A NEW WAY OF SHEAR TESTING GOLD BALL BONDS

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Biography

Robert Sykes is the Mechanical Design Manager for Dage Precision Industries Ltd and has worked in the Electronics Industry for twelve years. The majority of this time has been spent on designing and developing test equipment for many different types of interconnections and pick & place machines for surface mount assembly. He also has several years experience in design, project management and sales in a variety of industries not related to electronics.

Educated at Coventry University (England) he has an Honours Degree in Mechanical Engineering. Professional qualifications include membership of the Institute of Mechanical Engineers and a Royal Charter from the Engineering Council.

Abstract:

Historically, the integrity of the bond between gold balls and their mating pad has been tested by applying a shear force to the ball. A newly developed method of shear testing is described that significantly improved the quality of data obtained for a range of samples tested.

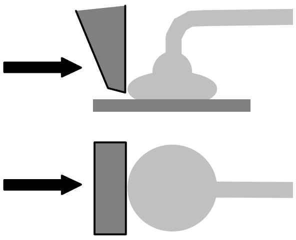
Principally, a new shear tool design is used with the following advantages.

- A marked increase in the number of bonds to fail at the gold to pad interface (Inter-metallic).
- A substantial increase in the test force applied to the bond.
- A reduction in the sensitivity to step-back height.

Data:

Introduction

A new shear tool design has been developed that may be superior to the current industrial standard, “Chisel” tool.



Standard gold ball chisel tool in plan and elevation.

Figure 1. *Schematic views of standard shear test.*

One aim of bond test equipment is to produce the maximum test force possible. For example in the case of wire pull, the ultimate tensile strength of the wire will set the limit to the maximum load. However, if the pull hook is poorly designed, it could reduce this maximum load. A system that has the capability to test at the maximum force has the potential to provide more information on the strength of the bond(s).

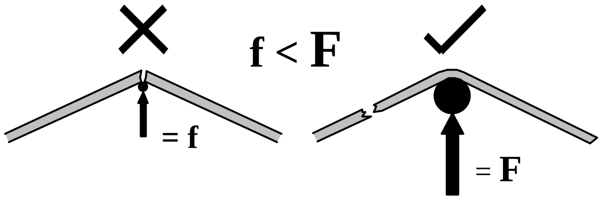
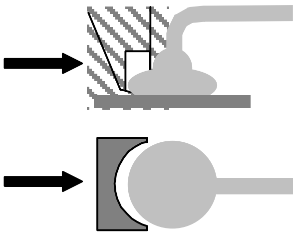


Figure 2. *Two schematic views of pull tests. In the first view the hook diameter is too small. In the second view the hook diameter is optimised to suit the wire being pulled.*

In the example shown in figure 2, the gold wire is broken by the small hook cutting into it. In a similar manner a standard shear tool deforms the ball before a significant force is applied onto the bond. In many cases the ball fails before the bond. The new shear tool, shown in figure 3, has a curved cavity to reduce the ball deformation and thereby increase the maximum possible force that can be applied to the bond.

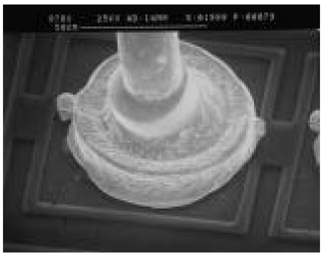


New “Cavity” tool in plan and sectional elevation.

Figure 3. *Schematic views of “cavity” shear test.*

The typical deformation of gold balls is shown in pictures 1 and 2. The samples in the pictures were shear tested to 95% of the mean peak bond strength. It can be seen that the deformation with a chisel tool changes the shape of the ball more than the cavity tool.

Picture 1. *Typical ball deformation at 95% peak load with a chisel tool. Ball diameter 70mm.*



Picture 2. *Typical ball deformation at 95% peak load with a cavity tool. Ball diameter 70mm.*

Comparing test data derived using Chisel and Cavity tools.

To evaluate the performance of the new tool design tests were conducted with a chisel tool and a cavity tool on the same sample. The type of tool used was alternated between adjacent balls to minimise any variation in the sample. Tests were conducted at the step-back heights of 1,2,3,4 and 5µm.

In all cases the failure mode was either separation at the inter-metallic 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 visually estimated. Three examples of this are illustrated in figure 4. The mean percentage for each tool type at each step back height is shown in graph 1.

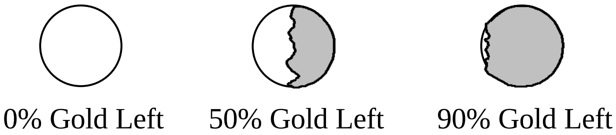
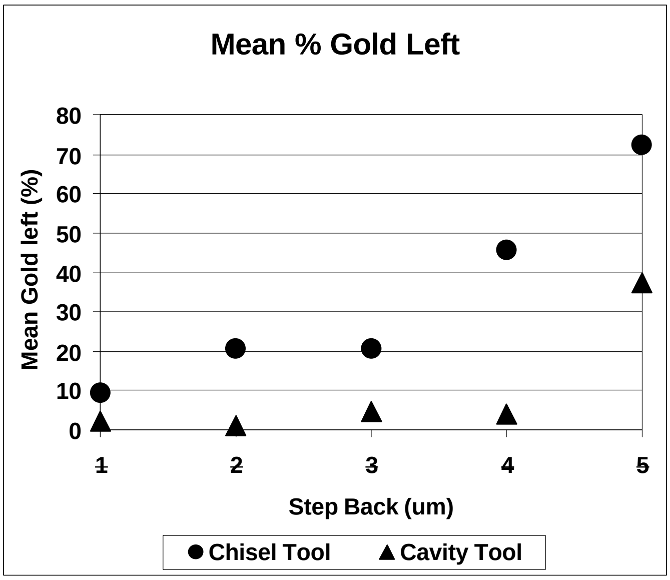
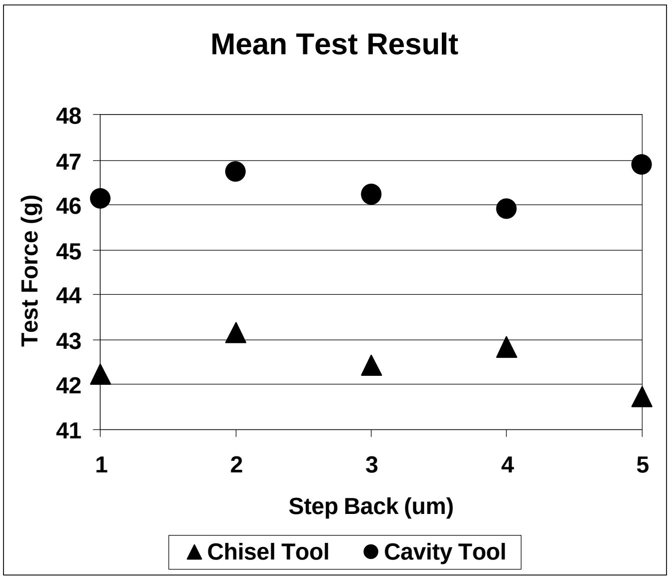


Figure 4. *Sketch illustrating how a variable amount of gold is left on the pad after testing.*



Graph 1. *% Gold left Vs Step back.*

The Mean Test Result for each tool type and step back height is shown in graph 2.



Graph 2. *Mean test result Vs Step back.*

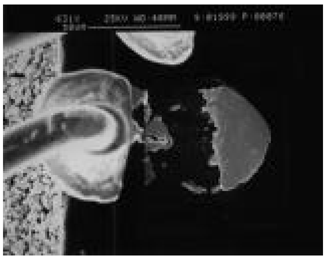
It can be seen from graph 2 that the mean test result for the cavity tool is higher than that for the chisel tool. On average the cavity tool test forces are 9% greater than the conventional chisel tool.

It is believed that the increase in the force applied to the bond results in a higher percentage of inter-metallic failures, shown by the mean percentage gold left. In addition, table 1 shows the percentage of total inter-metallic failures (0% gold left) for each test. As a result of the increased loading on the bond, the cavity tool produced many more totally inter-metallic failures.

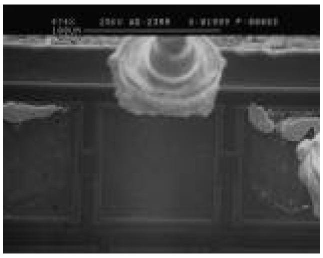
Step back	**% of Tests With No Gold Left** i.e. Total inter-metallic failure	
(um)	Chisel Tool	Cavity Tool
1	15	75
2	0	80
3	40	75
4	10	90
5	5	55

Table 1. *% Tests with no gold left Vs Step back.*

The tendency to produce many more totally inter-metallic failures is illustrated in pictures 3 and 4.



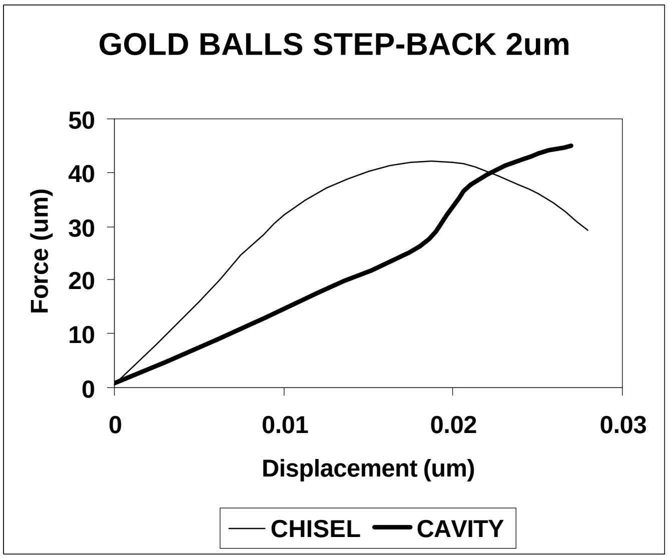
Picture 3. *Typical bond failure with chisel tool. Bond sheared from right to left of picture. Ball diameter 70mm.*



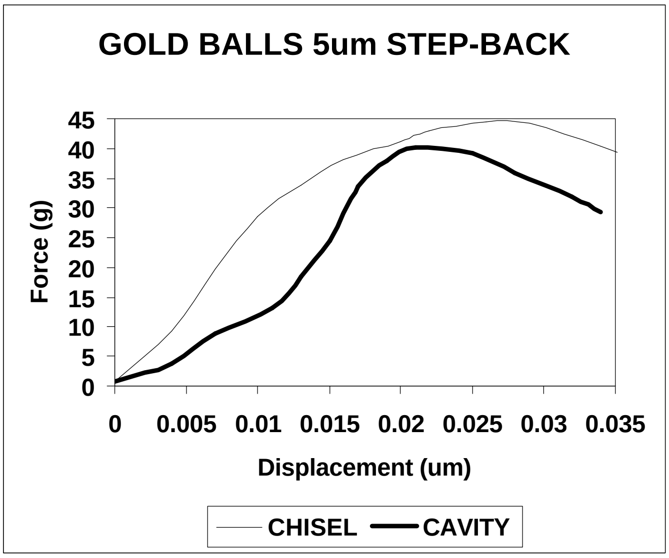
Picture 4. *Typical bond failure with cavity tool. Bond sheared from bottom to top of picture. Ball diameter 70mm.*

Up to 4μm step back the percentage gold left (Graph 1) and number of totally inter-metallic failures (Table 1) with the cavity tool is much more consistent. This consistency is an indication that results using a cavity tool are less sensitive to variations in step-back height.

Typical force displacement curves for the tests are shown in graphs 3 and 4. In the 5μm step-back example the peak force for the cavity tests are less than the chisel. Whilst the mean result from cavity shear was always higher than that for chisel shear, this was not always the case for individual tests. The tests selected to show the force displacement curves were chosen randomly and resulted as shown.



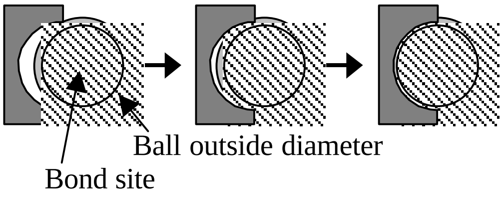
Graph 3. *Force Vs displacement for 2mm step back*



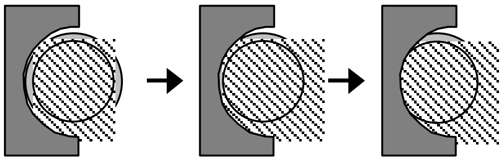
Graph 4. *Force Vs displacement for 5mm step back*

It can be seen from the force displacement curves, graphs 3 and 4 that the force for the cavity tool rises slowly at first, but its maximum slope is steeper than that of the chisel tool. The reason for this is thought to be as follows. In most cases the ball diameter will not be a perfect match with the cavity. As the load is applied, the ball is initially reformed by the side walls of the cavity. This initial reforming offers little resistance and is the first part of the curve where the slope is shallow. Once fully formed into the cavity the force rises more rapidly and the bond starts to yield, typically before the tool cuts into the gold above the bond site. This effect is shown in figure 5 for the three most likely mismatches between the cavity and the ball.

Cavity smaller than ball diameter



Cavity larger than ball diameter



Cavity miss-aligned to ball

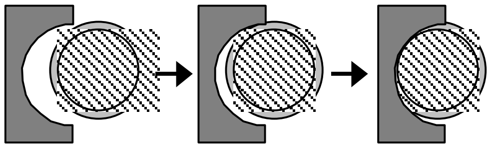


Figure 5. Ball deformation during cavity shear

During a typical chisel tool test the ball is deformed so that the tool cuts into the gold above the bond site, as illustrated in figure 6 and picture 3.

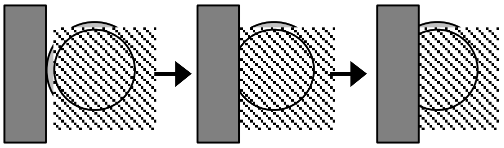


Figure 6. Ball deformation during chisel shear

The sectional view of a ball at the point of yield/bond failure, using a chisel tool, is thought to be as shown in figure 6.

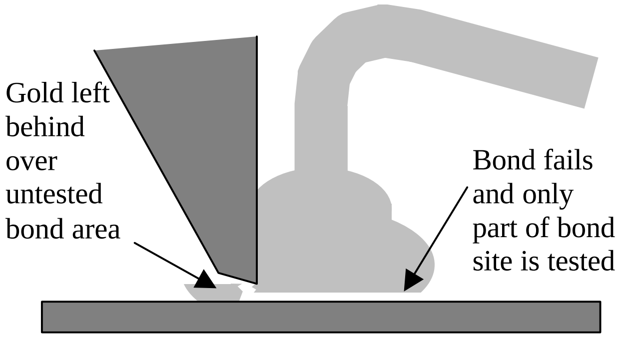


Figure 6. *Sectional view through ball bond at yield/bond failure using a chisel tool*

As the step-back is increased the percentage of gold left on the pad also increases. With step-backs above 4 micron it is common for the failure to be gold shear only, leaving the inter-metallic bond untested. This effect is more pronounced with the chisel tool than the cavity tool. This is thought to be for the following reason. At any point during a test either the gold can continue to deform, or the remaining bond area forward of the tool can fail. The balance of forces is thought to be as shown in figure 7.

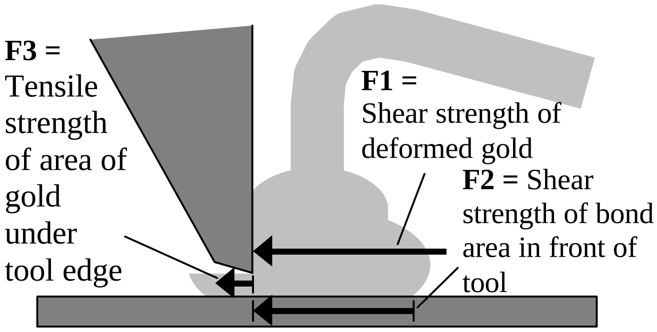


Figure 7. *Sectional view through ball bond showing the balance of internal forces in the ball and at the bond site*

If, F1>F2+F3 the bond in front of and gold under the tool will fail, leaving the gold behind the tool attached to the pad.
If, F1<F2+F3 the gold will continue to shear leaving the bond untested.

As step-back is increased F3 increases because the area under tension is larger. It is suggested that for low step-back heights F1>F2+F3, but at about 4 microns step back F1<F2+F3 (for chisel tools).

At the point of failure, F1 for cavity shear tools is greater than it is for chisel tools. The value of F1 is directly proportional to the cross sectional area of the gold ball in front of the tool and cavity shear tools take advantage of this. This is because the test force is distributed over the longer curved contact surface between the tool and the ball, so ensuring that for a given test force there is less deformation of the ball and a greater area of gold remains to resist shear. We can see from graph 1 that this results in a reduction in the percentage of gold left on the pad. In addition, a force greater than the total bond strength also occurs more often before the tool deforms the ball above the bond site, increasing the incidence of total bond failures.

Validation of the results.

The results published in this paper have been independently reproduced by a third party testing different samples.

Patents

The design and test methods discussed in this paper are the subject of a Dage Precision Industries Ltd patent application, number GB9910362.4

Conclusion:

1. Cavity shear tools produce higher maximum test forces and therefore have the potential to provide more information on bond strength than a conventional chisel tool.
2. The mean test force for the cavity shear tool was 9% higher than the chisel tool.
3. The cavity tool produced a minimum of 35% and a Maximum of 80% more totally inter-metallic failures.
4. The cavity shear tool test results were less effected by variations in step back height.

Acknowledgements:

The author would to thank all of his colleges at Dage Precision Industries Ltd for their support and assistance during the development of the “Cavity Shear” test method.