Precision beam positioning in electronics manufacturing

There has been tremendous progress in industrial laser sources over the past 15 years, particularly in diode pumped solid state lasers. This, combined with improvements in the precision and accuracy of beam delivery and work piece control, is driving many new laser applications in micro-processing.

Electro Scientific Industries (ESI) Inc was founded in 1944 in Portland, Oregon, USA, to manufacture high-precision resistance measurement instruments. In the early 1970s , ESI pioneered the development of laser systems for thick and thin film resistor trimming. Since then they have developed many other laser based systems for use in electronics manufacturing.

Laser memory repair

The technique of laser memory repair was co-developed by ESI and Bell Labs in the late 1970s. Since then manufacturers of dynamic random access memory (DRAM) have dramatically shrunk the footprint of individual memory devices. To combat the increasing yield losses that occur as feature size decreases, DRAM chips are produced with redundant rows and columns of memory. Wafers are then probed offline and the data is sent to a laser system which repairs the memory by cutting special laser fuses to remove defective memory and enable redundant memory, see figure 1a. Through this process the yield of the wafer can be improved from <10% to >99.5%.

The requirements for throughput and position accuracy in laser memory repair are amongst the most exacting for any laser application. Fuse pitches at the 56 nm node are around 1.5 µm, requiring a laser spot size of ~0.8 µm and the ability to position the laser beam to <0.15 µm over a 35 x 35 mm reticule field; and each 300 mm wafer can have >2 million laser fuses that need cutting.

Figure 1b shows a picture of the focusing lens employed to obtain a 0.8 µm spot on a memory yield improvement system. To minimize thermal expansion and background vibration effects the lens, which weighs ~15 lbs, is mounted in a ceramic block on an air bearing Z-stage. Beneath the objective lens, the chuck holding the wafer is moved by high precision X and Y linear motor driven stages and its position monitored interferometrically.

Fuse (link) cutting is done 'on the fly' using scanning optics without the main stages stopping. During a link run the wafer chuck is quickly accelerated up to speed. Using the interferometric data, low frequency position errors are compensated by the linear motor controllers; high frequency errors by a Fast Steering Mirror (FSM), a turning mirror before the final focusing lens mounted on piezoelectric transducers.

Despite the studious care taken in the design of the opto-mechanical mount and the selection of low expansion materials, vibrations are still transmitted through the system frame to the focusing lens. To compensate for movement in the X and Y directions, metal transducers measure the position of the lens (these can be seen contacting the lens at 0 and 270 degrees in figure 1b) and the offset compensated by the FSM.

Laser via drilling

The Multilayer PCB (Printed Circuit Board) was invented ~40 years ago and since then the basic buildup has undergone few changes. A PCB is manufactured by building up "redistribution" layers onto a core to allow a large number of electrical interconnections (vias) to be made between board components. A copper foil forms the conducting layer, laminated between alternate glass-fibre reinforced insulating layers for rigid PCBs and resin layers for flexible PCBs.

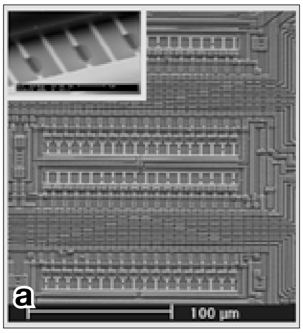

Figure 1: (a) SEM pictures of laser cut fuses; and (b) Focusing optics for ESi's Model 98XX series memory yield improvement system.

High Density Interconnect (HDI) PCBs on which integrated circuits are mounted have become increasingly more complex, with more input/output channels required in the same package size. This has led to PCBs of reduced thickness and increased layer count, a much greater number of vias within each layer and more accurate positioning. This in turn has led to many more vias being drilled by laser.

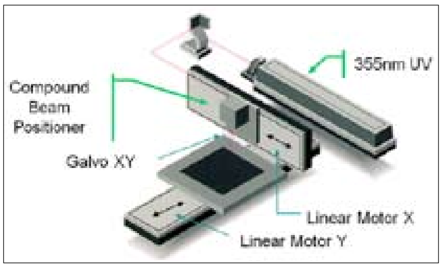

Figure 2: Schematic of an ESI laser drill for PSB via drilling. The XY galvo scanners are mounted to the X linear motor and the chuck that holds the PCB is attached to the Y axis linear motor. 'On the fly' laser drilling is used, the translation stages moving throughout.

ESI released the world's first UV laser drill 12 years ago. Like the memory yield improvement system, ESI's laser drills use a compound stage architecture, albeit with very different field size and positioning accuracy, see figure 2. 'On the fly' drilling is used, in which the scanning mirrors move the beam over the focusing optics so as to compensate for motion of the linear motors, keeping the via position stationary under the laser beam. Because there are no sudden accelerations of the linear motors, the system does not require a granite bed to damp vibrations. Customer requirements have driven improvements in successive generations of this beam positioner; the modern device offers <10 µm accuracy over a 21" x 25" area with only one single 4 point alignment at the edges of the PCB.

Summary

High precision and high throughput remain two of the most important considerations in the design of beam positioners for applications in the electronics manufacturing industry. Linear motor beam positioners are typically used for high accuracy applications and galvanometer beam positioners for high speed applications. ESI has developed a number of different compound solutions to enable different beam positioning technologies to work in parallel over a variety of different areas.

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