Study on measuring three-dimensional shapes of microelectronic parts

Mitsudo, Jun

This thesis describes a study of the in-line measurement of the three-dimensional (3-D) shapes of electronic parts, especially, the solder bumps arrayed on an LSI-chip package, which is called a Chip Scale Package (CSP). An in-line system of measurement needs to be installed inexpensively and needs to be compact so that it does not occupy too much space on existing production lines to fabricate semiconductor devices. It also needs to measure in real time. I investigated various methods of measuring 3-D shapes and adopted one based on focusing because it was simple and compact in terms of its system configuration and because it had the advantage of being able to measure the specular curved surfaces of objects over other methods based on triangulation. I devised two methods of measuring 3-D shapes based on focusing and constructed experimental systems using both to evaluate them from the viewpoint of practicability in in-line measurement. I first devised a method of establishing the focus-measure difference to detect the contour of the horizontal section of a solder ball bump quickly and precisely. This was where pixels from bump images that had the same focus-measure at two specified focal points along the height axis were selected. The height of the bump top was accurately estimated to match the sphere top by measuring the area of the horizontal section at a specified height and using it to fit a sphere in the bump. I applied it to measuring the heights of an array of 208 bumps that Ire 260-μm high arranged at intervals of 500 μm on the CSP. This sphere fitting achieved a height-measurement accuracy of 4 μm (σ). This degree of precision was sufficient to inspect the coplanarity of an array of solder bumps with a marginal top-height deviation of ± 50 μm. The measurement period in practical applications was estimated to be less than 2 s/package as a marginal time. Second, I devised a method of measuring the specular surface of a solder ball bump based on the shape-from-focus technique to determine the volume of the bump as Ill as its height. I used a copper-alloy mirror deformed by a piezoelectric actuator as a varifocal mirror to achieve a motionless yet rapid focusing mechanism with constant magnification. The shape of almost the entire upper hemisphere of the solder bump could be measured, which was sufficient to estimate the volume. The maximum error in measuring the bump heights was less than 12 μm and this was sufficient to inspect their coplanarity. Finally, I constructed an experimental system to measure the shapes of solder bumps in real time by using a high frame-rate (150 fps) CMOS image sensor and installing a prototype processor to exclusively enable focus-measure calculations based on Field Programmable Gate Array (FPGA) technology. It demonstrated its practicability in the in-line measurement of 3-D shapes.