Thin Wafer Handling Challenges and Emerging Solutions

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Temporary bonding attaches substrates to a carrier so that after thinning to the desired thickness further backside fabrications steps can be conducted with "normal" process flows in standard semiconductor equipment. The selection of a suitable temporary adhesive is key to the success of thin wafer handling. The major requirements of temporary adhesives are related to its process flow, thermal stability, chemical resistance, and mechanical strength. The ideal thermal stability should allow high temperature processing up to 400C for dielectric deposition in high aspect ratio vias, polymer curing, solder reflow, metal sintering, permanent bonding or other high temperature processing. The adhesive must be resistant to the chemicals commonly used after wafer thinning. Mechanical strength is required to hold the thin wafer rigidly during processing, especially during permanent bonding applications otherwise the thinned wafer will flex and prevent bonding. The challenge arises in finding a simultaneous solution to these problems while allowing for the gentle release of the thinned substrate to its final, permanent substrate or package without yield loss or stress. This paper will highlight some of the more recent solutions for thin wafer handling that have emerged through technology innovation.

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Introduction

Vertical integration of MEMS, IC's, Memory and CMOS Image Sensors is challenged by the demands of form factor requirements, economic benefits of whole wafer processing, and thin wafer fragility. The present 200mm and 300mm thin wafer thicknesses are far beyond self supporting limits and are generally 50 micrometers or less. Temporary wafer bonding and debonding have emerged as challenging but necessary processes used for most 3D integration schemes. Fortunately a variety of solutions have emerged to provide solutions to these challenges. Temporary bonding of the reversible adhesive materials fall into two broad categories: thermal curing or UV curing. Temporary debonding is achieved by thermal release, solvent dissolution, laser release or mechanical methods. The choices are decided by assessing the process flow requirements.

Process Flow Assessment

The first step is to fully understand what processes will need to be supported between the temporary bonding of a device wafer to a carrier. The most common processing steps that follow temporary bonding are grinding and polishing of the wafer to thicknesses ranging from a few 10's-100µm. Additional steps may include DRIE (dry reactive ion etching) cavity formation, trench and sidewall depositions of dielectric layers, adhesion layers, or seed layers. Metal deposition to surfaces or trenches via CVD or plating processes is quite common. Most of the steps just described also would include the necessary lithography steps to pattern the features. Table 1 lists the major steps and the types of stresses the temporary bonded pair may see. Clearly, thermal compatibility heads the list of concerns, followed closely by wet chemical considerations. Mechanical strength is an absolute since virtually all wafers on carriers are presently thinned prior to backside processing.

TABLE 1. Typical Backside Processing Steps after Temporary Bonding

Process Step	Mechanical Stress	Thermal Stress	Acidic Chemistry	Base Chemistry	Solvents	Water	UV	Plasma Chemistry
Grinding	√√√	√				√√√		
Polishing	√√√	√		√√√		√√√		
DRIE		√√						
Dieletric Dep.		√√√						
Metal Adhesion Dep.		√√√						
Metal Seed Dep.		√√√						
Metal CVD & PECVD Dep		√√√						√√√
Metal Electroplating		√	√√√			√√√		
Photoresist Dep & Pattern								
Photo Dev., Strip, & Clean				√√	√√√	√√√		
Plasma Ashing		√√					√√√	√√√
Wafer Cleaning		√	√√√	√√√	√√√	√√√		

Materials Choices and Properties

There are three leading candidates for temporary bonding for CMOS and 3D applications†. WaferBOND® HT10.10 made by Brewer Science Inc.[1], T-MAT by Thin Materials AG [2], and the 3M™ Wafer Support System[3] all use polymer materials to support device wafers on carrier for backside processing. Each of these materials has been shown to be successful for thin wafer handling although the details and process flows vary dramatically between each type of material [4].

Brewer Science Inc. WaferBOND® HT10.10

HT10.10 is a thermoplastic polymer adhesive that is spin coated onto the substrates. The higher viscosity of temporary adhesives benefit from advanced coating system such as the SUSS MicroTec SC200/300 coating modules that utilize reverse radial hyperbolic dispense motion and closed covers to achieve extremely uniform coverage. Thickness uniformity of the adhesive is a critical parameter to the thin wafer uniformity. After prebake of the adhesive the surface is not tacky although it is not fully cured. Bonding of the wafer to the carrier can be carried out in a low force thermal compression bonder such as the SUSS MicroTec LF200. Bonding is normally a center-on-center alignment between the carrier and the device wafer. The carrier can be oversized relative to the substrate wafer by a few millimeters to provide edge support. The bond process is done in vacuum at 180-200°C with less than 8KN force.

The primary distinguishing property between the various temporary bonds are the methods of debonding after backside processing. HT10.10, like waxes and high temperature Polyimides, is a thermal plastic material. By definition the material becomes soft as the temperature rises and the substrates can be slid apart. The so called thermal-slide approach is easily visualized but requires significant finesse in application. The thinned device wafer is often 25-75µm thick and will crack from shear forces if not properly supported during the thermal slide process. Proper thermal controls are needed to ensure the interface remains at a semi-fluid state with uniform viscosity during the debond.

After the debonding is complete, residual adhesive on the carriers is removed by batch cleaning processes. The residues remaining on the device wafer are cleaned in single wafer systems at point of debond in tools such as the SUSS MicroTec CL200/300 with solvents. Figure 1 is a schematic of the entire process flow, exclusive of backside processing details.

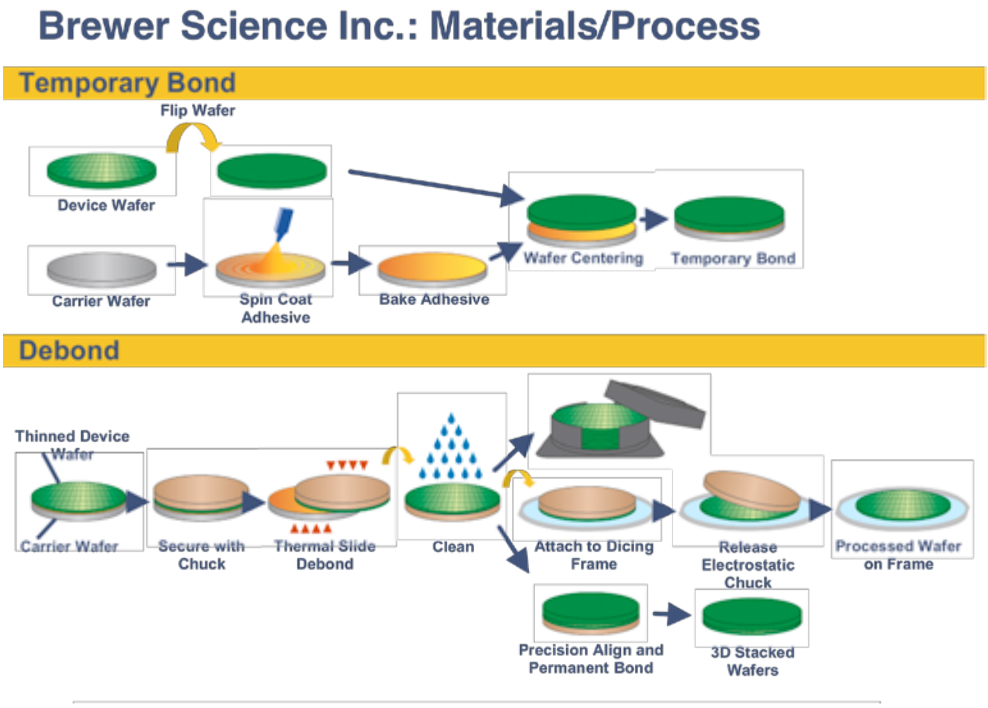

Figure 1.
Brewer Science WaferBOND® HT10.10 temporary bond and debond process flow.

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†LED and Compound Semiconductor applications also use a variety of waxes for temporary bonding that are not discussed in this paper.

3M Wafer Support System

The 3M wafer support system is based on a UV-cured bond process and a laser release debond. Thus it is imperative that the carrier used to support the device wafers is transparent. UV curing adhesives have been used extensively for permanent bonding to limit thermal expansion differences between vertically integration optical devices. To use the UV adhesive for temporary bonding applications a release layer must also be incorporated in the bond interface that allows for the laser to debond the wafers. The adhesive is coated onto the device wafer and a release layer, also known as the LTHC (light to heat conversion) layer is spun onto the carrier. Bonding is done at room temperature by aligning carrier and device wafer, placing them in physical contact, and exposing the interface to UV radiation in a flood exposure system. Crosslinking occurs at the interface and secures the substrates together. No heat or force are needed to complete the bonding.

After completion of the backside processing steps, the thinned and processed device wafer is attached to a taped film frame or additional permanent substrate. The stack is then placed in a debonder that uses a focused laser pulse to deposit energy at the adhesive/LTHC interface. The remaining adhesive on the thinned wafer is removed by detaping tape and does not require further cleaning of the surface.

Key characteristics of the 3M process include room temperature bond and debond, high thermal stability adhesive, and no post debond cleaning requirements for the device wafer. The process flow for this technology is shown in figure 2.

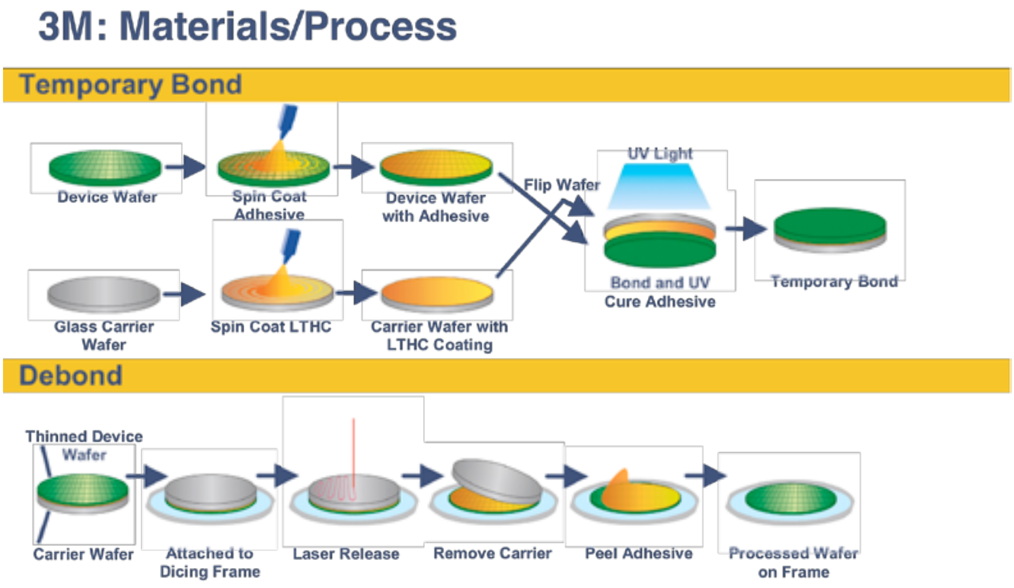

Figure 2. 3M Wafer Support System (WSS) temporary bond and debond process flow.

Thin Materials AG (T-MAT)

T-MAT temporary bonding also uses a bilayer adhesive interface. A 100-150nm precursor layer is deposited onto the substrate via a simple and rapid PECVD process. Then an elastomer layer is spun onto the wafers and the bonding is done in a thermal compression bonder. The carrier can be any material type and bonding is done at low force and <200°C.

T-MAT is unique in its mechanical release mechanism. This material debonds by tensile force application (perpendicular to the interface) at room temperature. The bonds are very strong under shear loading (within plane) and easily withstand aggressive wafer thinning steps (e.g. grinding). The thinned wafer can be support by film frames, additional permanent bonded substrates or electrostatic chucks for the debond process. The separation of the mechanical and thermal properties of the adhesive via the release material allows for tailoring of the adhesive for thermal stability. The process flow for the T-MAT temporary bond/debond process is shown in figure 3. The final step involves cleaning of the device wafer with mild solvent steps to remove slight residue layers. Table II is an overview of the mechanical and thermal properties of the temporary bonding adhesive and the requirements for bonding and debonding.

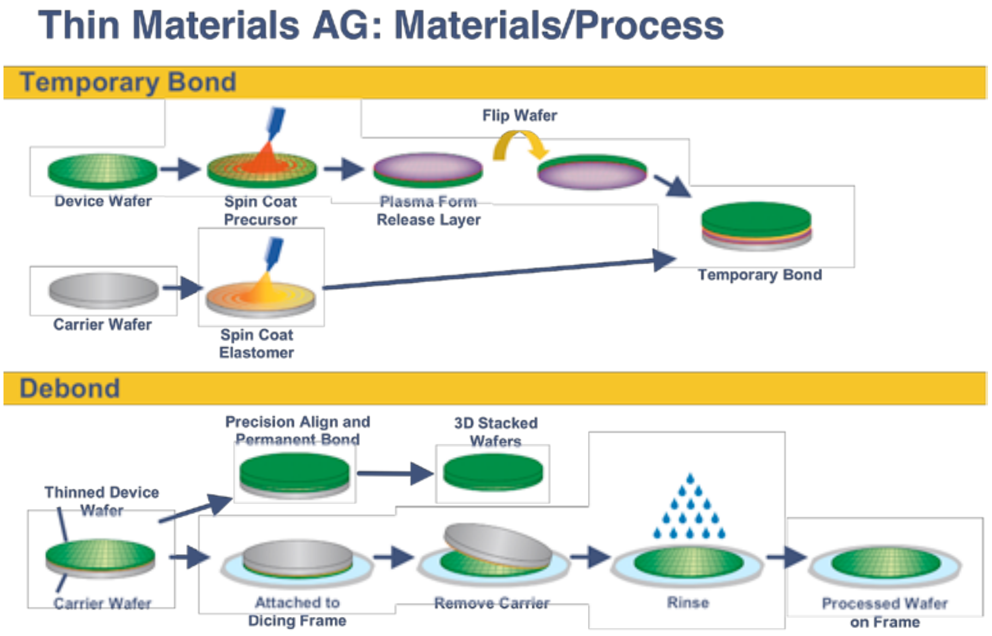

Figure 3. Thin Materials T-MAT bonding and debonding process flow.

TABLE 2.
Comparison table for the overall process requirements and physical/chemical properties of the temporary bond adhesives.

Property	WaferBOND® HT10.10	3M WSS	T-MAT
Material Class	Resin/rubber	Acrylic/rubber	Silicone
Spin Coat Thickness	10-40 µm	20-200 µm	20-200 µm
Adhesive Solvent	1-dodecene	100% solids	100% solids
Carrier Types	Si or glass	Glass Only	Si or Glass
Bond Temperature	~180°C	Room Temp	~180°C
DeBond Temperature	~150°−220°C	Room Temp	Room Temp
Chemical Resistance (1)	Good	Good	Good
Mechanical Strent @ upper temperature (2)	Poor	Good	Good

(1) Detailed chemical compatibility can be obtained from respective suppliers.

(2) Mechanical strength as tested at 250C or higher temperature

Summary and Conclusions

The selection of temporary bonding materials is governed by a comprehensive review of the thinned wafer processing steps. The physical and chemical requirements of these processes are well known and involve standard CMOS fabrication methods. The temporary carrier in essence is the facilitator that allows for the thin wafer to continue in standardized equipment steps. Bonding temporary adhesives is straightforward and uses low force bonders or UV-cure bonders that have been widely used in MEMS industry for nearly twenty years. The precision bonder replaced crude hot plate methods to allow for exacting control over of the bond interface thickness and final wafer yields.

Debonding methods can be tailored to the application with regard device compatibility. Thermal, solvent, mechanical and UV/Laser release can be chosen depending on the nature of the process flows. More importantly the variety of materials and carrier combinations enable designers to balance all considerations and arrive at volume manufacturing cost targets in line with market expectations.

Acknowledgments

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References

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2. 3M™ WSS product documentation.
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4. James Hermanowski, *Thin Wafer Handling – Study of Temporary Wafer Bonding Materials and Processes,* to be published in proceedings of the IEEE 3DIC Conference San Francisco, Sept. 27-30, 2009.