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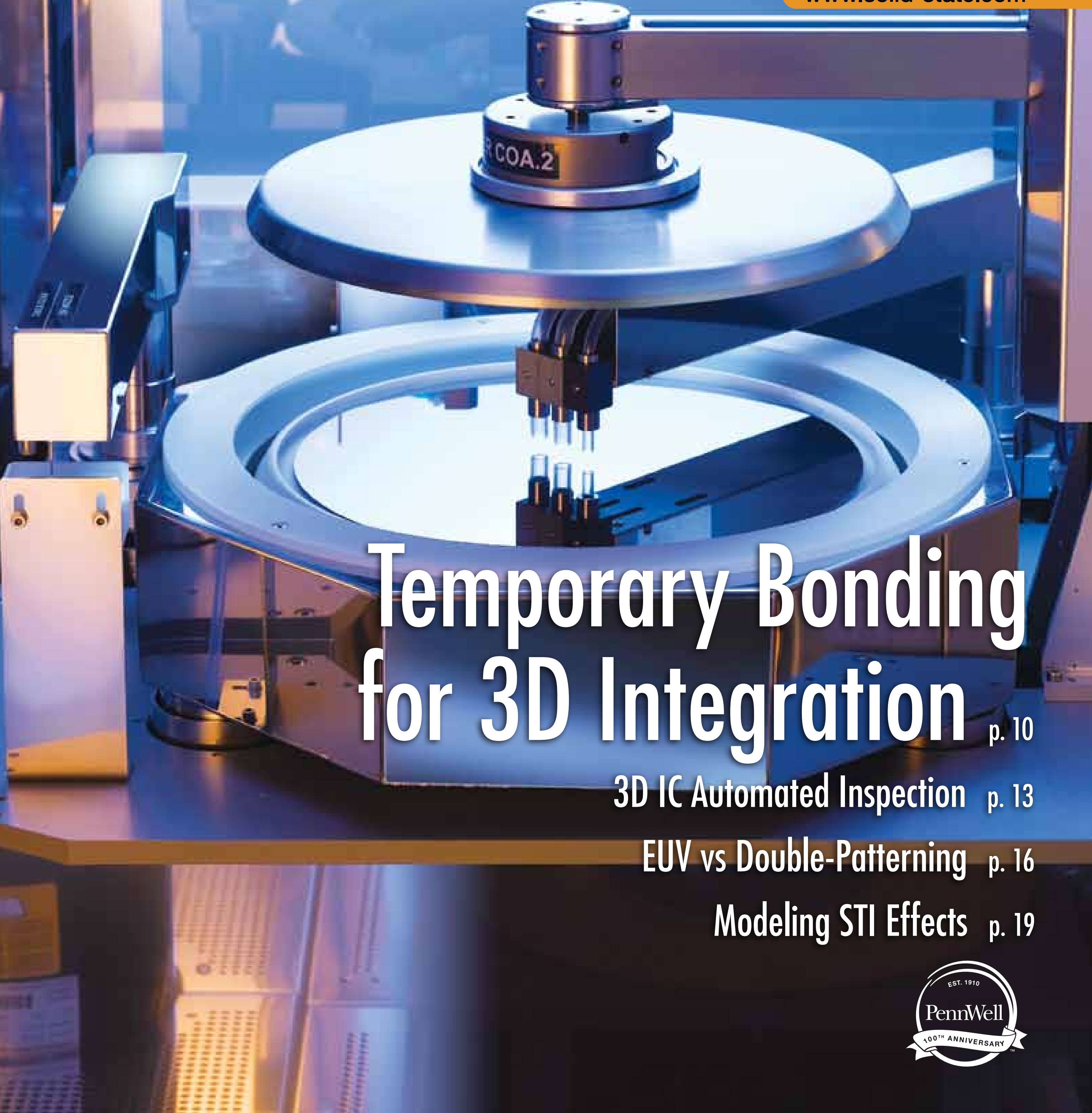

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Temporary bonding enables new processes requiring ultra-thin wafers

EXECUTIVE OVERVIEW Consumer electronics are driving the need for 3D packaging to produce smaller, higher performing, lower cost device configurations for use in applications such as memory and wireless devices. These new options, in turn, are pushing demand for ultra-thin semiconductor wafers. As wafer thickness decreases to 100µm and below, manufacturing challenges arise. Ultra-thin wafers are less stable and more vulnerable to stresses, and die can be prone to breaking and warping—not only during grinding but also at subsequent processing steps. To address these challenges, a Wafer Support System (WSS) was developed to support the wafer during backgrinding and subsequent post-thinning processes.

The Wafer Support System (WSS) uses a UV-curable liquid acrylic adhesive, designed to support high-temperature processing to bond the wafer to a glass carrier. After thinning and other process steps, a unique thermal release process uses a laser to separate the wafer from the glass carrier. The cured adhesive layer is then easily peeled from the wafer, leaving a surface that is as clean as those provided by conventional backgrinding tapes. The system is engineered to minimize stress during grinding and high-temperature post-thin processes. This system combines 3M materials with specialized bonding, debonding, and carrier recycling equipment provided by several of the world's leading semiconductor equipment manufacturers, enabling high-volume manufacturing of ultra-thin wafers down to 20µm.

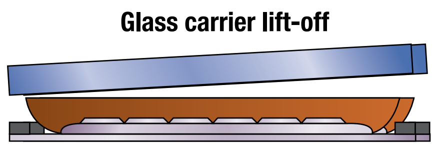

Figure 1. After laser processing, the glass carrier is separated from the adhesive layer with very low force.

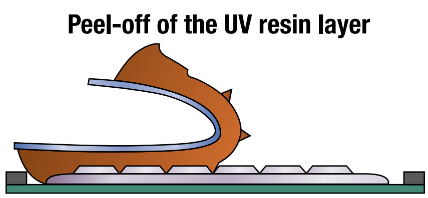

Figure 2. Wafer de-taping tape 3305 is used to peel the UV adhesive from the wafer.

The following illustrates the process flow of the system:

Process flow bonding. Liquid UV-curable adhesive is spin-coated onto the wafer. The wafer is then vacuum-bonded to the glass carrier, which has been treated with a release layer of a light-to-heat conversion (LTHC) coating. During spin coating, the adhesive flows into the topography of the wafer front side, providing overall support—even on large bump wafers. The system is designed to accommodate a single dispense and spin cycle on wafers with topography larger than 100µm. Multiple spin and dry cycles are not needed. As a liquid, it also provides more control over the total thickness variation (TTV). The adhesive is then quickly cured with UV light.

Backgrinding process. The mounted wafer is processed using standard backgrinding equipment, requiring no significant backgrinding process changes. The wafer is fully supported throughout the process, reducing edge cracking, chipping, and damage.

Backside processing. After thinning, the bonded wafer stack can be processed through standard semiconductor and TSV processes. The adhesives used are designed to withstand high temperatures, offer low outgassing in high vacuum semiconductor processes, and are resistant to typical process chemistries.

Tape application. After the wafer is processed, standard dicing tape is applied to the back of the wafer. The wafer/glass carrier assembly is then placed in the debonding module, where it is supported on a vacuum chuck for debonding.

Laser debonding. The glass is separated from the adhesive using a laser debonding process that decomposes the LTHC layer.

Glass carrier lift-off. After laser processing, the glass carrier is separated from the adhesive layer with very low force (**Fig. 1**). The carrier is then recycled, allowing it to be re-used multiple times.

Product name	Base resin	Color	Viscosity	Recommended application
UV-Curable Adhesive LC-3200	Acrylic	Clear, light yellow	3500 CP @25°C	Temperature; up to 150°C
UV-Curable Adhesive LC-4200	Acrylic, functional polymer	Clear, orange-brown	2150 CP @25°C	Temperatures; up to 180°C
UV-Curable Adhesive LC-5200	Acrylic, functional polymer	Clear, orange-brown	~2000 CP @25°C	Temperatures; up to 250°C

Table 1. Bonding adhesive properties.

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Peel off UV resin layer. Wafer de-taping tape 3305 is used to peel the UV adhesive from the wafer (**Fig. 2**.). Residue levels on the wafer surface after adhesive removal are minimal, comparable to conventional backgrinding tapes. No post-peel cleaning is required. The debonding process is a low-stress process that utilizes no chemicals and is carried out at room temperature.

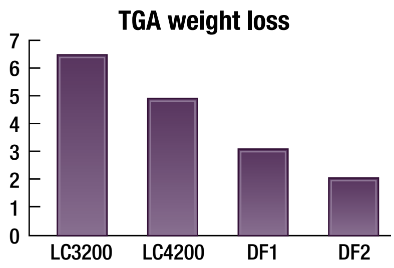

Figure 3. Weight loss data from ambient temperature through the isothermal step.

Adhesive properties

The heart of the system is a family of 100% solids, liquid UV-curable acrylic adhesives listed in **Table 1**. Adhesive LC-3200 is designed for lower temperature applications, while adhesive LC-4200 is useful for less thermally-demanding applications, such as short duration backmetal sputtering. The LC-5200 series support higher temperature processes, including solder reflow, and is formulated for use in typical TSV processes. Several formulations in this series, including DF1 and DF2, are currently under qualification by end users, and some of their fundamental properties are noted in the table. Each of these adhesive families begins with a different base oligomer and then adds monomers and an adhesion modifier to adjust properties as desired.

Surface/process	Adhesive			
	DF1-0.0	DF1-0.5	DF1-1.0	DF1-2.0
Silicon nitride / 1 hour @200°C	3.2	0.25		<0.1
Organic dielectric A / 1 hour @200°C	No removal	4		0.4
Organic dielectric B / 2 hours @200°C		2.4	0.25	
Organic dielectric C / 4 hours @200°C			3	1.9

Organic dielectrics A, B and C are materials of different chemical families

Table 2. Average 90° peel adhesion (N/25mm). The peel speed is 125mm/min.

The thermal stability of WSS adhesives is determined by fabricating a cured film sample and using TGA to measure the weight loss during the following thermal cycle: ramp to 250°C at 15°C per minute, followed by an isothermal step of one hour at 250°C—all under nitrogen. Total weight loss data from ambient temperature through the isothermal step are shown in **Fig. 3**.

A key requirement for any WSS adhesive is that it must peel easily from the surface of a mounted wafer after thinning, post processing, and glass removal. The peel force required to remove the adhesive depends strongly on materials on the surface of the wafer, and any topography present, such as solder bumps or copper pillars. An additive known as an adhesion control agent is used in the developmental formulations to control the adhesion to various surfaces. In particular, the additive is used to reduce the buildup of adhesion that typically occurs during processing at elevated temperatures.

Peel force is measured by heat aging and peeling a cured adhesive film from the surface of a bonded test wafer by laminating a detaping tape and measuring the force in Newtons, required to peel a 25mm wide strip of adhesive off of the wafer in a tensile tester at a speed of 125mm per minute.

Adhesion to various surfaces and the effect of the adhesion control agent are presented in **Table 2.** These results are on as-deposited surfaces; post-deposition processes that change the physical and/or chemical nature of the surfaces can have a large effect on the resulting peel force.

Data on the peel force required to remove DF1-X.X adhesive from various surfaces after post processing is presented in Table 2. X.X refers to the amount of adhesion control agent in the formulation. As this amount is increased, the peel force required after thermal cycling decreases.

The DF1 and DF2 families of adhesives as well as the LTHC layer have been tested and found to be compatible with the chemicals listed for the times and temperatures noted in **Fig. 4**.

Conversion coating

A key advantage of the WSS is the ability to simply and quickly remove the glass from the assembled stack during debonding. This is accomplished through the use of a LTHC (light to heat conversion) layer, which is approximately 1µm thick and is applied to the glass support during the glass recycling process prior to introducing the glass into the WSS mounter.

The LTHC layer is formulated to allow the transmission of UV radiation to cure the adhesive during bonding, and also to strongly absorb the laser wavelength during debond. During debonding, light energy absorption heats the LTHC layer, causing it to decompose, after which the glass support is simply lifted off of the assembled stack. The debonding process is then completed by laminating a detaping tape to the exposed adhesive and peeling the adhesive off the wafer surface. This step leaves a surface that is as clean as what is typically achieved with a conventional backgrinding tape.

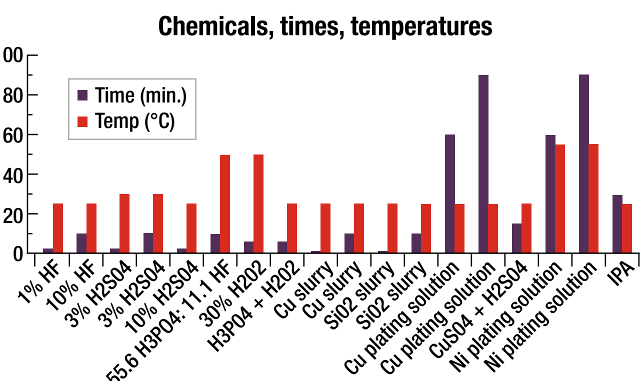

Figure 4. Chemicals, times, and temperatures for the DF1 and DF2 families of adhesives and the LTHC layer.

Dielectric surface	Topography/features	Adhesive	Adhesive thickness	Process	Post-process adhesion
Organic B	Patterned, 12-15µm	DF1-1.5	45µm	2 cycles of 2 hrs @ 200°C + 2 reflow passes (255°C peak)	0.4- 0.7 (N/25mm)
SiN	80µm high conductive features	DF1-2.0	133µm	20 min. @ 235°C + 3 reflow passes (255°C peak)reflow	3.1 (N/25mm)
Organic C	50µm high conductive features	DF1-2.0	108µm	20 min. @ 235°C + 1 reflow pass (260°C peak)	1.5-1.7 (N/25mm)

Table 3. Application examples.

Table 3 lists the capabilities of the wafer support system to accommodate different materials, topographies, and processes. In each case, a wafer or a wafer coupon was bonded with an adhesive layer coated in a single spin coating operation to the thickness specified. Because there is no solvent in the WSS adhesive, thicknesses sufficient for large topographies can be coated without the need for multiple coating steps. The resulting mounted wafer stack was subjected to the process conditions noted, after which the glass carrier was removed and the force required to peel the adhesive from the wafer surface was measured. While the forces noted in the table are low, the exact forces suitable for debonding will depend on the wafer thickness, topography, and details of the debonding operation

Conclusion

While WSS meets the needs of many current thin wafer applications, constant innovation is essential. We are looking ahead and continuing to pursue adhesive and LTHC development to expand the range of post-processing options available for use with the WSS. End user integration schemes and process flows continue to expand, requiring the WSS technology to evolve as well. This evolution includes formulations with higher temperature capability, controlled adhesion to a greater variety of surfaces, and improved mechanical properties to enhance removability from even larger, more complex topographies. ■

Acknowledgments

3M is a trademark of the 3M Company.

Biography

Richard Webb received his PhD in materials science from the U. of Minnesota, and is a lead research specialist in the Electronics Markets Materials Division at 3M Co., 3M Center, Maplewood, MN 55144 USA; rjwebb@mmm.com.