Camera-assist automation for bond testing of MEMS interconnect

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The term MEMS (microelectromechanical systems) appeared and started gaining popularity in the mid-80s. MEMS refers to a complete system on a single platform that consists of both mechanical and electrical/electronic components. This permits the system to incorporate both the sensors (e.g., pressure meters or accelerometers) and the control/reporting electronics on a single chip within the Si wafer. MEMS have enjoyed a tremendous growth in recent years because of the continuing trends for miniaturization and increased complexity that govern the manufacturing output in all fields including consumer products, industrial, medical, military, automotive, and so on. Currently, one can find these tiny devices within any contemporary cell phone or automobile diligently performing their tasks as high-quality microphones, micro accelerometers and gyroscopes, pressure sensors, RF modulators and microfluidic controllers.

Naturally, the increased complexity and miniaturization poses new challenges for testing equipment and testing methodology in general, and bond testing technology in particular. The need for automation is critical to streamline the testing process and also reduce the influence of human errors. While simple “step and repeat” automation has been sufficient in the near past, currently microelectronic interconnect in general is experiencing a number of changes. Geometries are continuing to shrink and the control/reporting electronics need to be exactly reproduced over and over again. Manual tool alignment and test execution is always prone to inaccuracies due to inconsistencies in individual operator performance, as well as the variation introduced by multiple operators using the equipment.

The first principle for automating the bond testing process is to make sure that all the parts that need to be tested are mechanically placed and secured at the same physical location at all times. This is accomplished using precise work holders that ensure placement accuracy. For MEMS devices as shown in Figure 1, the sample holder is of comparably simple design as the individual parts have fixed locations within the large printed circuit board (PCB) assembly. This is also valid for MEMS devices that need testing at the wafer level before being cut and packaged individually.

In the case of individual packages that have the MEMS device already installed within the plastic packaging, however, the requirements for the sample holder are significantly more demanding (Figure 2). The sample holder needs to be designed and built allowing for many different parameters, some of which are working against each other. The sample holder needs to accommodate as many devices as possible that need to be loaded as fast as possible and at the same time as accurately as possible.

In cases similar to the one in Figure 2, multiple sample holders are suggested so the parts can be loaded at the same time as the testing is executed. Appropriate fiducials for the camera-assist system need...
to be identified within the sample itself or machined within the sample holder. In addition to the sample holder accuracy, there are also very stringent requirements for speed and mechanical positioning to the X-Y stage. The stage needs to be as fast and accurate as possible and at the same time not prohibitively expensive in order to accommodate tight budgets typical for current economic conditions.

Once the best possible mechanical alignment and securing of the devices is assured, the rest of the auto programming and execution steps need to be done in an appropriate manner. While auto programming has been accomplished in the past by simply using the test tool as a teaching device, much better accuracy and ease of programming can be achieved by using integrated camera assist systems that are an essential part of every modern bond tester. As an added benefit, these camera systems can also be programmed to automatically take high-resolution images of the failure modes while the automatic test is carried out. There are routines within the software that account for the offset between the camera and the test tool, so all the teaching and fiducial recognition can be carried out by just using the camera system. In addition, in the case of wire pull applications, the software provides routines that handle possible hook eccentricity variations.

As shown in Figure 3, the camera system has looked at a feature of a ball grid array (BGA) type device that will be used as a fiducial. Usually a set of three fiducials is utilized that encloses the area of the testing. Advanced image recognition algorithms are employed by the bond tester software to compensate automatically for transitional and rotational misalignment. To achieve a repeatable system operation, the fiducial mark needs to be easily recognizable by the optical system and be of unique nature within the camera’s field of view. The capability of multiple fiducial levels assures that complex samples that exhibit die placement variations can also be programmed. Fiducials can also be machined within the sample holder for the cases of multiple discrete devices or if appropriate fiducials are not available in the case of PCB/wafer samples. It is very important to emphasize that, based on our experiments, the introduction of optical fiducials and image recognition algorithms brings the accuracy and the repeatability of automatic bond testing to a new, much higher level that cannot be achieved using only mechanical means.

After the fiducial alignment is programmed successfully, the next step is teaching the locations for the test. As mentioned before, these could be bond wires, BGA solder balls, Cu pillars, micro-bumps, or individual dies within a wafer. The main types of tests being automated include wire pull and various types of shear. For bond wire auto testing, there is the option to select the two ends of the wire and a testing point, or to select the two ends of the wire and specify the test position along the wire as a fraction or percentage of the wire length. As shown in Figure 4, the operator is using the crosshair displayed in the camera window to teach the essential location for the wire pull test. Using the camera streamlines the programming process and results in very high accuracy that is not achievable by simply using the test tool as a teaching device.

In addition, as shown in Figure 5, the graphical user interface (GUI) incorporates areas that graphically display the test surface, giving the opportunity to the operator to fine tune the program by using CAD tools and slightly modifying or even drawing test locations manually.

Copy/paste functionality is also available to the programmer. This programming capability is very useful for BGA balls/bumps/multiple die shear applications as well as wire pull applications of multiple discrete devices.

Figure 6 shows an example of CAD output automatically generated by the software. The inset shows the whole test area within the three fiducial marks. The
operator has programmed the first row and used the copy/paste functionality to populate the test positions for the next two rows. Ball diameter and tool offset have been input by the operator. The software automatically displays the CAD drawing, including fiducial image, and test locations for BGA balls and tool positioning. The area in the blue square within the inset corresponds to the enlarged view that includes the optical image of one of the fiducials. The operator can move the little blue square and display different areas of the testing surface.

Summary
The addition of high-resolution camera systems has resulted in a streamlining of the modern bond tester automation capabilities for a wide variety of applications exhibiting much improved testing repeatability. This includes high-accuracy/high-speed automatic testing of MEMS devices as discussed in the above paper. The camera-assist automation capability is also vital in many other bond testing applications including wafer-level bond and die shear, Cu pillar/flip-chip micro-bumps, ultra-fine pitch interconnect, wire pull, and shear/pull of hybrid devices.

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