High Performance Photoresist Removers Enable Through Silicon Vias:

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Abstract

This paper outlines the advances made by EKC in developing a solution for WLP resist stripping based on the globally established HDA® technology. HDA® technology has been expanded into WLP to give a solution that out performs traditional Solvent/TMAH blends.

The migration of electronic devices to become smaller, lower cost with more functionality is requiring innovative 3-D packaging approaches. Through silicon vias (TSV) is a packaging method, which bonds two or more die together in an integrated structure improving functionality, performance, power consumption, thermal properties and with reduced board real estate. There are two different methods of forming TSV- via first and via last depending on whether the via is made before or after wafer processing. Regardless of the via formation process, an imaging process that enables the formation of high aspect interconnects is a major challenge. New formulations for both dry film and photoresist removers have been jointly developed by DuPont’s EKC and APL businesses to enable TSVs for 3-D Packaging. This paper describes the compatibility and stripping performance achieved with innovative photoresist removal technology on industry representative TSV wafers.

Introduction

Consumer products such as digital cameras, PDAs and cell phones, along with next –generation servers, are driving the need for product miniaturization: increased functionality, increased storage capacity or both in a smaller package. Many Semiconductor manufacturers are investigating 3-D interconnect technology to stack die or wafers. This technology is driving the introduction of TSV etching. The challenges faced with the introduction of TSV etching for 3-D integration, are much tighter, especially in the areas of tool productivity, uniformity of profiles across the wafer and process drift.

The TSV photo image is defined using a dry film such as MX5015. Unlike standard resists used in the fabrication of CMOS devices, the dry film has some unique properties. The thickness of the film varies from 10 to greater than 100 um depending on the etch process and TSV. This in itself gives novel challenges.

Dry Film Stripping Technology

In this study we will consider the factors that are critical in this process. If we consider tool productivity the strip process must be capable of removing the film completely in times acceptable for manufacturing. Standard strip process technology for stripping wet photoresist of 2um is not capable of giving the productivity performance that is required.

DuPont EKC has developed EKC162™ a novel strip chemistry which will remove films such as MX5015 in times that meet the requirements of manufacturing.

Formulation Development

To further develop the chemistry to meet the increasing demands of TSV technology extensive testing and refinement was carried out at EKC laboratories in Hayward and East Kilbride.

A series of screening experiments identified three components with a strong influence of resist stripping.

A set of nine multi-component formulations, based on these components was generated by a statistical mixture DOE, over the formulation composition shown in Figure 2.
Fig 2. Simplex Design from DOE mixture

This matrix was extensively tested to determine the optimum formulation, minimizing metal and dielectric etch but retaining fast and efficient resist removal.

To test the formulation derived from the DOE testing was carried out on TSV structures with the following process:

- MX5015 dry film patterned on silicon substrate
- Bosch process carried out to etch the TSV structure
- Via size varied from 50 to 75 um
- The depth of the via approximately 300um

Samples of the wafer were then tested with the formulation across arrange of temperatures and times. The SEMS below show the TSV structure with dry film in place and the typical scallop effect produced by the Bosch etch process.

As can been seen clearly from the SemS the dry film is totally removed from the wafer surface. The top of the via is clearly visible with the scallop effect within the via clearly visible. So with EKC162™ we can remove dry film resists at relatively low temperatures and at times that match industry requirements.

Before we discuss the exact processing details, lets look at the major mechanism involved in the strip process of EKC162™
Mechanisms

Table 1 Photoresist stripping mechanisms for IC manufacturing.

<table>
<thead>
<tr>
<th>Dry Process</th>
<th>Wet Process</th>
<th>Mechanism</th>
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<tbody>
<tr>
<td>O2 Plasma</td>
<td>H2O2/H2SO4</td>
<td>Oxidation</td>
</tr>
<tr>
<td></td>
<td>(NH4) 2S2O8/H2SO4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuming Nitric Acid</td>
<td></td>
</tr>
<tr>
<td>SCCO2</td>
<td>Solvent Stripper</td>
<td>Dissolution</td>
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<td></td>
<td>Alkaline Developer</td>
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<td>H2 Plasma</td>
<td>Hydrazine/ Hydroxylamine</td>
<td>Reduction</td>
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Due to the unique properties of HDA®, a dissolution mechanism is proposed whereby disproportionate, dissociation and ionization combine to remove the resist.

Concept Schematics of the Radical Type Negative-tone Photoresist

Fig 6. Cross linking of negative resist

The resist is cross-linked after exposure and becomes base insoluble. A principle cleaning mechanism in EKC162™ technology is based on the chemical reaction to break down cross linked polymers and form more soluble oximes.
Technology

Oxime Formation

The reaction begins with nucleophilic addition to the carbonyl functional group.

The addition product is then protonated and dehydrated.

The result is an increased solubility of the product (oxime) formed.

The chemical activity imparted to EKC162™ through HDA® technology greatly improves the ability of the formulation to remove very thick, 10-100µm resists at far lower temperatures and shorter times than conventional offerings.
Results

EKC162™ has been tested across a range of substrates and via types.

Testing has been carried out in batch and single wafer tool sets.

With single wafer tools process times of less than 1 minute have been achieved with temperatures below 60°C.

With batch tools process times of 10 minutes with EKC162™ will completely remove the dry film with no impact on the via structure.

Conclusion

EKC162™ has been developed to meet the challenges from TSV processing. In conjunction with APL group EKC has developed a novel stripper specifically designed for dry film removal. But EKC162™ is also capable of stripping wet resists and can be applied to bump processing.

With short process times good metal and dielectric compatibility EKC162™ enables the TSV process.

References

