Silver Dendritic Growth in Plastic IC Packages

Silver dendrites are often found on the die surface of plastic dual-in-line packages after the compound is removed by chemical means. It was initially believed that the silver dendrites were caused by silver migration during moisture stress testing. Further investigations have shown the formation of silver dendrites occurs during the decapping process. Results of decapping experiments are represented, along with a proposed mechanism for the silver dendrite growth.

*By Fely N. Lieberman and Mark A. Brodsky**

(Editor's Note: Our July issue reported on the current litigation over a now-withdrawn Sumitomo "green" molding compound, the EMExxxxU Series (page 27).

The litigation brought against Sumitomo customer Amkor Technology by Philips claims that the use of the material caused silver dendrite growths to form between adjacent pins on packages, resulting in high-resistance shorts between the pins.

Upon reading this report, reader Mark Brodsky provided us with a paper he co-authored and presented at a conference 20 years ago.

Chip Scale Review **believes the paper authored by Mr. Brodsky and Ms. Lieberman is of sufficient importance for us to publish it, unedited, in its entirety, except for the substitution of some graphics that were no longer available. We are grateful to IMAPS for giving us permission to reprint it.)**

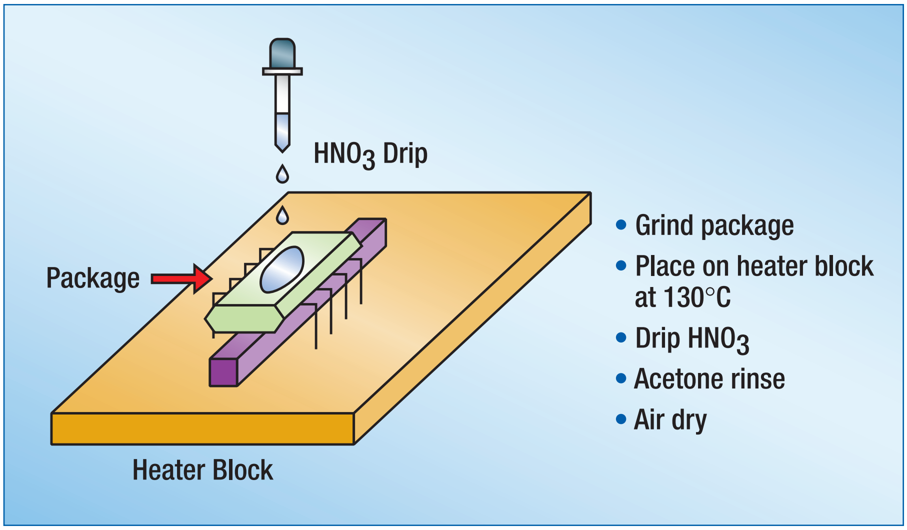

Figure 1. Standard decapsulation process

The advent of automation in plastic package assembly has brought about the widespread use of silver as one of the direct materials used in the package itself. Silver-filled epoxies are used as the die attach media of choice for automated die bonding.

Silver plating on the internal lead fingers of the leadframe has been used for some time as a cost savings over gold.[1]

The introduction of silver directly into the package has raised reliability concerns regarding the mobility of silver ions. This is based upon the fact that plastic packages are not hermetic and all modling compounds will absorb moisture through the package body and between the leadframe-molding compound interface.[2]

Additionally, silver migration in the presence of moisture and bias has been shown to occur.[3] For these reasons, evaluations to insure the reliability of silver-filled epoxies and silver-plated leadframes were performed.

The method used to evaluate the reliability of a plastic package is to subject a large sample of electrically good units to a series of accelerated stress tests.

Industry standard tests include temperature/humidity testing, 85°C/85% relative humidity with bias; steam pressure pot without bias; high-temperature operating life; and mechanical temperature shock.

Units are subjected to these various tests and removed at different time intervals to be electrically tested. Units which fail any of the electrical test points are subjected to failure analysis, which includes electrical characterization and decapsulation for internal visual inspection.

The standard method of removing the molding compound is done with red fuming nitric acid. With this process, illustrated in Figure 1, a small indentation is

Figure 2. Photo of SEM studies showing the presence of silver dendrites after the decap.

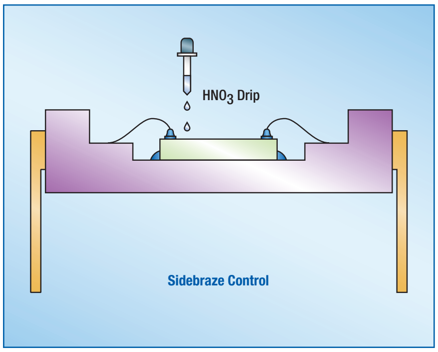

Figure 3. The standard decap technique used on sidebraze units with epoxy die attach and gold ball bonding in Experiment 2.

ground into the plastic above the die to create a well for the acid.

The unit is placed on a heater block at 150°C and acid is dropped into the well. Acetone is used to rinse the dissolved molding compound. This procedure is repeated until the die surfce and wire bonds are completely exposed. Then the unit is given a final rinse with acetone and left to air dry.

Upon visual inspection using a high-power microscope, silver dendrites were found around the bond pads and along the die edges. Figure 2 is a SEM photograph of silver dendrites found in units failing the moisture stress tests.

The size of these dendrites, sometimes 20 mils in length and 5 microns in width, created the suspicion that these dendrites could not have formed during the moisture bias testing when molding compound completely surrounds the gold wires and die. The silver dendrites appeared to be a product of the decapping procedure.

Experiment 1

Electrically good plastic units were sampled right after assembly (having seen no stress testing) and were chemically decapped in the same procedure described above.

Experiment 2

Die were assembled in side-brazed packages using epoxy die attach and gold ball bonding. These units were subjected to the same acid decapping procedure. (See Figure 3.)

Experiment 3

Unit which failed the 85°C/85% R.H., bias and pressure post tests were mechanically decapped with the shearing technique. This procedure is done by rapidly heating the units above the molding compound's glass transition temperature; then using a modified nail puller or B&G package shear clamp, the unit is sheared open. (See Figure 4.)

Though the success rate of this technique is very low, samples were obtained where the die surface and die impression in plastic were cleanly exposed for visual analysis.

Experiment 4

The decapping procedure was changed slightly where in the final acetone rinse step, the units were not allowed to air

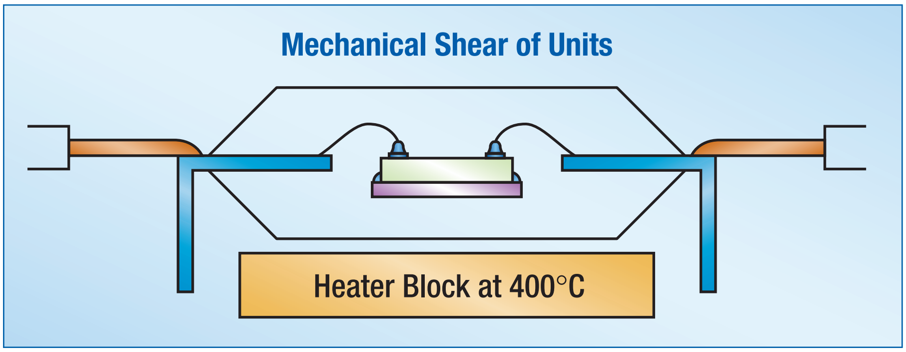

Figure 4. Mechanical shear of units from Experiment 3

dry. Instead, the units were dried immediately using an air gun. Electrically good units out of assembly, and failed units from moisture testing were used for this experiment.

Experimental Results and Discussion

Silver dendrites were found in units from Experiments 1 and 2, and were not found in units from Experiments 3 and 4.

Figure 5 is a photograph of the silver dendrites from Experiment 2 using sidebrazed packages. It was noted that the silver dendrites growth nucleated from either the gold ball bond or the rugged surface of the silicon die edge.

During the decapping procedure of units from Experiment 1, the actual silver dendritic growth was witnessed under a high-power microscope. With this sample, the acetone was not completely evaporated as it was being inspected. As the acetone evaporated, the silver dendrites formed. This phenomena was captured on a video tape.

Figure 5. Dendrite growth in sidebraze packaging Experiment 2.

The chemical mechanism proposed for the dendritic growth is as follows:

The fuming nitric acid breaks down the silver-filled epoxy. Silver in the presence of nitric acid will form silver nitrate (a liquid) and silver ions. During the acetone rinse, the silver nitrate and silver ions become suspended in solutions.

During the decapping procedure of units from Experiment 1, the actual silver dendritic growth was witnessed under a high-power microscope.

As the acetone evaporates, a super-saturated silver solutions forms. This provides a condition for silver crystallization to occur at the gold ball bonds and rugged die edges.

The reason for nucleating at the gold ball bond is due to the catalysis effect of gold. Gold, being a transition metal, is a very good catalyst in its reduced form.[4] Nucleation along the die edges is due to having a rugged or rough site for crystallization to start.

In Experiment 4, silver dendrites did not occur because a saturated silver solution never formed when the units were blown with pressurized air right after the acetone rinse.

Conclusion

Silver dendrites were found in plastic packages after decapping units which failed moisture stress testing. The size of the dendrites found created doubts that they could have actually grown in an intact package during stress testing.

Experimental results show that the dendritic growth is a byproduct of the acid decapping procedures. The formation of silver dendrites can be prevented by using the recommended techniques listed below.

Recommendations

1. When using the acid decapping procedure described here, do not allow the units to air dry in the final step. The unit should be blown dry with an air gun immediately after the acetone rinse.
2. Mechanical shearing as described within;
3. B&G sulfuric acid jet etch procedure

Acknowledgements

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