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Ball bond shear testing

ADVANCED SHEAR TOOLS FOR GOLD BALL BONDS

BY ROBERT SYKES

The mainstay procedure for testing gold ball bonds in the semiconductor and microelectronics manufacturing industries has long been shear force methods that use chisel tools. Although the use of chisel tools for measuring the integrity of bonds between gold balls and their mating pad is generally considered reliable, it is not without its limitations. Specifically, the accuracy and quality of the bond strength test data can degrade when attempting to measure higher bond strengths, and the procedure is also highly sensitive to step-back height (the clearance between the tool tip and the bond substrate). Moreover, the maximum test force that can be successfully applied to a sample is often too small to produce a sufficient test resolution and an accurate measurement of bond strength and failure mode behavior.

A New Shear Test Method

To directly address these problems, a new method of shear testing — called “cavity” shear testing — has been developed.[1] The method was developed to improve the quality of data obtained during gold ball bond shear testing, and it is useful to compare existing chisel-based shear test methods to the new cavity shear approach. This will also provide a perspective on the basic mechanics underpinning gold bond testing.

One of the primary goals of all bond test equipment is to produce the maximum test force possible to maximize failure mode resolution. It makes sense that a system with the capability to test at the maximum force has the potential to provide much more information on the strength of the bond(s).

In the case of wire pull, for example, the ultimate tensile strength of the wire will govern the maximum load that can be applied to the bond. However, if the pull hook is poorly designed, it could reduce this maximum load.

In a similar manner, a traditional bond test shear tool (Figure 1a) deforms the ball before a significant force is applied onto the bond. In many cases, the ball fails before the bond. The “cavity” shear tool shown in Figure 1b, however, has a curved cavity to reduce the ball deformation and thereby increase the maximum possible force that can be applied to the bond.

The typical deformation of gold balls is shown in Figure 2. The samples in the pictures were shear tested to 95 percent of the mean bond strength, so that the ball is deformed but the bond did not fail. It can be seen that the deformation with a chisel tool changes the shape of the ball more markedly compared to that produced by the cavity tool.

Test Results

The enhanced test performance of the new cavity tool design can be illustrated by analyzing the test results from two samples, Sample A (a 70 µm diameter ball) and Sample B (a 60 µm diameter ball). For the tests, the type of tool used was alternated between adjacent balls to minimize the effect of natural variations in the sample. The samples were also tested at different step-back heights.

In all cases, the ultimate failure mode was separation at the intermetallic zone, shear through the gold or a combination of both. For each test, the area of gold sheared and left on the substrate as a percentage of the total bond area was estimated visually. When no gold is left on the pad, the bond has failed; this is considered a “good” test, as the test data relates solely to the strength of the bond. Conversely, when gold is left on the pad, the entire bond wasn’t tested and the information on the bond strength is corrupted. In cases when the bond site is left completely covered with gold, the test result relates only to the strength of the gold. Both of these situations are considered to be “bad” tests. As the load is applied to the bond through the gold ball, the

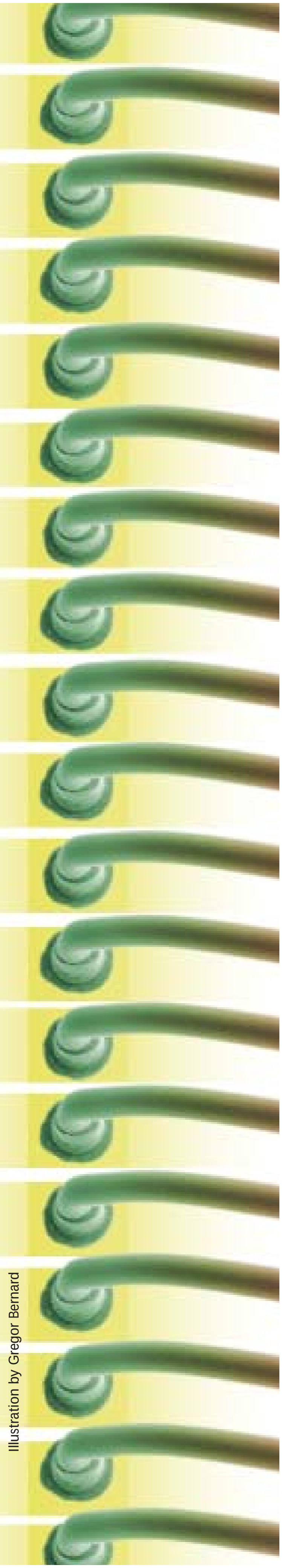
Illustration by Gregor Bernard

Reprinted with revisions to format, from the May 2002 edition of **ADVANCED PACKAGING**

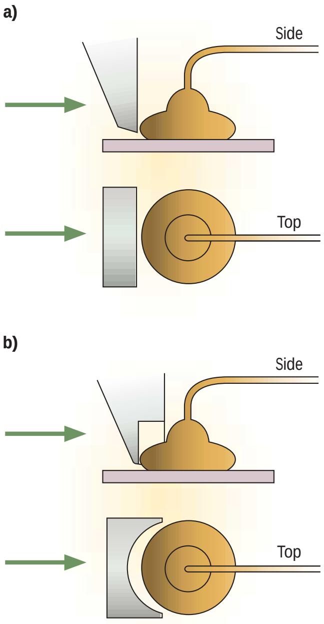

Figure 1. Diagrams showing the side and top views of ball bond shear testing using (a) a standard tool and (b) a cavity tool.

strength of the ball will ultimately limit the maximum bond strength that can be successfully measured. However, the tool design also has major impact on the test results, and it will be seen that the cavity tool can test to higher bond strengths before the quality of the data becomes corrupted.

Figure 3a illustrates the percentage of "good" tests (i.e., those where no gold is left on the pad) for samples A and B. It can be seen that the cavity tool produced more good test results.

This is also illustrated in Figure 3b, comparing the mean percentage of gold left behind. The cavity tools on average left significantly less gold on the pad. Up to a 4 µm step-back, the maximum mean percentage of gold left with the cavity tool was only 4.75 percent. This low value would have much less of a detrimental affect on the bond strength data than the corresponding values that would be obtained from using a chisel tool.

As shown in Figure 2a, there is substantial ball deformation when a chisel tool is used. When the ball deforms a thin layer of gold is left behind on the pad, under the edge of the advancing tool. At the same time, the load on the bond in front of the tool increases until it exceeds its strength and the bond fails. At typical step-back heights, the tensile strength of the gold behind the tool is less than its bond strength, causing the gold to tear. This part of the ball remains on the pad with its portion of the bond strength untested.

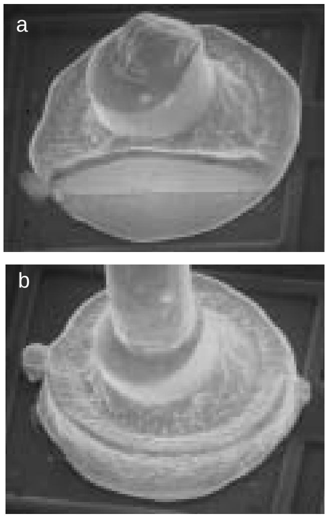

Figure 2. Typical ball deformation (70 µm diameter) at 95 percent peak load with a) a standard chisel tool and b) a cavity tool.

Because only part of the bond area has been tested, the measured bond strength will be less than the real value. This is illustrated in Figure 3c, where the mean test results for the chisel tools were between 9 and 4 percent less than when measured with the cavity tools. This, of course, does not mean that the bond strength is increased when the cavity tool measures it. Rather, the bond strength is more accurately measured.

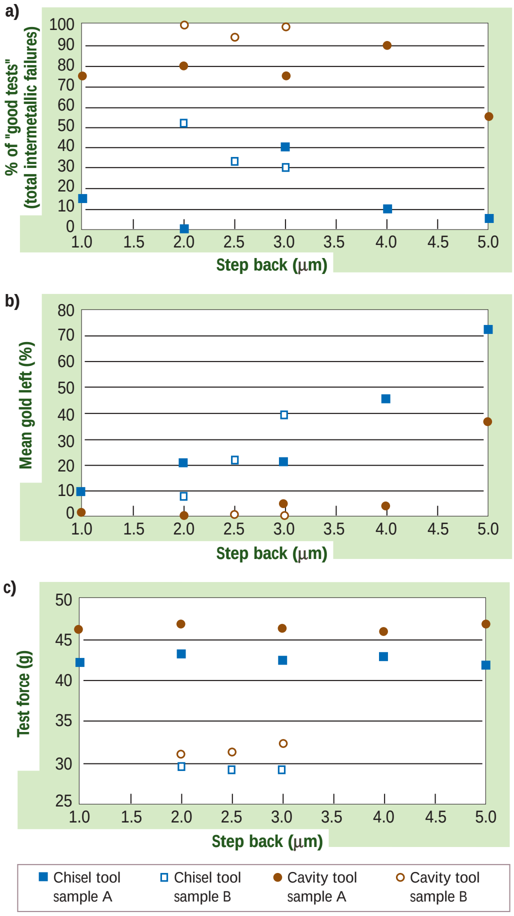

Figure 3. a) Percentage of "good tests" (no gold left); b) the mean percentage gold left vs. step-back for different shear tools; and c) mean test result vs. step-back for different shear tools.

Failure Modes

When a chisel tool is used, ball deformation often affects the failure mode. This initial deformation and subsequent failure mode can be significantly affected by the step-back height. As the step-back is increased, the amount of gold left increases and the quality of the test result decreases. With the cavity tool, its curved shape supports the ball and the initial deformation is less. Consequently, more total bond failures occur and the effects of step-back are reduced. This is evident in Figure 3b, where the percentage of gold remaining (the untested portion of the bond) is much lower and consistent for the cavity tool.

Although the chisel tool remains a useful gauge, if the maximum possible accuracy is required, a cavity tool is likely to be better. Compared to existing chisel-based techniques, cavity shear testing delivers a significant increase in the accuracy and quality of the bond strength test data, reduces the sensitivity to step-back height, and allows a substantial increase in the test force applied to the bond.

Bond strength per unit area will only continue to increase as bumps on wafers and chip scale packages continue to decrease in size. Therefore, the cavity shear test could quickly supersede existing shear test techniques as they increasingly fail to deliver an acceptable level of test accuracy and reliability in gold ball bond testing.

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References

1. Patent application U.S. 09/564171; Japan 00-135142.

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