Resist Removal Solutions in Advanced Packaging Applications

Mike Phenis, Kimberly Pollard, Diane Scheele, Gene Goebel,
Nichelle Wheeler, Allison Rector
Dynaloy LLC
6445 Olivia Lane
Indianapolis, IN, USA
T: +1 (317) 788-5694; F: +1 (317) 541-9617; dianescheele@dynaloy.com

Wafer level packaging (WLP) encompasses a large number of processes including FlipChip processes for printed and plated and ball drop bumps. Most recently various *3-D* processes, including through silicon via (TSV) processes and modified ShellOP processes are being refined. Each is characterized by many steps that have their own technical challenges. Today, one of the 'most prevalent and most critical of all semiconductor manufacturing process steps is wafer cleaning. [...] it has evolved to the point where not only most cleans must be specifically tailored to the preceding or subsequent fabrication steps, but to a level of sophistication that is better labeled as surface preparation or surface engineering'[1].

To follow Moore's law, there is a need to simplify resist strip, post etch residue, and surface preparation into a single process. It is this goal that focuses design and IP development on simplification. In addition, the technology has been built on a platform that is environmentally sound, using a solvent that generally meets the EH&S requirements of today's society and is capable of being modified through processing and additives, to meet the need for complete cleaning in one process step. The advantage is the elimination of capital, materials, and cycle time needed in support of complex processes.

We are presenting an entirely new technology for photoresist, post etch and ash residue removal and surface preparation processes. The technology is a novel dry solvent system, referred to as OneStep™[2] technology and which has not been available previously. The focus of this paper is to show how this technology may be integrated into a variety of advanced packaging applications.

This discussion will concentrate on applications for which the material eliminates immediate barriers to high volume production in current WLP processes as well as presenting solutions for new *3-D* packaging processes currently under development. It will be shown that products incorporating OneStep technology are capable of eliminating the very common perception that a specific remover cleans chemistry is necessary for each resist type and supplier used. Most notable is the ability to remove resist as well as post etch or post ash residue in the same step, thereby eliminating costly reprocessing, handling, and cycle time in the fabrication of modern semiconductors.

Results and Discussion

Table 1 contains cleaning results for several different solder bumping and copper post applications that use a variety of photoresists. Table 2 contains results for resist and residue removal in 3-*D* applications. Post etch residue is usually considered to be organometallic in nature, due to reaction between the polymer being etched and the etch stop layer. In TSV processes which use deep reactive ion etching (DRIE), a high energy process, post etch residues can be more difficult to remove. In photoresist removal, it is common to find a solution that will remove photoresist or post etch residue, but not a single solution that will remove both in one step.

Test samples with TSVs created using DRIE are shown in Table 2. This shows a typical defect, post etch residue remaining on the via after cleaning. The resist and post etch residue are completely removed in one step.

Process	Photoresist	Metallization	Optical Microscopy Image	SEM image
Electroplated solder bumping	JSR THB 151N	Plated lead-free solder		
Electroplated solder bumping	Asahi CX-A240	Plated high-lead solder		
Electroplated solder bumping	Asahi CX-A240	Plated eutectic solder		
Electroplated Cu redistribution/pillar	Asahi CX-A240	Plated copper		
In-situ print solder past	DuPont™[3] WBR 2075	lead-free solder		
Electroplated solder bumping	TOK 5104	Plated eutectic solder		

Table 1. Cleaning results using products using OneStep technology.

Process	Photoresist	SEM before image	SEM after image
TSV	JSR THB 151N (One Step Resist and Residue Removal)		
TSV	JSR THB 151N (Residue Removal)		
Modified ShellOP	R&H Eagle II		

Table 2. 3-*D* application cleaning results

Test samples were cleaned in immersion baths using products containing OneStep technology and then examined for resist removal using optical microscopy, scanning electron microscopy and FTIR microscopy.

Permanent materials on the wafer surface provide additional challenges for removal solutions, whether metallic or organic. Characterization of the organic permanent materials gave results such as those shown in Fig. 1. FTIR spectra were obtained for the organic-based permanent materials before and after two hours exposure to a product formulated using the OneStep technology, heated to 70 °C. No change was detected in those permanent materials. Characterization of metallic components on the wafer included qualitative evaluations using optical and SEM images, shown in Table 1. In addition, static etch rates for Al and Cu were measured <1 Å/min .

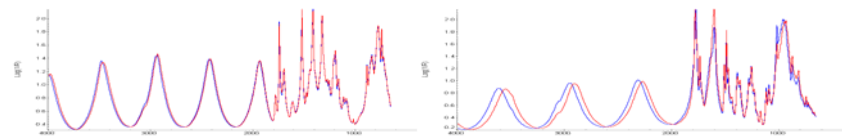

Fig. 1. FTIR spectra of polyimides before and after exposure to product containing OneStep technology for 120 min at 70 °C. (a) Asahi LS800T, (b) HD Micro 4104.

The complete removal of photoresist in electroplated WLP applications is critical to the success of subsequent processes. Defects created during photoresist removal may go undetected upon inspections, but show up after a later processing step. For example, in electroplated solder bump processes, the field metal etch step may be impeded by photoresist residues on the wafer surface. If the wafer is not clean, copper field metal is left on the surface, see Fig. 2(a), (b). The cause of the resist residue can be a function of the age of the photoresist remover, the amount of photoresist already in the photoresist

remover or that the remover is not well matched to the solubility parameters of the photoresist.

If the photoresist removal solution has high metal etch rates, defects are created. Fig. 3(a) shows a severe example Al etching where the Al pads are lifted off and removed. Control of Al etch is typically done using additives which remain the intellectual property or trade secrets of Dynaloy. Fig. 3(b) shows what the sample looks like when it is cleaned with a product containing OneStep technology and additives that preserve the aluminum.

Fig. 2. (a) and (b) show optical images of a wafer surface with Cu metal residue, (c) optical image of wafer cleaned using a formulation with OneStep technology and without metal residue after field metal etch.

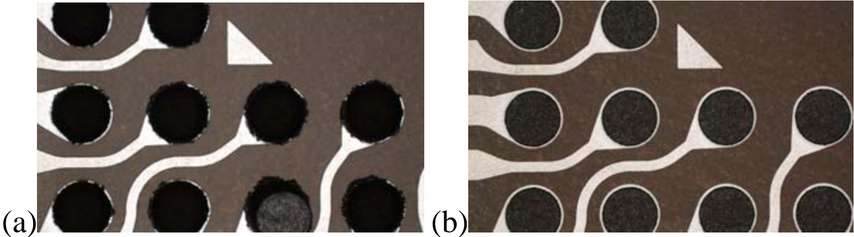

Fig. 3 (a) Image showing removal of Al pads after photoresist removal step. (b) Image showing pristine Al pads after photoresist removal using a formulation containing OneStep technology.

Conclusion

An entirely new technology using a dry solvent system has been shown to meet photoresist and post etch residue removal challenges. It has been shown to be useful in a variety of advanced semiconductor process applications.

---

[1] Peter Singer, *Semiconductor International*, June 15, 2006.
[2] OneStep is a trademark of Dynaloy, LLC
[3] DuPont is the trademark of E.I. du Pont de Nemours and Co.