Improvements in Processing - Carrier and Material Impacts

Molly Hladik[1] and Aric Shorey[2]

[1]Brewer Science, Inc., 2401 Brewer Drive, Rolla, MO 65401, mhladik@brewerscience.com, (573) 364-0300
[2]Corning, Inc., SP-YE-A10D, Corning, NY 14831, ShoreyAB@corning.com

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Abstract:

The advancements in carrier technology for thin wafer handling are multifaceted. The ability to adjust the coefficient of thermal expansion (CTE) of glass to match that of different device substrates is a driving force that can allow implementation of glass carriers in this process technology space. The main points presented include a) a comparison of CTE-matched glass across the different III-V semiconductor substrates, b) the ability of the glass to survive different backside processes without pretreatment, which normal carriers, such as silicon, cannot, and c) the ability of glass carriers to negotiate the array of debonding methods. These improvements allow for process developments starting with small substrates that translate to larger substrates that may require different debonding mechanisms. Such improvements provide flexibility in the post-thinning processes that are not available with traditional carriers.

INTRODUCTION

Compound semiconductor companies have been performing wafer thinning as a means of heat dissipation for over 20 years. GaAs wafer sizes, which started as wafer pieces, are now 150 mm in size and are run at relatively high volume in the world's leading fabs. As volume increases, the size of the substrate will also need to increase further to reduce cost. Moreover, III-V semiconductor substrates are becoming a larger part of the product mix for making chips. As this trend continues, the ability to support these more fragile substrates or thinned substrates with high topography throughout all backside processes, from initial thinning through debonding, has become more important.

To make this capability possible, new materials must be designed which enable the device to be subjected to less stress throughout the process. Even though more support is needed, it cannot be obtained at the cost of materials or throughput.

In this paper, the new glass carriers and new materials will be benchmarked against industry standards and new materials.

BACKGROUND

Brewer Science and Corning have been working together to implement a carrier technology that allows for a more stable, low-cost-of-ownership carrier that can span all of the different debonding technologies with increased performance.

Glass provides many advantages for use as a carrier in wafer processing applications. First, its transparency provides an opportunity to visually inspect the bond prior to expensive processing operations. This simple, low-cost inspection can have important process and yield implications. A second advantage provided by the transparency of glass is the ability to utilize laser debonding approaches in addition to other approaches such as mechanical and thermal processes. Also, glass has good chemical durability in important chemical environments and provides opportunities for many reuse cycles and lower cost. Finally, and perhaps most importantly, is the ability to adjust the coefficient of thermal expansion (CTE) of glass by adjusting the glass composition. This ability provides the opportunity to manage the warpage, and the associated stress, of the bonded stack. Last year, Brewer Science introduced BrewerBOND® 220 material. This material can be applied in a single thick coating, is stable at higher temperatures, and generates stress comparable to wax.

EXPERIMENTAL

Materials:
Corning® CTE-matched glass wafers
BrewerBOND® 220 temporary bonding material
Wax adhesive[1]

Equipment:
Cee® 1300CSX thermal slide debonder
Dektak® profilometer

[1]Crystalbond™ wax adhesive was used for comparison purposes.

RESULTS

As technology progresses, the ability to move to a lower cost of ownership becomes not just desirable, but a necessity. Moving to CTE-matched glass versus traditional carriers does just that. The glass carriers are less expensive, as well as reusable; they survive backside processing that opens up debonding processing options; and they can eliminate processing steps such as performing a confocal scanning acoustic microscope (CSAM) analysis to check the bond line. These capabilities result in a throughput increase. The CTE of the glass was measured using ASTM method E228 and referenced at 25˚C. The results for the matched glass are shown in the right-hand column in Table 1.

Substrate	CTE (ppm/˚C)	CTE of Matched Glass (ppm/˚C)
Si	2.6	3.2
GaAs	6.68	6.6
Sapphire	5.3	n/a

TABLE 1: COEFFICIENT OF THERMAL EXPANSION (CTE) FOR THE DIFFERENT DEVICE SUBSTRATES AND THE CORRESPONDING MATCHED GLASS.

While Table 1 shows the CTE match at a given temperature, Figure 1 shows the CTE match of Si and glass across the temperature range within which backside processing occurs.

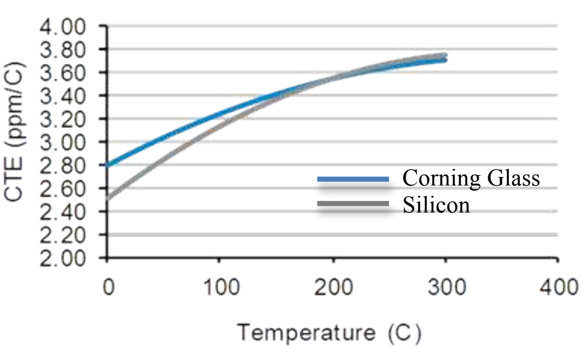

FIGURE 1: GRAPH OF CTE COMPARISON OF SI COMPARED TO CORNING GLASS ACROSS THE TEMPERATURE RANGE WITHIN WHICH BACKSIDE PROCESSING OCCURS.

In most GaAs processing, sapphire is used as a carrier because its CTE is similar to that of GaAs. However, as shown in Table 1, the CTE of sapphire is not an exact match to the CTE of GaAs. Also, sapphire is at least 10 times the cost of glass and is more susceptible to thermal shock than glass. The thermal shock susceptibility of the sapphire can cause a reduction of throughput due to the need to heat or cool at a slower rate, which is not required for glass.

One of the known benefits that typical wax bonding materials have is little to no material stress before, during, or after processing. This quality is important for processing so that the bonded stack can move through typical backside processing without experiencing handling issues. The bow measurements in Table 2 compare BrewerBOND® 220 material to a wax adhesive across 200-mm wafers. The bow of the materials in Table 2 was measured using the Dektak profilometer. It measured the bow of a 200-mm Si wafer prior to coating and then re-measured the bow of the same Si wafer after coating the bonding material at the specified thickness.

Film Thickness (µm)	BrewerBOND® 220 Material (µm)	Wax Adhesive (µm)
25	-1.67	2.2
50	5.26	
100	0.16	8.8

TABLE 2: BOW COMPARISON OF BREWERBOND® 220 MATERIAL WITH A WAX ADHESIVE ON 200-mm SILICON WAFERS.

Although the wax can generate low stress, throughput is a large portion of the processing cost. Achieving the appropriate film thicknesses for different topography can be a challenge for wax. Figure 2 is a spin-speed curve for the wax adhesive at 50% solids compared to the BrewerBOND® 220 material at 47% solids. This curve shows that device wafers requiring a thicker coating could require multiple coatings of the wax adhesive, whereas with the BrewerBOND® 220 material, a 100-µm coat could easily be achieved in a single step. The thicknesses of the coatings were measured by using the Dektak profilometer.

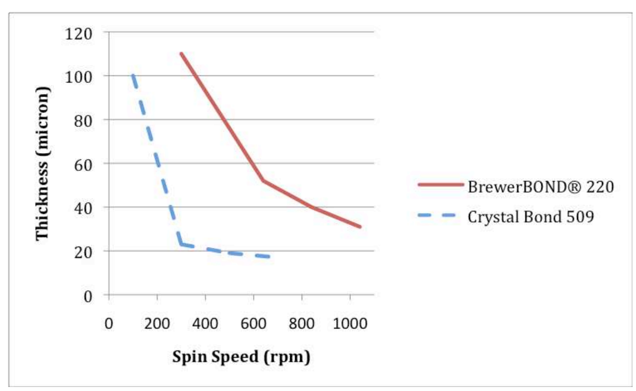

FIGURE 2: SPIN-SPEED CURVE COMPARING THE WAX ADHESIVE TO THE BREWERBOND® 220 MATERIAL.

Whether the debonding method is thermal slide, room temperature mechanical, chemical release, or laser, the bonded pair must survive the backside processing. The fluidity of the bonding material at the processing temperature plays a role in how stable the thinned device is. The rheology curve in Figure 3 shows that the wax adhesive reaches a much lower rheology at a lower temperature than the BrewerBOND® 220 material. This property may help in debonding after processing; however, during backside processing, this may create issues. If there is too much mobility in the bonding material during the backside processing, it can lead to an increase in yield loss. This yield loss can be manifested as broken or cracked wafers.

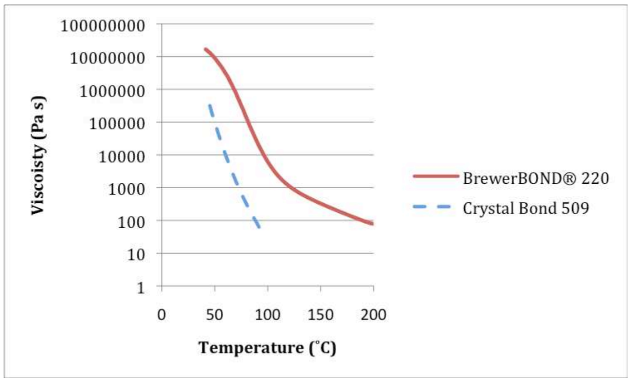

FIGURE 3: RHEOLOGY OF THE WAX ADHESIVE AND THE BREWERBOND® 220 MATERIAL.

As viscosity is reduced, the stress during thermal slide debonding is also reduced. Wax materials are usually debonded by thermal means and have very low stress during the process. The BrewerBOND® 220 material has the ability to debond at a range of temperatures from as low as 150°C to over 200°C. Figure 4 and Figure 5 are comparison graphs of the thermal slide process used with the BrewerBOND® 220 material and the wax material. The debonding process was completed at two different temperatures. The temperatures were determined based on rheology.

Figure 4 shows that the BrewerBOND® 220 material reduces the force or stress that the wafers experience during the debonding process faster than the wax adhesive. This reduction allows for a faster debonding speed. The wax adhesive can be debonded at a higher temperature, which would also reduce the force during debonding and increase the speed of the process. However, this does not improve the stability of the backside processing. The relative debonding times for BrewerBOND® 220 material and the wax adhesive are ~1 minute and ~2 minutes, respectively.

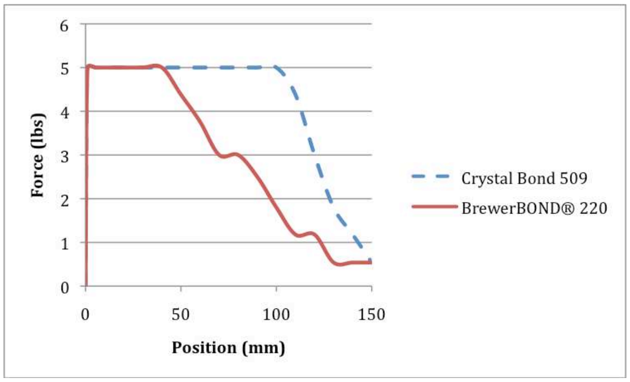

FIGURE 4: THE FORCE OF THE THERMAL SLIDE DEBONDING OF WAX ADHESIVE AT 85˚C COMPARED TO BREWERBOND® 220 MATERIAL AT 190˚C.

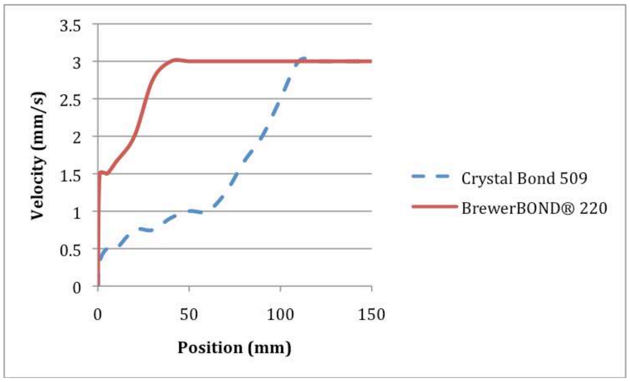

FIGURE 5: THE VELOCITY OF THERMAL SLIDE DEBONDING OF WAX ADHESIVE AT 85˚C COMPARED TO BREWERBOND® 220 MATERIAL AT 190˚C.

CONCLUSIONS

As discussed in the results, the CTE match of the glass to the different device substrates allows for uniform expansion of both the carrier and the device wafer during the different backside processes. Glass has less of an issue with thermal shock than some of the traditional carriers such as sapphire. Also by using CTE-matched glass, the need for bond line inspection such as CSAM analysis is eliminated, and any debonding method can be used, whether it is laser, chemical release, thermal slide, or mechanical. Glass is a key enabler of the laser debonding method with a throughput upwards of 40 wafers per hour. This allows for an overall increased throughput and lower cost of materials.

The BrewerBOND® 220 bonding material allows for a lower stress that is comparable to wax, a wider backside

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process window that is better than wax, and a single coating step for devices that require coatings thicker than 20 µm. With these attributes, this material allows for a higher throughput and yield while maintaining a lower stress throughout processing.

Combining these carrier and material changes can greatly impact total cost of ownership for device processing.

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ACRONYMS

CTE Coefficient of thermal expansion

CSAM Confocal scanning acoustic microscope (Sonix)