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A Novel Water-Washable Coating for Avoiding Contamination During Dry Laser Dicing Operations

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Abstract

Laser micromachining has been used for years and is accepted as a common method to dice wafers [1-3]. The advantages of laser processing over sawing are well known to include a reduced kerf width and more flexibility in cutting irregular-shaped die or through-cuts of fragile substrates below 50um [4]. It has been reported that protective coatings are required to eliminate particle contamination generated from material ablation in a dry laser [5]. A simple water-soluble coating is desired to offer engineers more flexibility to use dry lasers without contamination or serious impacts to manufacturing. A novel aqueous-soluble coating, Aq-PCoat™, is available from Lee Chang Yung Chemical Industrial Corporation (LCY) [6]. Several coating chemistries have been developed by LCY to address a range of process demands, all offering a rapid water rinse. In one demonstration, LCY's Aq-PCoat™ chemistries were applied to wafers and laser scribed followed by subsequent water washing. The results suggest that certain polymers of a high molecular weight and inert chemical character (i.e. straight-chain, high saturation, etc.) produced the best results with least residue and the smallest kerf. This report offers further details on our development of water washable coatings used to eliminate debris and improve laser processing of GaAs wafers.

INTRODUCTION

In an effort to meet common miniaturization and thermal management trends to small die on thinner substrates, innovations in dicing operations must occur. These trends are seen as the ITRS in establishing standards for 32nm processing [7], production announcements similar to INTEL on 90nm chips offering transistor densities >3million/mm [8], and thinning substrates to a few microns [9]. Laser processing as compared to conventional sawing is known to reduce the occurrence of many unwanted phenomena such as chipping, kerf size (i.e. cutting trough), and undefined breakage from the stresses of mechanical dicing [10]. Laser ablation (evaporation/removal of contamination by high temperature substrate impact) may help to minimize the problem, however, the most promising conditions appear to involve the use of protective coatings. Combining the use of simple water-wash coatings with laser operations will further improve the quality of laser processing in a cost effective manner.

During a typical dicing operation, the process is focused at a series of division lines that separate the die, commonly referred to as "streets". When using a laser to scribe or cut linearly down these streets the beam is focused onto the substrate. For a common optical device, the material may be composed of GaAs, GaN, Si, SiC or sapphire. The beam energy transfers to the substrate and melts the material to cause evaporation, trenching, and thermal conduction. The melt temperatures of these substrates are 1240°C (GaAs/GaN), 1414°C (Si), 2730°C (SiC) and 2040°C (Al_2O_3). Heat is transferred out from the beam to an extent defined by the heat affected zone (HAZ) depicted in Figure 1.

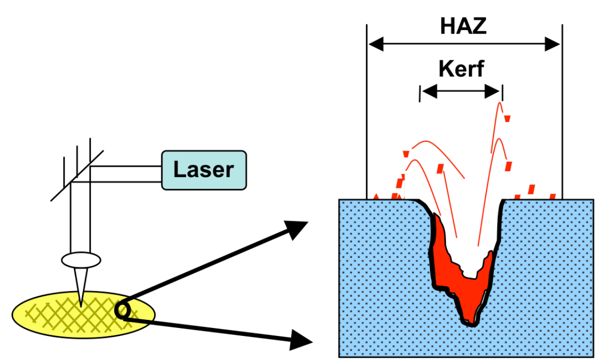

Figure 1. The particle contamination formed while laser dicing is due to significant heat in the heat-affected zone (HAZ).

The laser beam interaction is very intense and forms a vapor-cloud surrounding the work area. The vapor-cloud is composed of material from the substrate and subsequently rains down onto surrounding areas of the HAZ. Regardless of whether the laser operation is conducted on the wafer front-side or back-side, the resulting particulate contamination is deemed unacceptable for production of quality die.

The application of water or the use of coatings to minimize or eliminate contamination during laser dicing has been reported [1-4, 10]. A simple water-washable coating that is applied just prior to laser scribing and followed with a simple room temperature dump rinse or SRD can produce very clean results as shown in Figure 2.

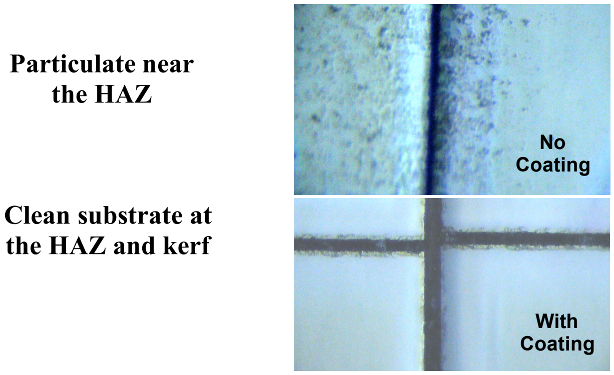

Figure 2. Photos of a water surface after laser cutting without (top) and with LCY's Aq-PCoat™ product (bottom) after rinsing.

There are various levels of success in the use of water-wash coatings which are dependent upon the chemistry and process. In this paper, we will present several chemistries, applications, and results which lead towards a simple room temperature water-washable process.

EXPERIMENTAL

Several coating chemistries were identified based upon their make-up as organic or inorganic. For contamination and corrosion concerns, all of these candidates were metal ion free and exhibited a neutral pH upon dilution in DI Water. The materials were tested to confirm coating smoothness (i.e. uniformity @ <1% TTV - total thickness variation) by common spin-coating practices for a thickness @ < 5um. The materials tested are shown in Table 1 and their chemical structures are given in Figure 3.

Table 1. Description of water-washable coating chemistries tested for laser processing.

#	Chemistry	Carrier Solvent	Thickness (um)
1	Pyrollidone	Semi-aqueous	<3um
2	Glycol	Semi-aqueous	<3um
3	Glycol + Ethoxylated Ethanol	Semi-aqueous	<3um
4	Glycol + Ethoxylated Ethanol	Semi-aqueous	5-10um
5	Glycol + Borax	DI Water	<3um
6	Pyrollidone + Alkylsulfoxide	DI Water	<3um
7	Pyrollidone	Solvent	5-10um

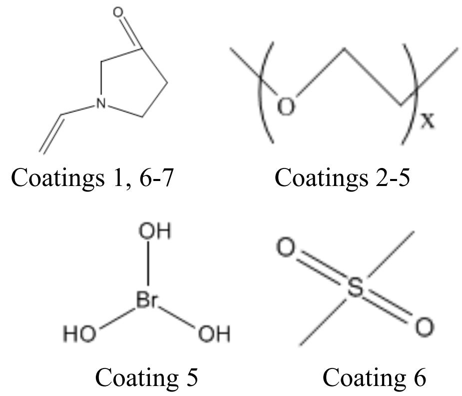

Figure 3. Representative structures for the chemistries identified in Table 1.

The application process for these coatings is by spin-coat technology, although other means may provide equal or better results, such as spraying or dipping. A typical coating of approximately 3um thickness may be achieved with spin-speed of 1000-1500rpm and curing @ 130˚C on a hot plate for 5mins. The coating is stable at room temperature under normal humidity conditions found in a fab. Following curing, the wafers are processed by the laser and rinsed by DI water and dried. They are inspected for the presence of contamination. A flow chart is shown in Figure 4.

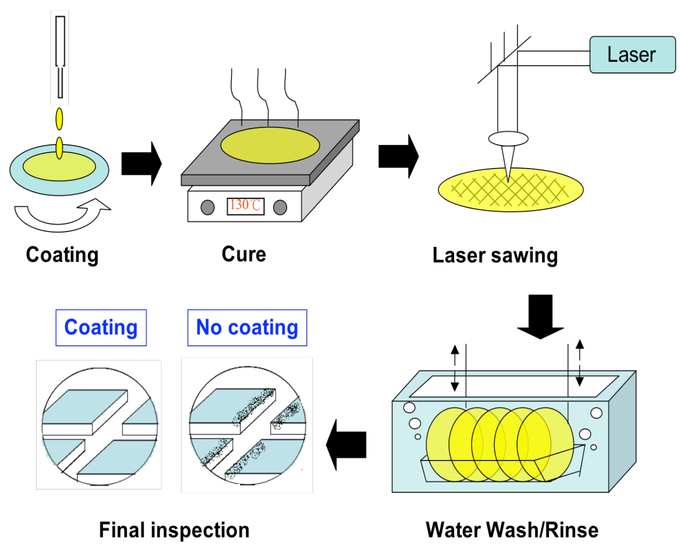

Figure 4. Flow chart for laser dicing process, indicating coat, cure, laser scribe and cleaning process with a final inspection.

GaAs wafers of approximately 100um thickness are coated with the chemistries identified in Table 1 and Figure 3 by the process described in Figure 4. The wafers are then laser processed on a NewWave Research, Inc. AccuScribe™ SS40EL dry laser tool using a 365nm laser at 0.45W, 60 kHz repetition, and a scribing speed of 15mm/sec [11]. Using SiC wafers as reference, the system is calibrated to produce laser trenches to a depth of 20um and a kerf width of approximately 5um.

RESULTS

The chemistries identified in Table 1 and Figure 3 all appear to exhibit similar solution characteristics when prepared to a solids content varying from 20-40%. A stable condition in the coating chemistry is key for material performance as any stability issues will affect the material viscosity over time and ultimately change thickness and the ability to focus the laser onto the substrate. The viscosity and spin-speed thickness for the coating are indicated in Figures 5 & 6, while Figure 7 shows the microscopy pictures for the kerf and HAZ.

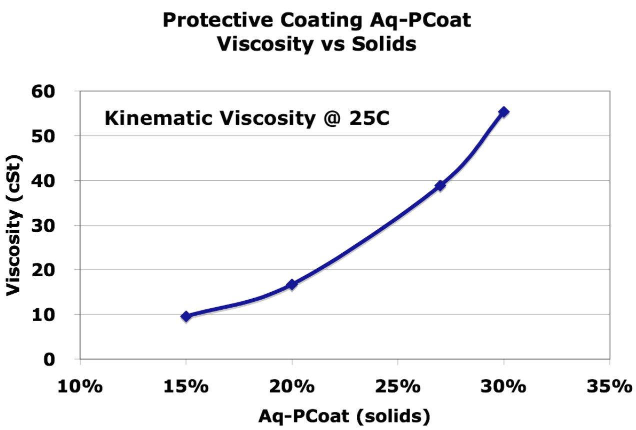

Figure 5. Viscosity vs. % solids curve showing low values of LCY's Aq-PCoat, consistent with the premise of a coating material.

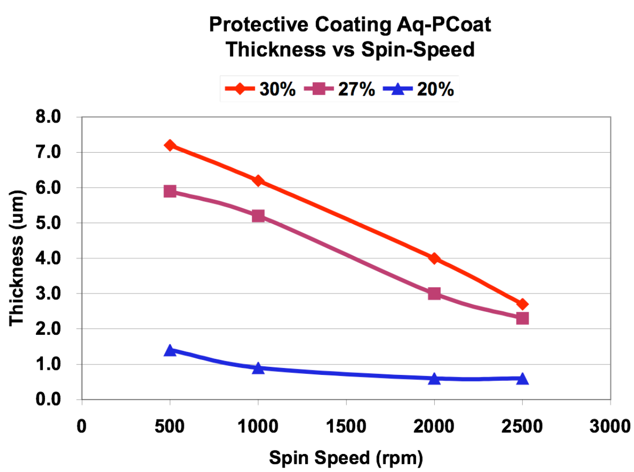

Figure 6. Thickness vs. spin speed for a range of viscosities of coating systems for laser operations.

Following laser processing and rinsing, the wafers were photographed by an optical microscope, paying special attention to the kerf and HAZ for each respective coating. The water-wash conditions were done conservatively, with no agitation and the temperature was controlled to room temperature and hot (approx 60-80˚C). The wafers were successively cleaned in two room temperature (RT) DI water immersions and finished with the hot rinse. The time for each exposure was 30sec. Photos were taken between each exposure and attempts were made to measure the kerf width. The photos in Figure 7 are following completion of all rinses.

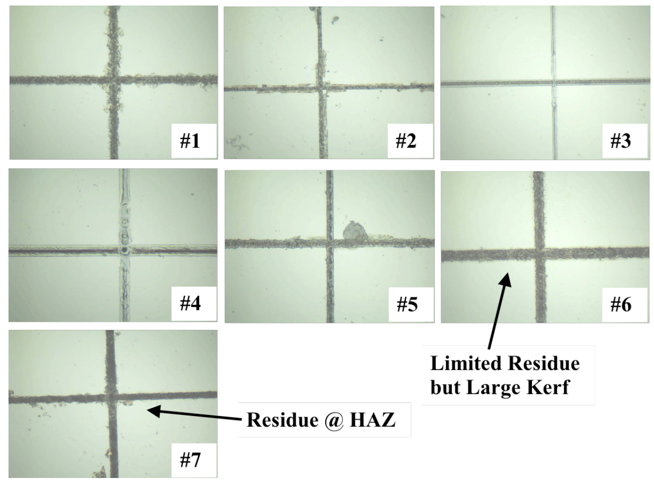

Figure 7. Optical photos of laser processed GaAs wafers with coatings listed in Table 1 and with DI Water. Note that limited residue exists on sample #6 with a large kerf while #7 exhibits a small kerf but large residue.

The kerf area of each sample was measured at 4 locations within x-y locations from different cross-hatch (i.e. criss-cross streets). Specific attention was given to samples #3 & #4 where the chemistries are similar, however, #4 is a "thicker" coating. It is noted that sample #3 exhibits significant improvement as qualitatively observed for lack of residue and a small kerf width. Photos of these areas and the kerf measurements were made and are shown in Figure 8.

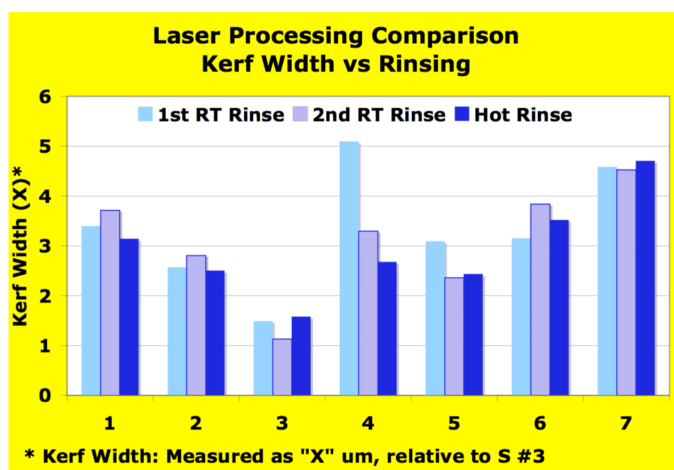

Figure 8. Bar graph of kerf width measurement relative to sample # 3 (i.e. sample # 3 = x). Each bar refers to DI Water washing as: a) 1st RT rinse, b) 2nd RT rinse, and c) hot rinse.

DISCUSSION

The photos in Figure 7. suggest that several coatings may contribute to an irregular condition in the HAZ as a result of thermal induced cross-linking to render the coating material insoluble. Cross-linking is a condition of polymerization from reactions between different regions in a particular molecular species where C=C (double bonds) exist. These regions are active sites that may combine with others to increase the molecular weight of the species.

When reviewing Figure 3, we observe the chemistry, pyrollidone, to exhibit the highest double bonded carbons in the group of materials tested. From this, cross-linking appears to be a good explanation for the residue, which remains after water washing. This cross-linking explanation supports the observations of sample #'s 1, 6 and 7 to exhibit residue. For item #6, we see no improvement with the addition of the alkyl sulfoxide - a thermally stable molecule. As far as the glycol is concerned, this chemistry shows the most promise. Adding Borax®, a common ingredient to most glasses, did not improve thermal stability and reduce the residue. Rather, only the addition of the unsaturated ethoxylated straight chain ethanol was the most dramatic improvement (Sample #3). Finally, it was also noted that thickness did not appear to affect improved results (i.e. #4 & #7).

CONCLUSION

Laser processing of semiconductor wafers with room temperature water-washable coatings can produce contamination-free surfaces without HAZ residue. This effort can also be done while maintaining cuts with a desirable small kerf width. The aqueous coating, LCY's AqPCoat™, is available in a range of solids contents. Although it may be preferred to use thin coatings, their may exist processes where it may be desirable to use thicknesses >10um (i.e. mems). The cured coating is stable under normal fab conditions and is removed easily with a range of water temperatures and washing practices.

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