there appears to be some damage to the substrate itself.

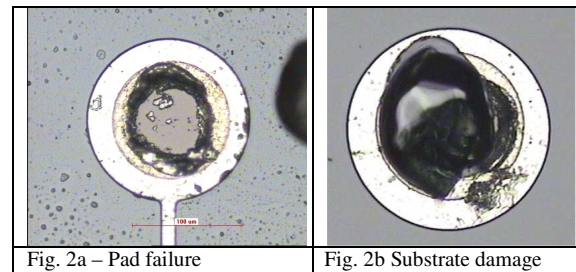


Fig. 2a – Pad failure

Fig. 2b Substrate damage

Conclusions

The current work demonstrates the feasibility of pull testing for copper interconnects, in this instance, stud bumps. This provides an alternative to shear testing for assessing the mechanical quality of these interconnects.

Unlike cold bump pull, the jaws do not interact with the bump to reform it, but grip it in a friction fit. Different shapes of copper interconnects may require slight modifications to jaw design.

Acknowledgments

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