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Copper Wire Bonded Devices: Using Plasma Mold Decap

**By David Foote, Global Applications Manager,
Nordson MARCH, Carlsbad, CA**

Copper has been replacing gold for wire bonding to enhance performance and reduce semiconductor package costs. While beneficial for the customer, it presents challenges for those performing failure analysis of molded copper bonded parts. Gold is immune to attack from the fuming acids used to etch away the mold compound of the package; copper is not. During the failure analysis process, these underlying layers need to remain unaffected and intact. Removal of the molding, without altering the metals, is required for successful device inspection.

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Fuming Nitric Acid

Fuming nitric acid is the mold decapsulation (decap) method of choice when using gold or aluminum wires in the chip package because it is very effective in removing the mold compound while not attacking the wires or aluminum bond pads on the die. Unfortunately, nitric acid will readily attack copper wires and any other exposed copper in the package. Sulfuric acid has been shown to remove the mold compound without attacking the copper wires, but it readily attacks the aluminum bond pads.

Laser ablation is another process used to remove mold compound from the top of the package, but it works best for exposing just the tops of the wires. Further ablation will damage the wire bonds and the device itself.

Plasmas have been used to etch polymers in controlled environments. Oxygen plasmas are very effective for etching polymers, such as photoresist, and other organic compounds used in electronics. With the addition of a fluorine source, the etch rates of polymers increase dramatically. This has been demonstrated in the etching of drill smear in printed circuit board through-holes. Because the passivation layers typically etch well in fluorinated chemistries, the key to using fluorinated oxygen plasmas is to tailor the process so it minimizes etching the die.

Plasma Processing Systems

An experiment was conducted to determine the best method for removing mold in the decap process without damaging the copper. A Nordson MARCH RIE-1701™ anisotropic reactive ion etching (RIE) vacuum plasma processing system with oxygen plasma was used. A quad flat pack (QFP) packaged device, which had previously undergone laser ablation, was processed using the RIE with pure oxygen chemistry. A total of three hours of process time was performed on the samples, which were sonicated between runs to remove any loose glass filler material. After three hours, it was difficult to determine if any significant mold compound removal had occurred. It was evident that more aggressive chemistries are required if decap is to occur in a timely fashion.

Oxygen: CF4 Plasma

The addition of small amounts of fluorine to oxygen in plasma greatly enhances the etch rate of polymers. Etch rates typically increase as the CF4 concentration increases up to about 20 percent CF4 in O_2. Mold removal rate enhancement was dramatic for a QFP part following 30 minutes of processing using 20 percent CF4 in O_2, followed up with an additional 30 minutes using only 2 percent CF4 in O_2. Much of the top of the die was exposed following the initial 30 minutes. The

additional 30 minutes of dilute CF4 processing cleaned away the residue leaving the topside of the die clear.

Optimization of the plasma process is critical to minimize damage to the wire bonds and die. In another experiment, a 20 percent CF4 etch process was used to clear the mold compound from the die surface of a QFP package. A compressed air blow-down to remove the filler compound blew most of the wires from the die surface.

Upon SEM evaluation it was obvious the fluorinated chemistry had severely etched through the topside passivation and undercut the dielectric below the bond pads. Compressed air blow-downs were subsequently replaced with megasonic cleans to minimize the impact on the wire bonds.

Optimizing etch times and chemistry prevents this damage. For one hour, the wires were exposed to high fluorine concentration plasma processing while the die was still encapsulated in epoxy. Exposing the sample to one hour of pure oxygen plasma produced little visible evidence of additional mold compound etch. The fluorine chemistry accelerated the etch reaction. Using a lower concentration of fluorine for an additional 15 minutes of etch time exposed more of the wires and the die top was almost visible. The sample was etched for 15 additional minutes with the lower concentration process and this cleared the die top completely without damaging the wire bonds.

Copper wire bonds have challenged the failure analysis community because the etch properties of the metals and the decap acids typically used are not compatible. An anisotropic RIE vacuum plasma processing system with oxygen plasma is a very versatile processing tool for solving this mismatch. Using optimized fluorinated plasma processes resolves the decap issues with copper wire bonded products. However, careful attention must be given to fluorine concentrations, etch rates, and times to remove the mold compound without damaging the die itself.

Contact: Nordson MARCH, 2747 Loker Ave. West, Carlsbad, CA 92010 ☎ 760-431-1919
Web: www.nordsonmarch.com ❒