REMOVAL OF POSITIVE PHOTORESIST FOR A LOWER COST OF OWNERSHIP PROCESS

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Abstract

Due to the economic downturn and rising costs of raw materials and finished goods, many industries are exploring strategies to improve processes while simultaneously reducing costs. In the semiconductor industry, such measures are being taken to reduce the cost of photoresist removal. To accomplish this goal, Dynastrip™ DL88™ was formulated and optimized as a cleaning solution suited for positive photoresist removal in both thin and thick film applications. These applications include cleaning processes in wafer bumping, bond pad formation, and sensitive metal line formation. Dynastrip DL88 meets the criteria of complete polymer removal from the surface and removes resists such as AZ 1513, AZ 10xt, and Shipley 827(Dow Chemical Company). The solution also meets low metal etch rate criteria on copper, aluminum, titanium, and leaded and lead-free solders. It is compatible with polyimide, silicon, and SiO_x, and does not attack permanent materials on the wafer surface. In addition to meeting the above criteria, Dynastrip DL88 was formulated in keeping with Dynaloy's commitment to be a responsible steward of the environment by providing green technology. This poster describes the polymer removal characteristics of Dynastrip DL88 and the removal processes which together, meet the desired goal of cost of ownership reduction.

Introduction

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 cleaners 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'.[i] Due to the economic downturn and rising costs of raw materials and finished goods, semiconductor manufacturers are exploring strategies to improve processes while simultaneously reducing costs. The challenge is in recognizing the importance of photoresist removal and its importance in a fully integrated process. To address the challenge, Dynastrip DL88 was formulated and optimized as a cleaning solution suited for photoresist removal in both thin and thick film applications. These applications include cleaning processes in wafer bumping, bond pad formation, fan out, and sensitive metal line formation. Dynastrip DL88 meets the criteria of complete polymer removal from the surface and removes resists such as AZ 1513, AZ 10xt, and Shipley 827(Dow Chemical Company). It was also formulated in keeping with Dynaloy's commitment to be a responsible steward of the environment by providing green technology in a catechol-free solution. Dynastrip DL88 considers a holistic design for manufacturability and integrates a fully enabled system provided that all criteria are met for its platform. Figure 1 shows typical images from an optical microscope and SEM images of wafer pieces that were cleaned in an immersion process using Dynastrip DL88 for 5 minutes at 60 °C, 70 °C, and 80 °C. The wafer pieces were coated with 8 µm of Shipley 827 photoresist and patterned to form bond pads.

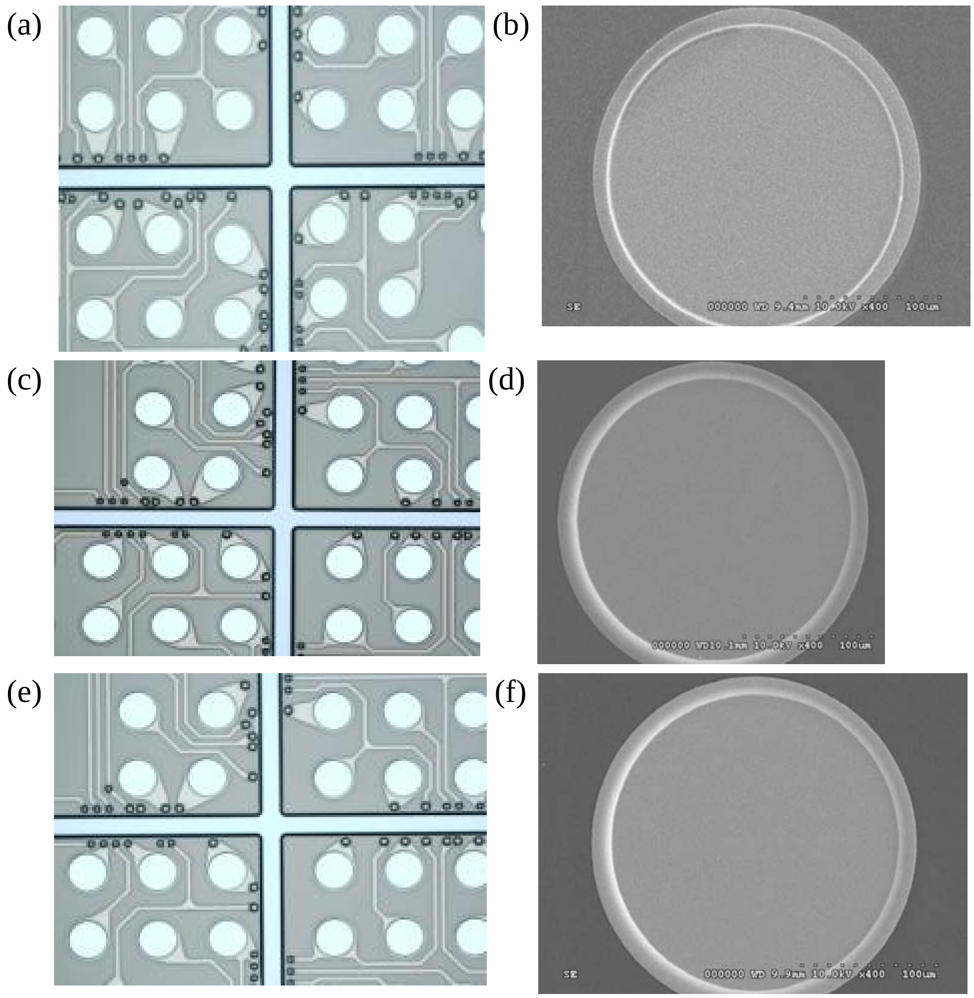

Figure 1. Cleaning results of wafers cleaned using Dynastrip™ DL88™ over a wide temperature range. (a) 60 °C, 5 min, optical image, (b) 60 °C, 5 min, SEM image showing compatibility with underlying metal; (c) 70 °C, 5 min, optical image, (d) 70 °C, 5 min, SEM image showing compatibility with underlying metal; (e) 80 °C, 5 min, optical image, (f) 80 °C, 5 min, SEM image showing compatibility with underlying metal.

The images above indicate the cleaning performance. Cleaning was complete and without redeposition of particles or residues on the surface. The dielectric was left unharmed, and without cracking or crazing. Through examination of the metal surface at the bond pad and discovery of a smooth, unaltered metal surface, favorable compatibility results are shown.

In many manufacturing processes, particularly in immersion systems, control of the bath composition in terms of the amount of moisture or oxygen it absorbs, is difficult. Since typically, these types of products are designed to have high flash points, low toxicity and compatibility with polymer systems, the main solvents have been somewhat limited to polar aprotic solvents such as n-methylpyrrolidone (NMP), dimethylsulfoxide (DMSO), tetrahydrofurfuryl alchohol (THFA), etc. Characteristically these types of solvents are hygroscopic but absorb different amounts of water depending on their temperature. A change in moisture level of a percent or two can have a significant impact on the cleaning results. Figure 2 shows the tendency for of Dynastrip™ DL88™ to absorb water at 23 °C to 70 °C.

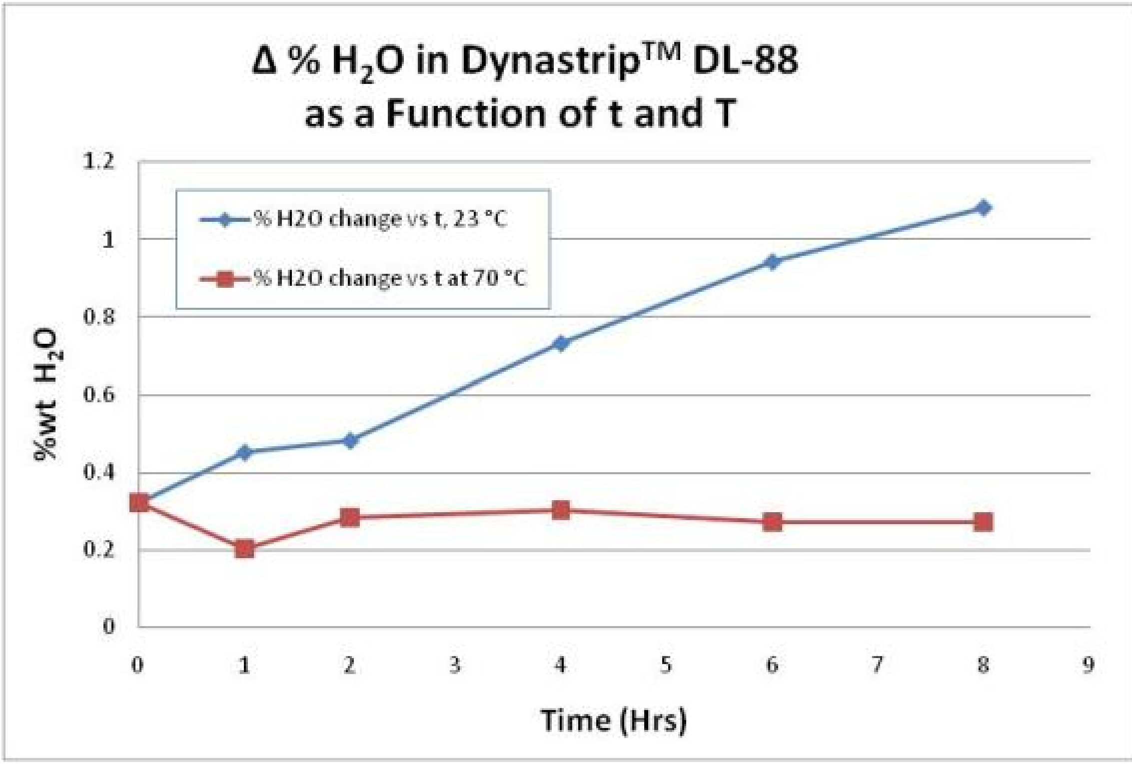

Figure 2. Moisture absorption characteristics over time at 23 °C and 70 °C.

The operating temperature often offers opportunities to control how much moisture is absorbed and the higher the temperature, the less moisture absorbed. However, in most cleaning applications, higher temperatures provide the potential to damage permanent materials on the wafer surface and so are generally avoided if possible. The final process is engineered to balance these effects. Samples such as those above, show cleaning characteristics comparable with those results shown in Figure 1, even with 3% water added into the Dynastrip DL88.

Many products suffer from reduced shelf life due to inclusion of reactive components such as acids or bases that cannot withstand high temperatures. Dynastrip DL88 has been heated to 70 °C. Samples have been taken and the pH of an aqueous solution of those samples has been measured during the test. Table 1 shows the stability of Dynastrip DL88 using pH measurements throughout the course of a shift when it has been heated to 70 °C for the duration.

Time (hrs)	**0**	**1**	**2**	**4**	**6**	**8**
pH	10.93	10.88	10.87	10.85	10.85	10.86

Table 1. Dynastrip DL88 stability though potlife, heated to 70 °C

In manufacturing processes, many interruptions can cause problems for line engineers. One such problem can occur when wafers are left in the strip tank for more than the allotted time. In Figure 3, optical and SEM images were obtained of samples that were cleaned for 2 (10 minutes) and 3 times (15 minutes) the recommended cleaning time. Typical defects that could be found are cracking or crazing of the dielectric or problems of metal etch due to increased exposure to the solution. None of these problems are seen in the optical or SEM images shown in Figure 3.

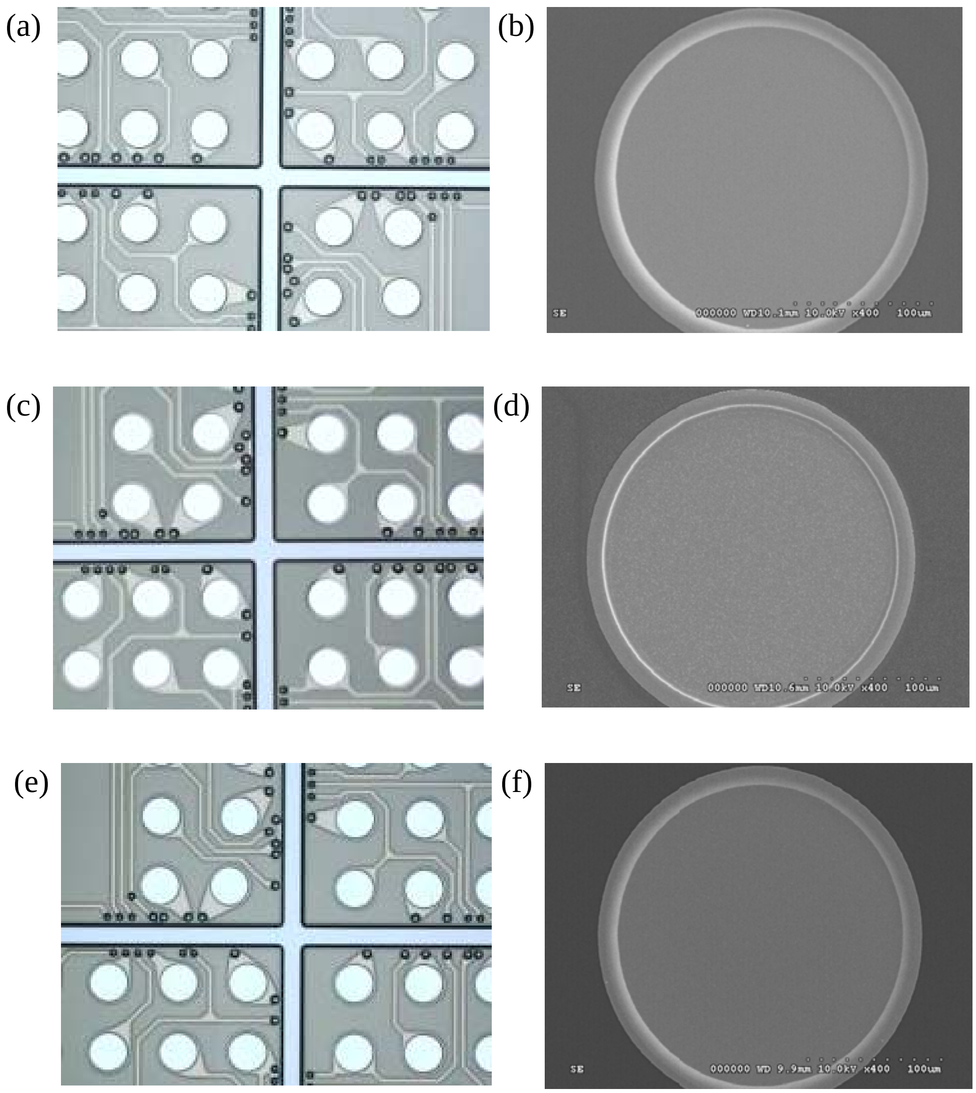

Figure 3. (a) 70 °C, 5 min, optical image, (b) 70 °C, 5 min, SEM image showing compatibility with underlying metal; (c) 70 °C, 10 min, optical image, (d) 70 °C, 10 min, SEM image showing compatibility with underlying metal; (e) 70 °C, 15 min, optical image, (f) 70 °C, 15 min, SEM image showing compatibility with underlying metal

Another typical issue for line engineers occurs when they heat up a solution to begin cleaning wafers and then are delayed due to a problem in another area of the facility. This situation can leave the cleaning solution heated to temperature (70 °C) for extended periods of time but with no wafers being cleaned in it. Dynastrip™ DL88™, heated to 70 °C for a total of 168 hrs (7 days). At 24 hour intervals, starting at 48 hours, wafer pieces were cleaned for 5 minutes. Cleaning was effective through the entire bath life time (pot life) test.

The solution has been designed, engineered, and tested to meet low metal etch rate criteria on copper, aluminum, titanium, leaded and lead-free solders. Some typical etch rates are shown in Table 2. In addition, etch rates have been recorded for solutions that have absorbed moisture from the air. In many typical formulations, an increase in water will have adverse effects on the

Metal	**Dynastrip DL88**	**Dynastrip DL88 +1%H_2O**	**Dynastrip DL88 +3% H_2O**
Cu	<4 Å/min	<4 Å/min	<4 Å/min
Al	<1 Å/min	<3 Å/min	<3 Å/min
Ti	<1 Å/min	<1 Å/min	<1 Å/min

Table 2. Metal etch rates determined by exposing PVD films of each metal to Dynastrip DL88 or Dynastrip DL88 + some water at 70 °C for 30 minutes. Etch rates were determined using changes in metal resistivity which were measured multiple times on multiple samples to come up with the averages presented above.

Compatibility with permanent materials on the wafer surface has been shown to closely related to the long term device performance. Dynastrip DL88 was tested for compatibility with a series of dielectric materials. The test window was increased to up to 3 times the typical process window to account for the potential production problems that might delay removal of wafers from this solution. Results are shown using fourier transform infrared (FTIR) spectroscopy and are shown in Figures 5-8.

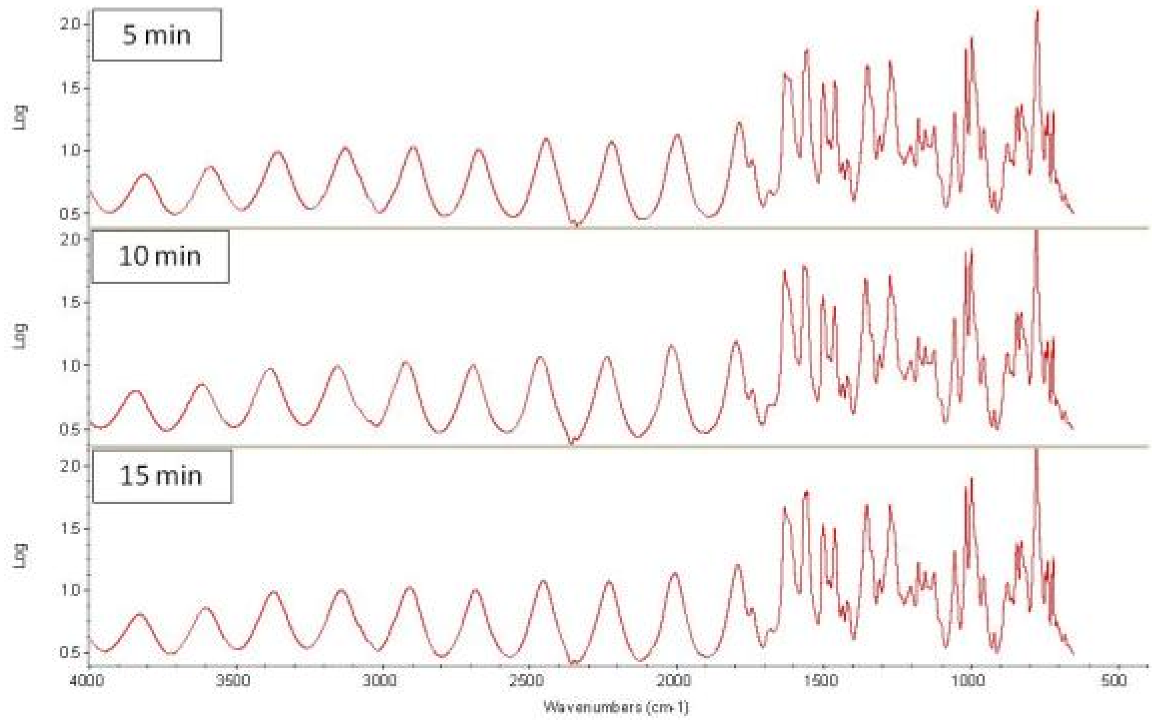

Figure 5. Compatibility results using FTIR for Dynastrip™ DL88™ and PBO

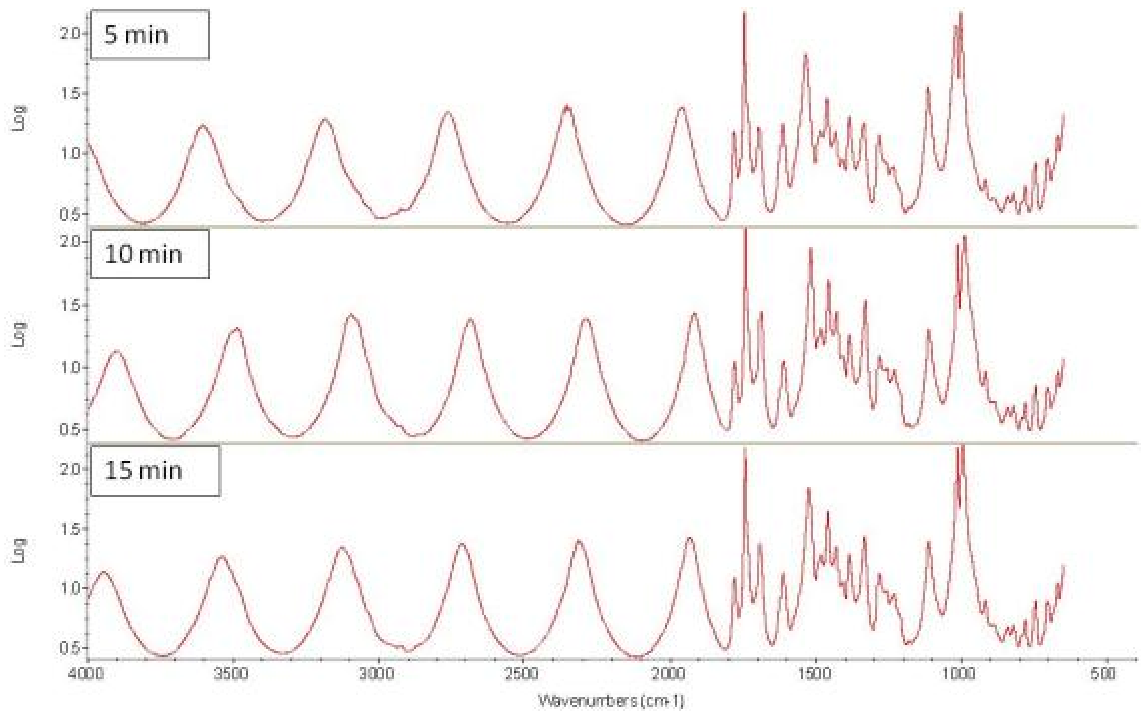

Figure 6. Compatibility results using FTIR for Dynastrip DL88 and PI

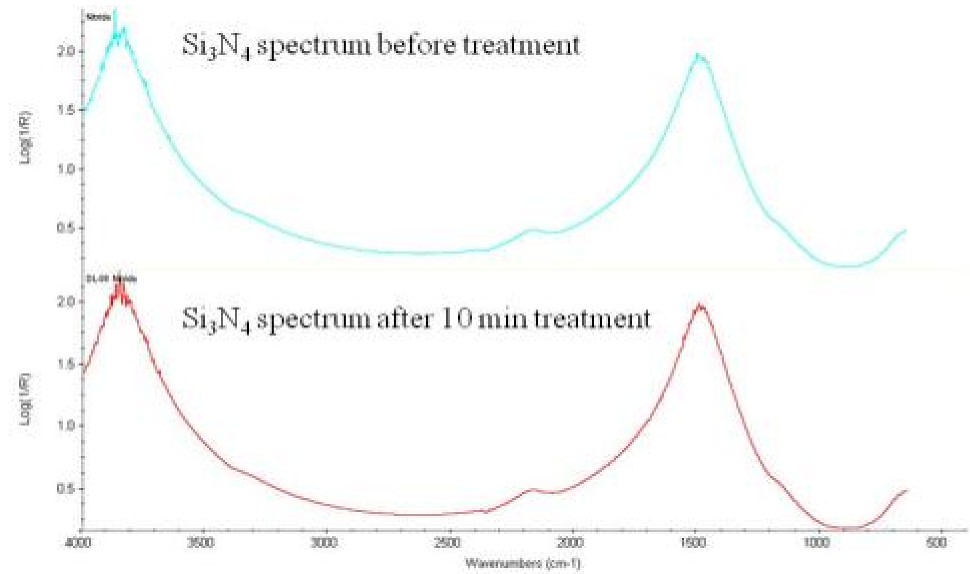

Figure 7. Compatibility results using FTIR for Dynastrip™ DL88™ and Si3N4

Manufacturing processes have been driven to evaluate low temperature cure dielectrics for use in their processes. Compatibility of photoresist removers that are designed to penetrate, swell and attack polymer systems, with these lower temperature cure samples, is difficult to obtain.

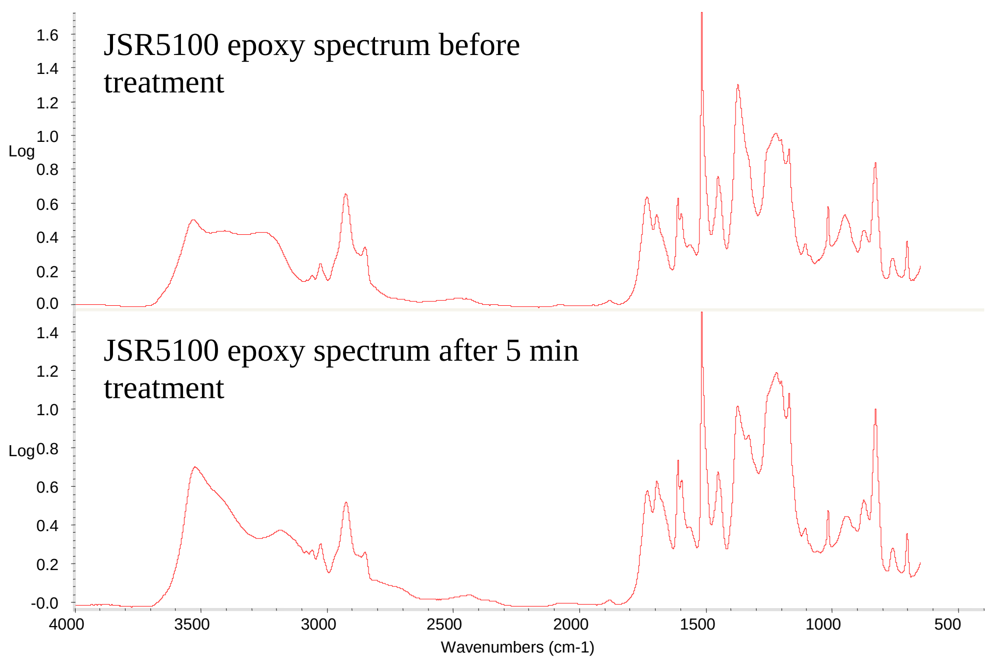

Figure 8. Compatibility results using FTIR for Dynastrip DL88 and low temperature cure JSR5100 epoxy

Figure 8 shows initial compatibility of Dynastrip™ DL88™ with a low temperature cure epoxy, JSR5100, from JSR Corporation of Japan. The film was cast onto the wafer surface.

A general spray solvent tool method has been developed for those applications where spray tools are required and is shown in Table 3. It is a general starting point for further optimization.

Solution - Tank #1: Dynastrip AP8800
Recommended Process Temperature: 70 °C

Step	Cycle	Time	RPM	Description
1		1-10 min	50-100	Wash cycle
2	Dwell	10 s	50	Allow chamber to drain to Tank 1
3	DI water rinse	10-20 s	50	Chamber drain to chemical drain
4	High speed DI rinse	3-5 min	500	Chamber to water drain
5	Low speed DI rinse	1-2 min	50	Chamber to water drain
6	Dwell	10 s	50	Chamber to water drain
7	N_2 purge	10 s	50	Chamber to water drain
8	High speed N_2 dry	8-10 min	500-1000	Chamber to water drain
9	Low speed N_2 dry	1 min	50	Chamber to water drain

Table 3. Generalized spray tool method for a batch spray solvent tool

Conclusion

In keeping with the ideal that cleaning is an intricate part of the semiconductor manufacturing process, Dynastrip™ DL88 was formulated to meet the most common challenges. The formulation was optimized for cleaning processes in a variety of applications such as wafer bumping, bond pad formation, fan out, and sensitive metal line formation. Dynastrip DL88 was designed with a high flashpoint, low toxicity, and compatibility with polymer systems. When combined with operating parameters suitable for its design, this product can be part of an integrated comprehensive system that reduces cost of ownership and increases productivity. Test results demonstrate complete polymer removal, low metal etch, reduced process time, and compatibility with permanent organic materials on the surface.

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[i] Peter Singer, *Semiconductor International*, June 15, 2006