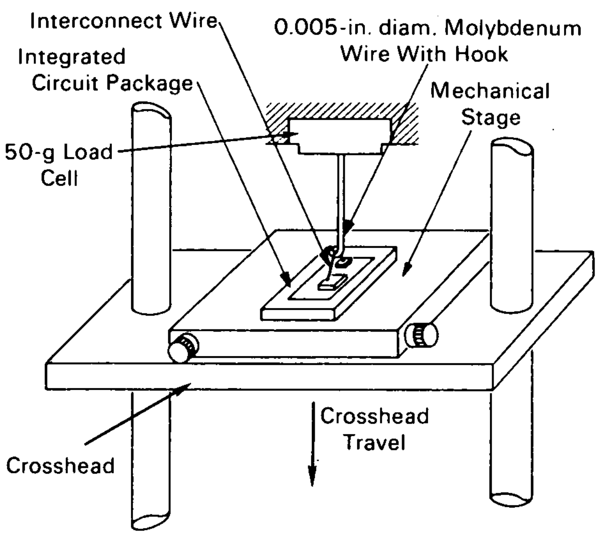
NASA TECH BRIEF

An Investigation of the Strength of Aluminum Wire Used in Integrated Circuits



Integrated Circuit Interconnect Wire Test Configuration

It is common practice in the fabrication of integrated circuits to interconnect electrically the aluminum metallization of the silicon die to the package leads by using a fine aluminum alloy or gold wire. Electrical interfacing between other devices and the active material in the die depends on these wires. There has been a trend towards using 0.001-in. diameter aluminum-1% silicon wire ultrasonically bonded in place to achieve this flying lead interconnection; this technique has presented serious problems in assuring the reliability of such devices. The strength of the aluminum wire and the bond it makes to the metallization on the silicon die and package leads have been found to be marginal during mechanical stressing.

To investigate the strength of the wire in the packaged integrated circuit device, a technique was developed to stress the wire loops in situ until failure. The applied loads, the nature of the fracture, and its location were recorded.

To understand better the type of failures and wire strength being observed in the wires of the packaged device, additional testing was done with wires of a known thermomechanical history. This information was obtained by tensile testing aluminum-1% silicon wire obtained from a leading manufacturer.

A microloop pull test was developed to test the interconnect wire configuration in the integrated circuit packages. This test consisted of carefully removing the package lid and positioning a 0.005-in. diameter molybdenum wire hook under the loop of the flying lead and loading the hook in a tester until the wire or wire bond failed. The circuit package was mounted on a mechanical stage and the hook, hanging from a 50-g load cell, was positioned under the wire. The wire was loaded by a downward movement of the crosshead and the applied force was measured with the load cell. The loading cycle was recorded on an x-y recorder as load-crosshead travel. Accuracy of the measurement of applied loads was ± 0.05 g or better. The failure loads for aluminum flying leads in the integrated circuit packages were found to be usually in the range of 3.0—4.5 g. As would be expected, there was considerable variation in the failure load of the flying leads inside a single package. As a typical example, one 14-lead circuit tested had an average failure load of 3.6 g with a variation of individual failure loads from 3.2 to 3.8 g. These leads were ultrasonically bonded to aluminum metallization on the die and to

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gold-plated Kovar package leads. As a point of comparison, a typical 14-lead circuit using thermo-compression bonded, 0.001-in. diameter gold wire had an average flying-lead failure load of 5.1 g with a variation of individual failure loads ranging from 4.3 to 5.7 g.

After mechanical testing, the location of each wire or bond failure was noted and representative failures were examined with a scanning electron microscope. Two modes of failure have been found: failure of the bond in the region of the bond heel, and tensile failure of the wire between the hook and wire bond. No failures of the aluminum wire bond at the aluminum metallization interface were detected. The tensile failures in the wire closely resembled those of a single-crystal fracture. Individual slip planes were easily identified. Flat, sharply angled shear planes extended entirely across most of the fracture faces.

The microloop test stresses not only the aluminum wire but also the wire bonds. Because of the variable angle at which the bonds are loaded, a simple, direct comparison of various bond-failure loads is not valid, but qualitative comparisons of bond integrity can be made.

Wire, 0.001-in. diameter, was also tested both in the as-received and annealed condition. A group of these wires was annealed at 700°F for five minutes, cooled in nitrogen to 500°F for 20 minutes, and then air quenched. The fracture load of these wires was 3.0 $\pm$ 0.1 g. Scanning electron microscope examination of these wires revealed a fracture character similar to that found in the integrated wires.

The fractures in the integrated-circuit wire and the annealed wire suggest that extensive recovery, recrystallization, and grain growth occurred in both cases. The grain size of the wire in the integrated circuits, being as large as the wire diameter, means that the wire failure occurs in essentially one grain. Therefore, the plastic flow and mechanical properties of the wire, until the fracture load is reached, resemble those of a single crystal.

Note:

Requests for further information may be directed to:

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Patent status:

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