Using Plasma Processing as a Mold De-Cap Method for Copper Wire Bonded Devices

Author: David Foote
Global Applications Manager
Nordson MARCH

Introduction:

In order to enhance performance and reduce the costs of semiconductor packages copper has been replacing gold as the metal of choice for wire bonding. While this is beneficial for the customer it presents challenges for those that perform 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 while, unfortunately, copper is not. Numerous acid mixtures and temperature combinations have been evaluated with little success removing the mold compound and leaving viable copper interconnects behind. In this paper we will evaluate the capabilities of using plasma processing to remove the mold compound on packaged devices.

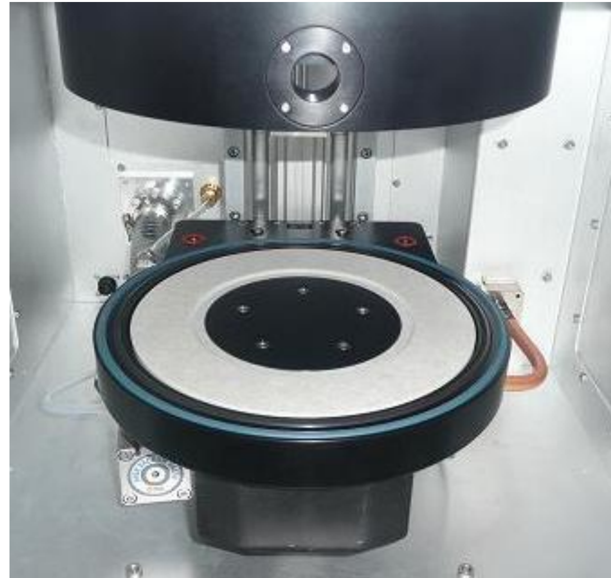
Background:

Fuming nitric acid is the mold de-cap method of choice when using gold or aluminum wires in the chip package. The acid is very effective 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 readily attacks the aluminum bond pads. No acceptable method using fuming acids for de-cap processing of copper wire bonded devices has yet been demonstrated.

Laser ablation is also used to remove the mold compound from the top of the package but works best to expose the tops of the wires. Further ablation will damage the wire bonds and device itself.

Plasmas have been used to etch polymers in controlled environments for nearly fifty years. History shows that oxygen plasmas are very effective at etching polymers such as photoresist used in the manufacture of most electronics. When oxygen plasmas are catalyzed with the addition of a fluorine source the etch rates of polymers increase dramatically. This has been demonstrated for years etching drill smear in through holes of printed circuit boards.

The key to using fluorinated oxygen plasmas is to tailor the process so as to minimize the attack of the die passivation layers which typical etch well in fluorinated chemistries. Examples of plasma de-cap processing using the Nordson MARCH RIE-1701™ Plasma System follow.



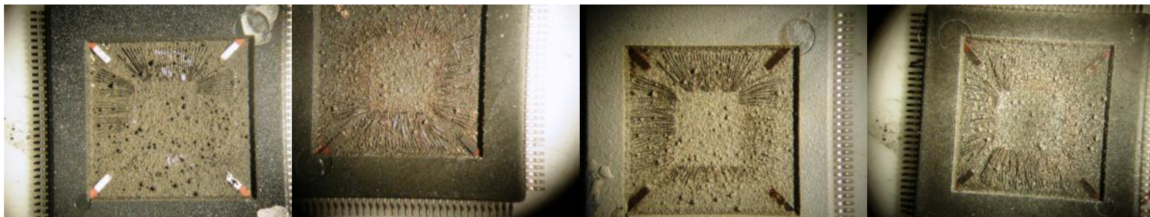
Nordson March RIE-1701™ Plasma Processing System

Plasma De-Cap

The RIE-1701 Plasma System is a parallel plate 13.56 MHz vacuum plasma processing system. The electrodes are water cooled in order to control the sample temperature. The chamber and electrodes are anodized to withstand corrosive environments such as fluorine and chlorine chemistries. Chamber volume is very small for quick pump down times and the 600 watt RF generator delivers a very high power density for enhanced performance.

Oxygen Plasma

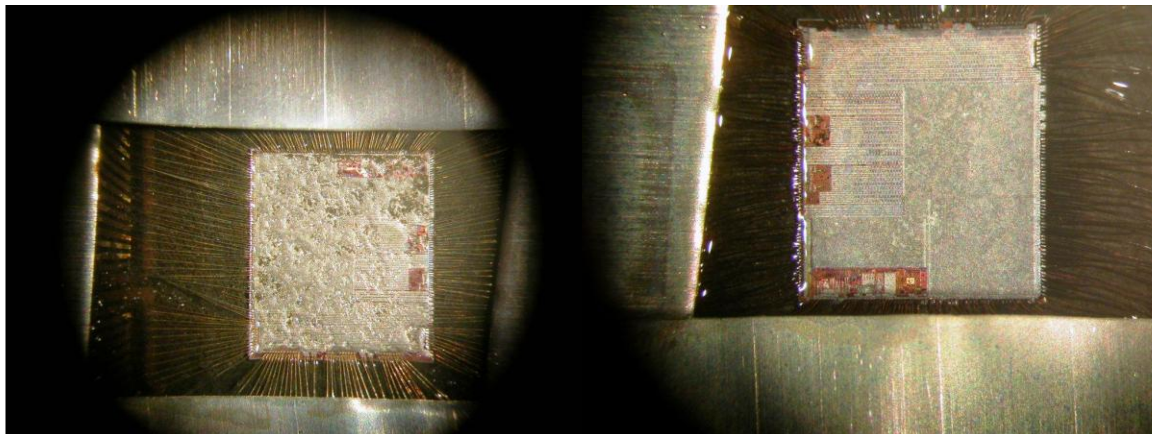
Oxygen plasma processes are very effective etching polymers and any other organic compound. It is desirable to remove the mold compound on semiconductor devices using pure oxygen as the chemistry will not attack the topside passivation of the device. A QFP packaged device which had previously undergone laser ablation was processed using the RIE-1701™ with pure oxygen chemistry. A total of three hours of process time was performed on the sample. The samples were sonicated between runs in order to remove any loose glass filler material. It was difficult to determine if any significant mold compound removal had occurred following a total of three hours of processing. More aggressive chemistries are required if the de-cap is to occur in a timely fashion.



No Plasma **1 Hour** **2 Hours** **3 Hours**

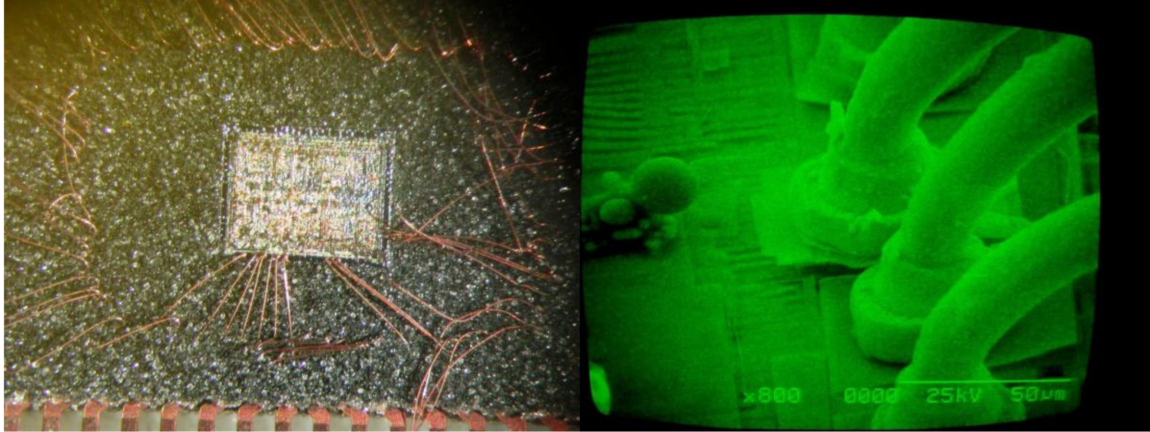
Oxygen: CF_4 Plasma

It is well known that the addition of small amounts of fluorine to oxygen in plasma greatly enhances the etch rate of polymers. Etch rates will typically increase as the CF_4 concentration increases up to about 20% CF_4 in O_2. Below are examples of a QFP packaged part following 30 minutes of processing using 20% CF_4 in O_2 and then followed up with an additional 30 minutes using only 2% CF_4 in O_2. The mold removal rate enhancement is dramatic. Much of the top of the die was exposed following the initial 30 minutes of processing and the additional 30 minutes of dilute CF_4 processing cleaned away the residue leaving the topside of the die clear.



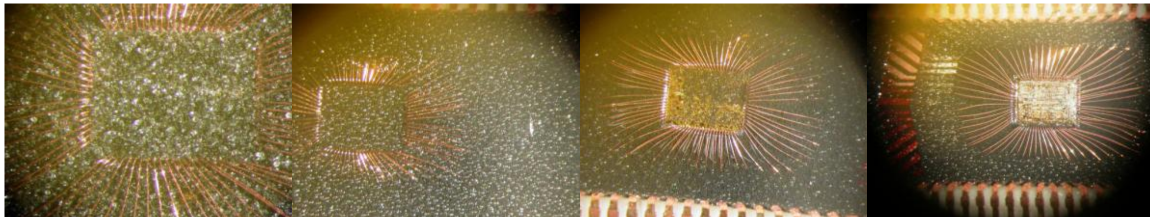
30 min, 20% CF_4 **30 min, 2% CF_4**

Optimization of the plasma process is critical in order to minimize damage to the wire bonds and die. The next example is a QFP package where 20% CF_4 etch process was used to clear the mold compound from the die surface. 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.



Full De-cap and CDA Blow Down **SEM of Failed Bond Pads**

By optimizing the etch times and etch chemistry this damage can be prevented. One hour of high fluorine concentration plasma processing exposed the wires 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 is required in order to accelerate the etch reaction. Using a lower concentration of fluorine for 15 additional minutes of etch 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.



1hr 20% CF_4 **1hr 100% O_2** **15min 10% CF_4** **15min 10% CF_4**

Conclusions:

The Nordson MARCH RIE-1701 is a very versatile plasma processing tool for failure analysis (FA) applications. It is presently in use for de-layer applications to etch dielectrics and metals within the die itself. Copper wire bonds have challenged the FA community because the etch properties of the metal in typically used de-cap acids are not compatible. Using optimized fluorinated plasma processes resolve the de-cap issues with copper wire bonded products. Careful attention to fluorine concentrations, etch rates and times enable the user to remove the mold compound without damaging the die itself.