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Conductive adhesives increase microchip packaging density

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Interconnecting microelectromechanical systems directly to printed circuit boards can improve reliability and reduce costs of medium-caliber fuzes.

Cost-effective assembly of custom-designed microelectromechanical systems (MEMS) for medium-caliber fuzes is challenging. In particular, the environment must have a setback acceleration exceeding 60,000g and centripetal acceleration of 9000g/mm out of center in a 30mm×173 projectile. In addition, the space available is very limited. The traditional approach is to mount the MEMS chip in a package that is then soldered to the printed circuit board (PCB). However, by mounting the MEMS chip directly to the PCB using conductive adhesive, we can increase the packaging density while reducing manufacturing cost.

One of the challenges when mounting silicon-based MEMS chips on a PCB is the large difference in thermal expansion coefficient between the silicon and the glass-epoxy PCB laminate. Suitable materials for interconnects need good electrical conductivity combined with sufficient compliance to accommodate the strains that occur during thermal cycling (without causing fatigue).

Isotropic conductive adhesive (ICA) has been used for interconnection of electronic devices for several decades.[1] Traditionally, such adhesives have been made using silver particles mixed with a non-conductive adhesive typically based on epoxy. Other metal particles for creating conductivity have also been used, such as copper and nickel. A typical problem with such ICAs is brittleness caused by thermomechanical and elastic mismatches between the metal particles and the adhesive matrix. Since these traditional ICAs do not have the necessary compliance for our application, we used a novel type of conductive adhesive with better thermal and mechanical properties.

Our approach is to use metal-coated polymer spheres to achieve adhesive conductivity (see Figure 1). The size distribution of the spheres is narrow, with a typical variation of less than 3%. The metal layer of the spheres is about 100nm thick. Noble metals are used to coat the spheres, but the cost of using these metals is limited since less than 10% of the particle volume is metal. The mismatch between the thermal expansion coefficient of the adhesive and the polymer-based spheres is much less than between metal particles and adhesives used in traditional ICAs. In addition, the polymer spheres are flexible, which improves the mechanical properties of the conductive adhesive.

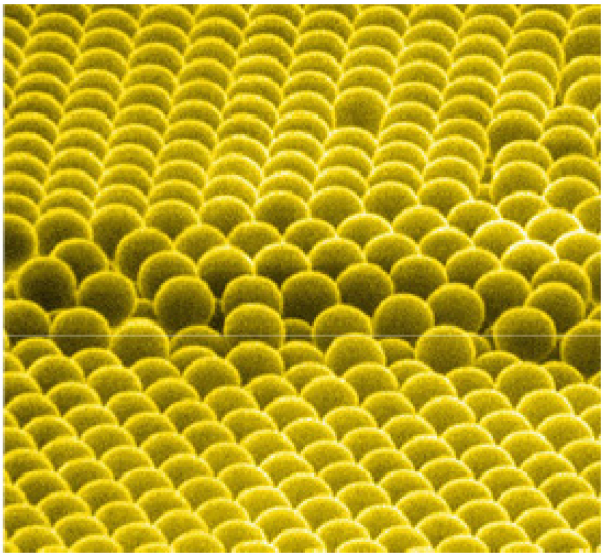

Figure 1. *Scanning electron microscope image of mono-sized polymer balls arranged in a 3D crystal-like structure.*

We have investigated the properties of our ICA in rough environment applications. MEMS test chips with no movable parts have been manufactured and mounted onto a PCB. The size of the MEMS test chips is 3.5mm×3.5mm. We performed accelerated stress tests, including air-to-air thermal shock cycling and realistic firing.

Temperature cycling tests between −46 °C and +70 °C used an adhesive with 30μm silver coated spheres (see Figure 2). The tested contact resistances, which have a pad size of 250 × 350μm,

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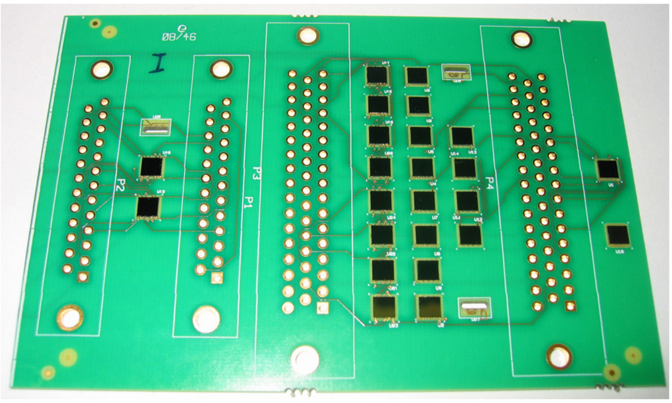

Figure 2. *Printed circuit board with microelectromechanical system test chips. The card is used for measuring contact resistances during temperature cycling tests.*

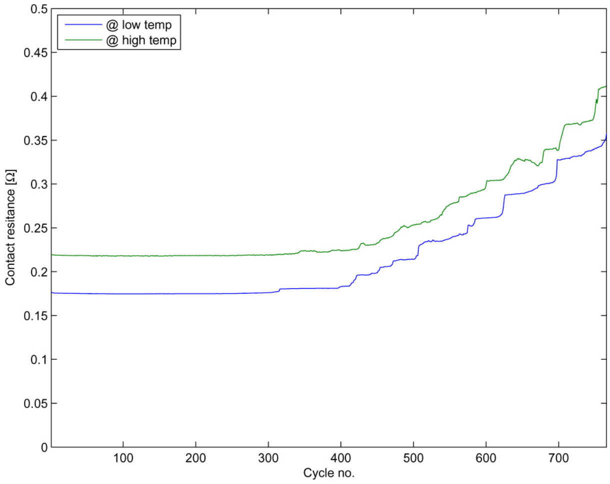

Figure 3. *Contact resistance at high and low temperature as a function of the number of temperature cycles.*

displayed no notable changes after 127 thermal cycles between −46 °C and 70 °C. One PCB was exposed to more than 700 temperature cycles. All contact resistances passed 274 cycles, and one passed more than 750 cycles (see Figure 3).

Shear tests^2 have also been performed on test chips mounted with adhesive containing 10μm gold spheres. The average bond strength was 24N, which exceeds the requirement in military standard MIL-STD-883G.^{3}

Some of the MEMS test chips that had been exposed to temperature cycling were packaged into a 30mm×173 projectile. Recovery firings were performed. The average change in contact resistances after firing was less than 6% compared to values obtained prior to the temperature cycling tests.

The use of conductive adhesives based on uniformly sized polymer spheres for MEMS interconnect in medium-caliber fuzes has so far shown promising results when exposed to temperature cycling and mechanical stress tests. We currently are performing extended temperature and mechanical testing. The results will be presented at the 2010 SPIE Photonic West conference at the end of January in San Francisco.

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