Highly purified water-soluble protective film for semiconductor processes

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Abstract

Laser ablation is a process that can cut brittle materials and difficult-to-machine materials while maintaining productivity and quality. Miniaturized and highly integrated semiconductor die are singulated through the cutting of the silicon substrate using blade dicing after removal of the wiring layer using laser irradiation. However, during processing, laser ablation produces debris, which adheres to the workpiece surface and is difficult to remove. To resolve this issue, DISCO developed HogoMax, a water-soluble protective film for use in laser processing. This review describes HogoMax’s characteristics and explains its importance in laser ablation processing.

1. Background

With efforts to achieve better performance through improved integration, the miniaturization of semiconductor devices has progressed. Because the distance between wires has decreased due to device miniaturization, parasitic capacitance has become greater, leading to concerns about signal delay. To lower parasitic capacitance, low-k material is used as interlayer dielectrics. However, the mechanical strength of this material is low, and film peeling may occur if the workpiece is processed using standard blade dicing. In addition, due to the low feed speed needed to achieve high processing quality, it was difficult to obtain high productivity using blade dicing for compound semiconductors such as red LEDs (light emitting diodes), for which demand has been increasing in recent years, and gallium arsenide (GaAs), which is used as a substrate for high-frequency devices.

To cut these materials with both high quality and productivity, laser ablation is used for dicing.

For example, for semiconductor devices that use low-k material, the wiring layer on the surface is removed using laser ablation, and then the silicon substrate is cut using blade dicing. For devices that use a compound semiconductor substrate, singulation is sometimes performed using only laser ablation.

Laser ablation is a processing method that focuses laser energy on a small area for a very short time, causing the workpiece material to sublimate or evaporate.

However, if the molten material (debris) dispersed by laser ablation adheres to the electrodes on the workpiece surface, it will be difficult to remove using only DI water cleaning and may cause electrical property defects in the wire or bump bonding (figure 1).

To resolve this issue, DISCO developed HogoMax, a water-soluble protective film for use in laser processing.

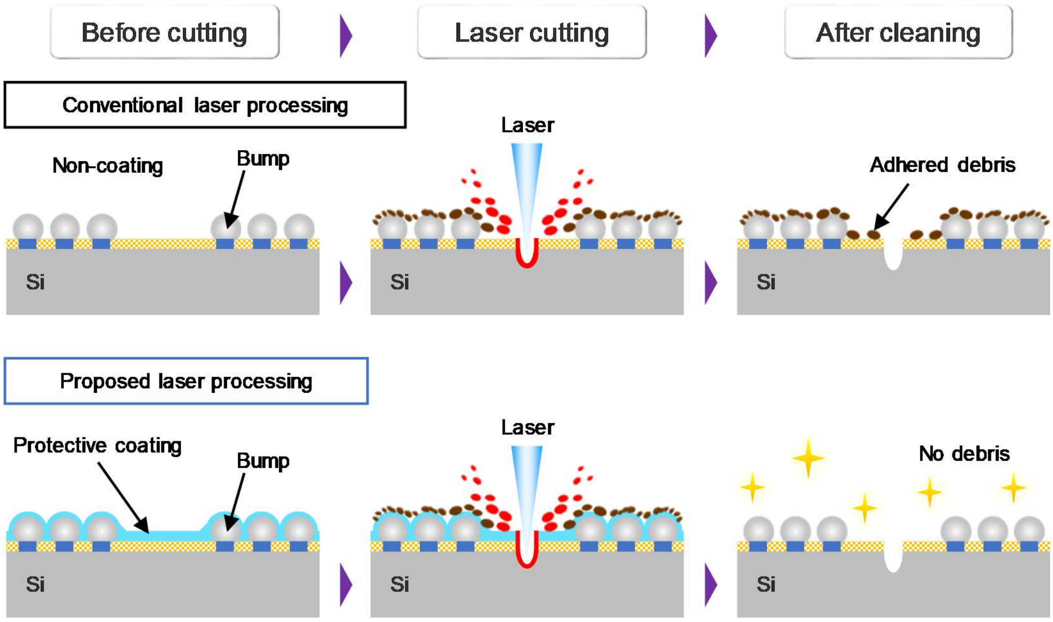

Figure 1. Schematic drawing of laser grooving process; *Top*, conventional laser grooving process without protective film; *Bottom*, laser grooving process with water-soluble protective film

2. HogoMax usage

If HogoMax is spin coated onto the workpiece surface before laser ablation processing, debris will accumulate on the protective film instead of making direct contact with the workpiece surface. As HogoMax is water soluble, when it is removed during DI water cleaning, the debris that has accumulated is removed as well. As a result, laser processing without debris adhesion to the workpiece surface becomes possible (figure 2).

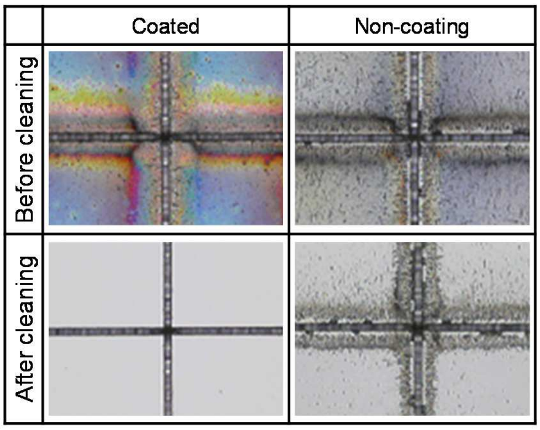

Figure 2. Comparison of ablation processing with and without HogoMax, using a GaAs mirror wafer

3. Physical properties of HogoMax

The major physical properties of HogoMax are listed in table 1. One feature is its metallic impurity concentration of 50 ppb or less, which minimizes impact on the semiconductor device, enabling processing in which heat is applied locally, such as laser ablation.

Table 1. Major physical properties

Material properties	HogoMax103
Viscosity (cP)	235
pH	3.3
Surface tension (mN/m)	50.2
Specific gravity	1.012
Absorbance (undiluted @ 420 nm)	0.019
Metal impurity concentration Na, K, Fe, Cu @ ppb	<50

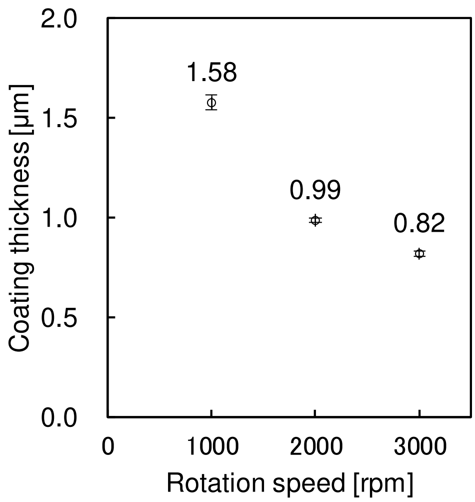

Figure 3. Film thickness at different rotation speeds

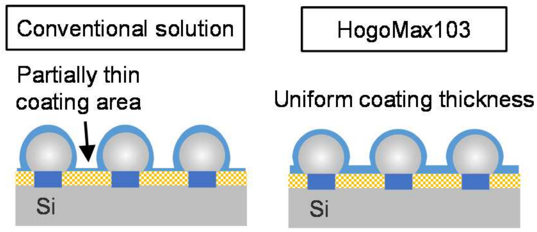

Figure 4. Differences in coated film thickness based on type of protective film

4. HogoMax coating performance

Variation in coated film thickness caused by spin coating rotation speed was measured using a silicon mirror wafer (figure 3). It was discovered that protective film thickness can be controlled to between 0.82 and 1.58 µm using rotation speed. Maximum coated film thickness variation, 0.04 µm at 1,000 rpm, was minor with excellent uniformity.

In addition, when film is coated onto an uneven surface, such as ball bumps, deviation typically occurs near the uneven area due to surface tension, causing thin sections in the coating (figure 4).

HogoMax is composed of materials that suppress surface tension, achieving uniform film thickness even in areas near the street or densely covered with ball bumps.

In addition, depending on the type, commercial protective films may leave some areas uncoated during spin coating due to the workpiece surface pattern (figure 5). Because it optimizes the wettability of the wafer, HogoMax can be coated onto the entire surface of the workpiece through spin coating without liquid accumulating on areas of the workpiece surface with a different shape or materials.

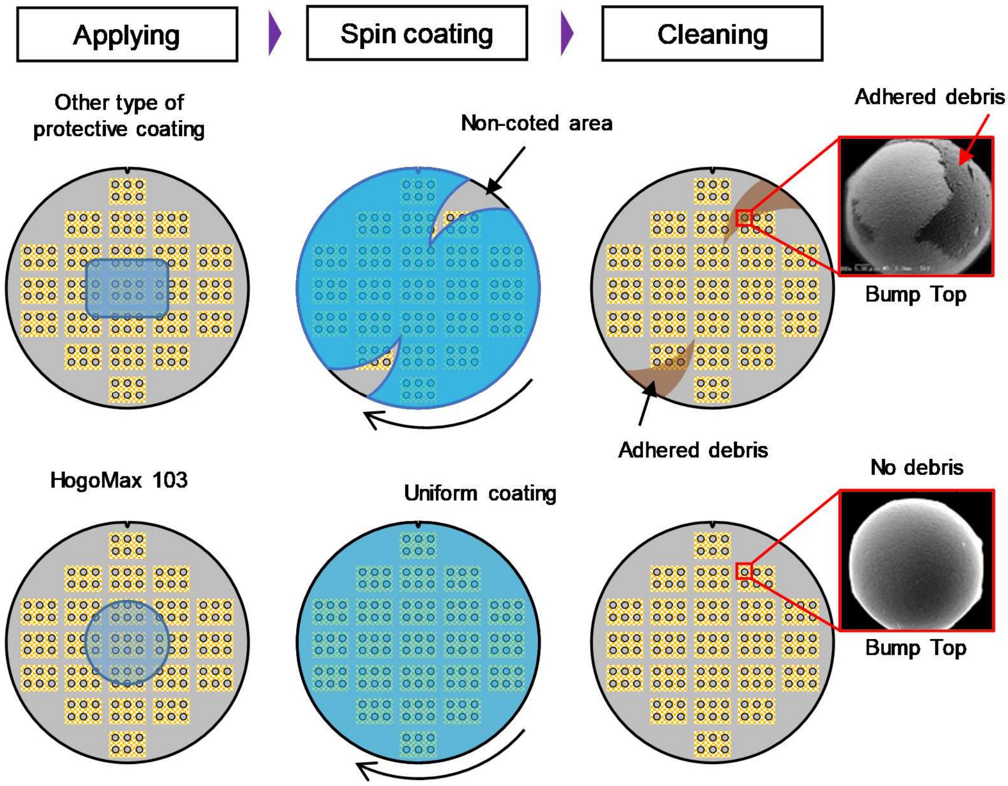

Figure 5. Different protective films coated onto wafers with bumps; *Top*, debris adhesion when protective film manufactured by another company was used; *Bottom*, debris adhesion when HogoMax was used

5. Processing performance with HogoMax

With protective films made of high-polymer material, the constituent material may coagulate on the surface due to cross-linking during laser ablation, which makes it difficult to remove through cleaning (figure 6).

Because HogoMax is manufactured for use with laser processing, materials are optimized to prevent cross-linking. Thus, no coagulation due to heat was observed, even after laser ablation processing.

6. HogoMax cleaning residue

To measure HogoMax residue after cleaning, the workpiece surface was measured with FT-IR after coating and after DI water cleaning. In the sample that had been coated, the spectrum clearly

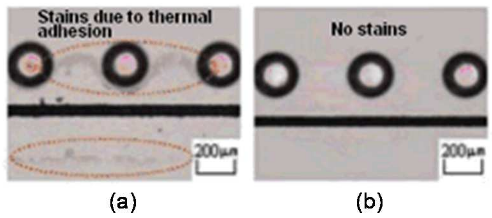

Figure 6. Comparison of protective film coagulation due to heat generated by ablation processing; (a) product without countermeasures, (b) HogoMax

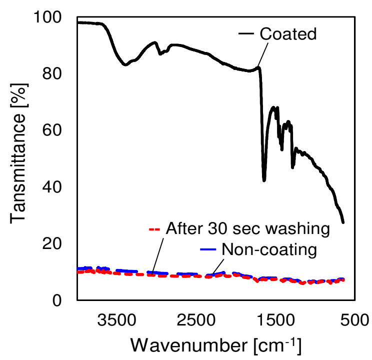

Figure 7. FT-IR spectrum on the wafer surface after protective film coating and DI water spinner cleaning.

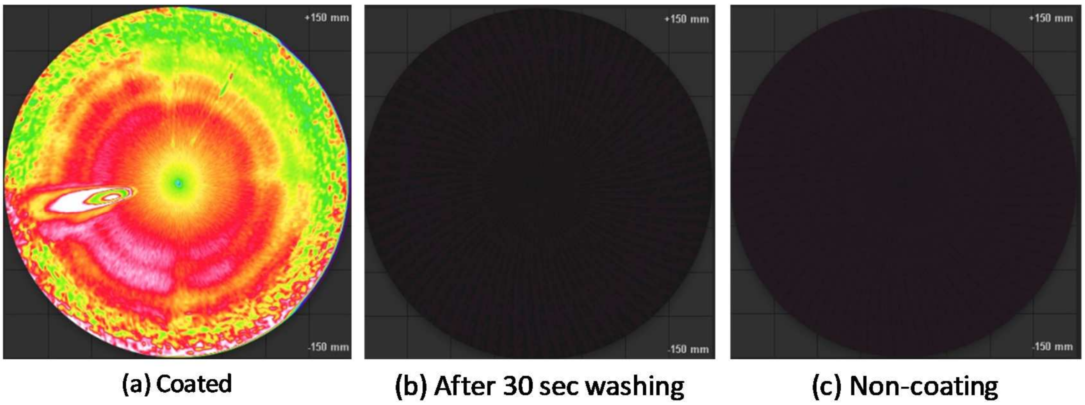

Figure 8. Comparison of coated film thickness on the wafer surface after protective film coating and after DI water spinner cleaning

shows the presence of HogoMax on the workpiece. The measurement results after 30 seconds of DI water cleaning were similar to those before HogoMax was coated (figure 7).

In addition, figure 8 shows a visualization and comparison results for HogoMax coating. As shown, HogoMax, which had been evenly coated onto the workpiece surface, was removed with 30 seconds of DI water cleaning. These results show that it is possible to remove HogoMax satisfactorily through only DI water cleaning.

7. Conclusion

This review shows that using HogoMax can prevent debris adhesion caused by laser ablation processing. With the combined use of laser ablation processing and HogoMax, it is possible to process difficult-to-machine materials and compound semiconductors, such as low-k film, while achieving both high productivity and quality.

References

(1) M. Kumagai, N. Uchiyama, E. Ohmura, R. Sugiura, K. Atsumi and K. Fukumitsu, "Advanced dicing technology for semiconductor wafer -Stealth Dicing," 2006 IEEE International Symposium on Semiconductor Manufacturing, 2006, pp. 215-218, doi: 10.1109/ISSM.2006.4493065.

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