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Application of 3D Measurement System with CCD Camera in Microelectronics

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Ball grid array package (BGA) warpage due to mismatch of the coefficients of thermal expansion and the asymmetric package geometry, has created some solder joint reliability problems, especially for chip scale packages. Methods to assess the design and process factors influencing warpage include electronic speckle pattern interferometry (ESPI), shearography and moiré. However, these methods are generally time consuming and expensive.

A non-contact and material independent determination of deformation and strain using three-dimensional (3-D) image correlation method and high-resolution digital CCD cameras has now been successfully implemented for measuring package warpage. This method significantly reduces the cost and time-consuming preparation necessary. For fast measurements, standard cameras can gather data at up to 20 fps as necessary, and for high-speed manufacturing tests, high-speed cameras can gather data at 485 fps to rates of up to 10M fps, or in real-time. Therefore this technology can collect data 30 times faster. It also has a much higher dynamic range of deformation measurements and is hundreds of times less sensitive to vibration interference than ESPI.

The 3-D Image Correlation Method

The 3D image correlation method features a static or dynamic non-contact, full field, 3-D strain measurement. To implement, a pattern which can be random or regular with good contrast is applied to the surface of the test object. The pattern deforms along with the object. The deformation of the object under different load conditions is recorded by two CCD cameras (Figure 1) and evaluated using digital image processing. An initial image prior to loading defines a set of unique correlation areas across the entire area of interest. These areas are known as macro-image facets, typically 5-20 pixels across. The macro-image facets are tracked in each successive image during loading with sub-pixel accuracy. Using photogrammetric principles, the 3D coordinates of the surface of the specimen, can be calculated precisely. The results are the 3D coordinates of every point in the area of interest, the contour of the component, the displacements during the test, as well as the plane strain tensor [1]. Although, only two image sets are required to measure the change from minimum to maximum loads, multiple image sets provide a progressive measurement of the deformations and strains.

Ball Grid Array Warpage

Fine pitch BGAs (FBGA) have been developed for high-end logic devices. Figure 2 shows the vertical structure of a FBGA package with a 2-layer PCB. It is constructed of a substrate (BT) onto which a die is mounted, and an array of solder balls is attached. The die is encapsulated with epoxy molding compound (EMC) for protection. A basic FBGA uses the same construction but reduces the size of the substrate, as well as the pitch and size of the balls [2].

Warpage in the FBGA has become a serious problem affecting solder joint reliability. Researchers have tried to measure warpage level directly for better understanding of packages [3]. Some efforts have been made to evaluate package warpage in terms of design and manufacturing factors by using simulation [4]. However, simulation requires verification, including adjustments for assumptions made during analysis. Three-dimensional measuring of the total deformation of complex objects, rather than relative deformation is necessary for that reason.

In figure 3, color plots of out-of-plane displacements using a 3-D image correlation measurement system show generally symmetrical behavior, which is expected under the applied thermal conditions. The slight asymmetric bulging at that area could indicate a defect such as an internal debonding or asymmetric surface mount bonding. Figure 3 also shows series of images showing the progression of warping during cool-down. The bulge at the top right edge shows consistently. It could be a focus of failure analysis efforts. Either direct measurement of warpage or capturing abnormal deformation can help design and reliability engineers to understand what is going on under the surface of packages. Figure 4 plots out-of-plane displacements along the diagonal section line shown in figure 3.

Conclusion

Package warpage due to mismatch of CTEs among construction materials affects the reliability of high pin count BGA devices. This study shows cost effective and fast method to measure warpage and identify anomaly in electronic devices.

Reference

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4. Kaga Y., "Thermal fatigue assessment for solder joints of underfill assembly", EEP-Vol.26-1. In: Advances in electronic packaging, Vol.1. ASME, 1999.

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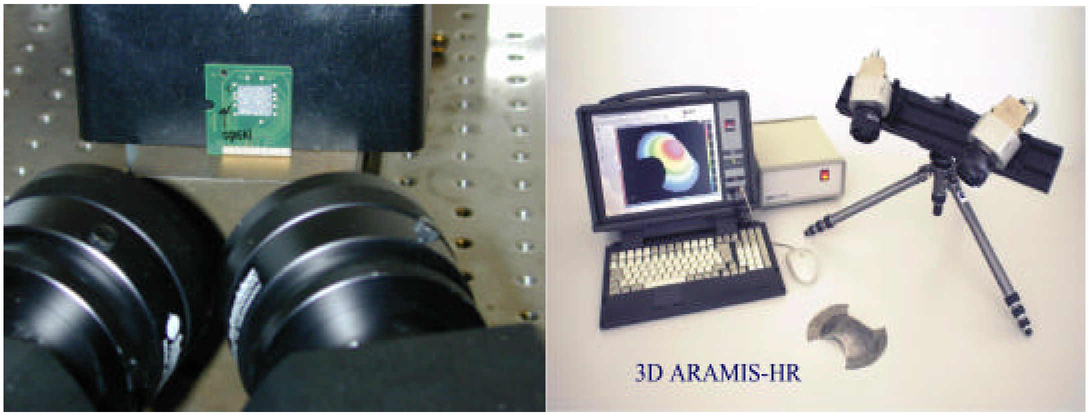

Figure 1. Setup shot showing pair of cameras with 50 mm lenses and built-in macro rings aimed at the prepared ball grid array assembly (left). A 3-D image correlation measurement system (right). (Courtesy of Trilion Quality Systems)

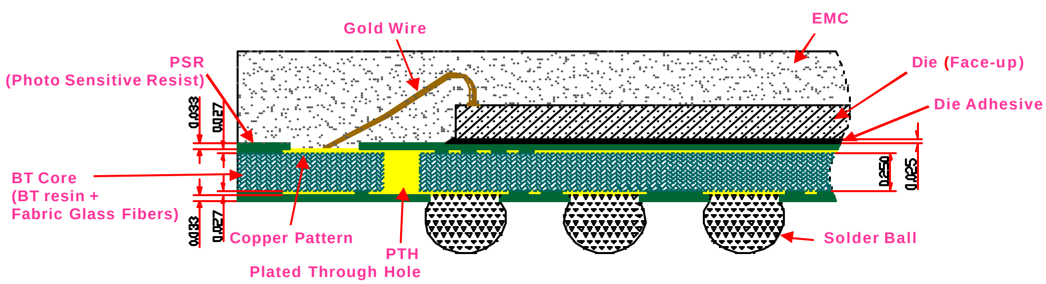

Figure 2. Vertical Structure of a FBGA Package with 2-Layer PCB (courtesy of Samsung)

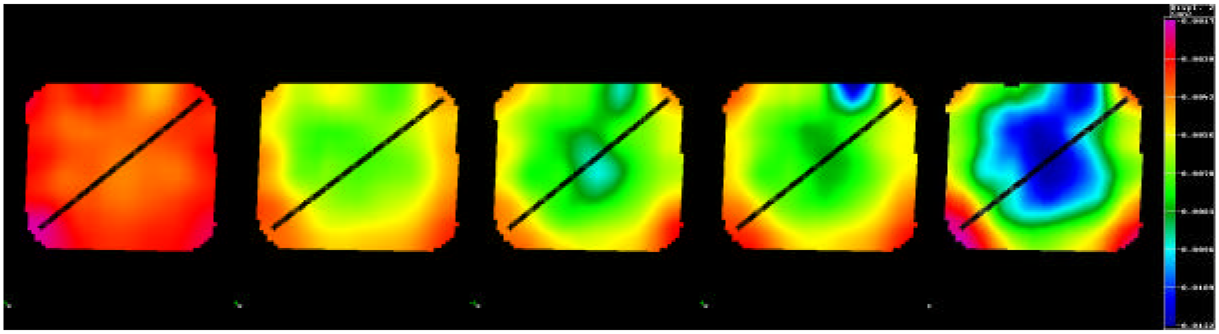

Figure 3. Series of Images with Fixed Scale Showing Progression of Warping during Cool-down Process.

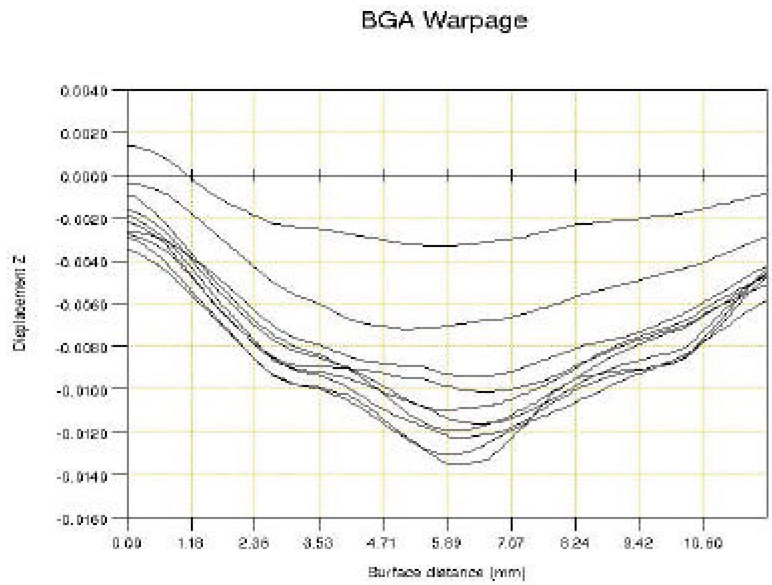

Figure 4: Plots of out-of-plane Displacement along The Diagonal Section Line indicating Warpage.