High Temperature–Resistant Spin-On Adhesive for Temporary Wafer Mounting Using an Automated High-Throughput Tooling Solution

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Abstract

This paper reviews a high temperature–resistant spin-on adhesive platform and the equipment solution used to apply the adhesive to a wafer, temporarily bond the wafer to a carrier, and debond the thinned wafer in an automated high-throughput method. The focus of this paper is on the physical and chemical properties of the spin-on adhesive material that enable an automated process. The information included here covers process flow, application parameters, equipment setup, TGA, coating total thickness variation (TTV), rheology analysis, transparency plots, experimental procedure of Brewer Science material on EVG®850 tool, and post-bonding TTV values on 150-mm and 200-mm substrates. Throughput numbers achieved with the WaferBOND™ HT 220 adhesive and EVG equipment solution are given.

INTRODUCTION

Bonding wafers to temporary support carrier wafers is a method used for supporting brittle substrates such as GaAs, GaN, SiC, and InP during backside processing in the fabrication of many compound semiconductor devices including heterojunction bipolar transistors (HBTs), pseudomorphic high electron mobility transistors (PHEMTs), monolithic microwave integrated circuits (MMICs), and others. Numerous adhesives are available in the market [1-4] which use a standard chemical release process or are manually slid apart. Chemical release processes often depend on the use of expensive perforated carriers, special fixtures, and a manual processing step. Release times vary between 1 and 8 hours depending on release chemistry performance, temperature, agitation, and hole configuration on the carrier sapphire. These conditions are adequate for low-volume manufacturing, but they present a substantial consumable cost for high-volume manufacturing. For companies that require high-volume manufacturing, i.e., more than 5,000-10,000 wafers per month, the limitations with this process are that it requires a manual step and throughput is relatively slow [4]. This paper defines a new high temperature–stable (i.e., greater than 200ºC) adhesive, designed by Brewer Science, which uses commercial tool sets available from EV Group as equipment solutions to increase wafer throughput [5].

PROCESS OVERVIEW

The typical process for reversible wafer bonding is shown in Figure 1. The carrier wafer will be coated with adhesive on the front side, and the wafer will undergo an initial bake to remove the solvent from the polymer matrix.

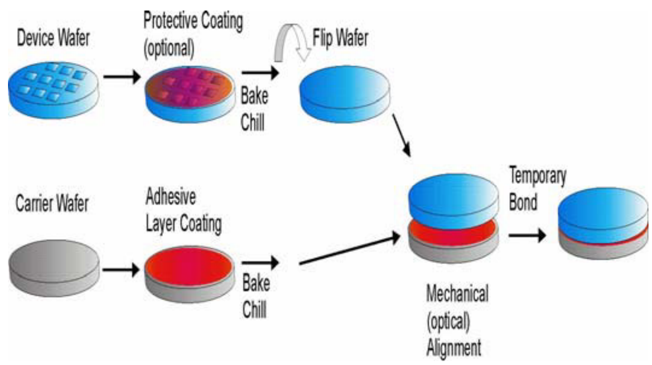

FIGURE 1
GENERAL PROCESS FLOW FOR COAT, CURE, AND BOND STEPS

The carrier (also referred to as handle) wafer is then brought into contact with the adhesive-coated device wafer under vacuum, temperature, and pressure. Depending on the coating thickness desired, Brewer Science offers various adhesive solutions. Process schemes for WaferBOND™ HT 220 adhesive are reported in Table 1.

TABLE 1
GENERAL PARAMETERS FOR COAT, CURE, BOND, AND DEBOND STEPS

Spin coat	1000-3500 rpm
Bake for solvent removal	150-220ºC, 2-4 min
Bond to carrier wafer	150-250ºC, 2-5 min
Process backside (i.e., thinning, etch, deposition , plating, etc.	Up to 200ºC
Automated Debonding	200-270ºC, 2-5 min

The coat, cure, bond, and debond tools used in this work were the EVG®850TB and EVG®850DB tools. The bonding module is depicted in Figure 2.

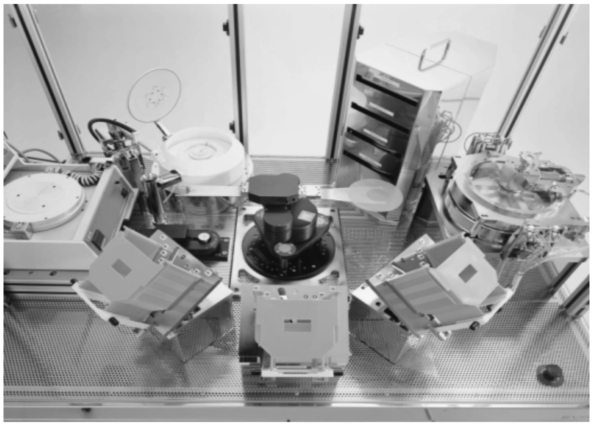

FIGURE 2
COAT, CURE, AND MOUNT MODULE IN THE EVG®850TB TOOL

ENABLING PROPERTIES OF WAFERBOND™ HT 220 ADHESIVE

Several criteria must be considered when choosing an intermediate adhesive layer. Mindful of backside processing prerequisites, some of the crucial properties include maximum temperature capability, vacuum compatibility, total thickness variation (pre- and post-mount), chemical resistance, ease of application, wafer edge protection, and optical transparency.

WaferBOND™ HT 220 adhesive is **thermally resistant** to 200ºC as determined by thermogravimetric analysis (TGA). The material has less than 0.25% weight loss when isothermally held at 200ºC for 1 hour. This is a critical attribute for post-mount via etching, metal deposition, and other high temperature processes.

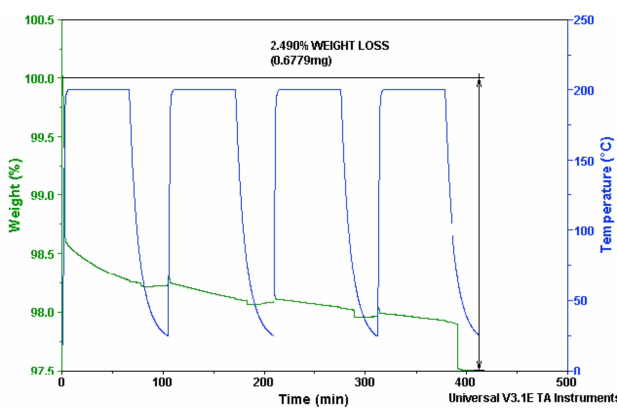

FIGURE 3
THERMAL CYCLING AT 200ºC OVER 4 HOURS

When subjected to repeated heating and cooling cycles that simulate the actual deposition and other high-temperature steps, WaferBOND™ HT 220 adhesive showed very minimal weight loss. Figure 3 shows the TGA plot with four heating cycles with isothermal heat treatment at 200°C for 1 hour per cycle. The temperature stability is also confirmed by observing the stable vacuum levels during mounting in the bond tool.

Spin-on polymer solutions offer better thickness control compared to waxes and tapes used in wafer bonding [4]. **Total thickness variation (TTV**) in bonding materials can increase grind damage (in the case of voids), breakage at the edge during thinning, and wafer-to-wafer post-thinning variation. Thickness measurements on the WaferBOND™ HT 220 films were carried out using an Alpha-Step 200 (Tencor Instruments) and Nanospec® 6100 (Nanometrics, Inc.). A typical film measured had a mean thickness of 13.5 µm, with a uniformity of ±1.5%. In addition, the edge bead (another critical factor, since this bond is being performed across the full layer) was <2 µm high and <0.5 mm wide, which is excellent for wafer edge stress reduction and total bond package TTV [6].

Coating TTV is significant because of its effect on the final post-bond uniformity (TTV) of the mounted pair. The bond program with respect to the rheology (Figure 4) of the adhesive material can also improve package TTV. To ensure good post-bond uniformity, the pressure and temperature uniformity of the bonding system are critical. In the case of the WaferBOND™ HT 220/EVG®850 system, total wafer post-mount TTVs of ≤ 5 µm were achieved on both 150-mm and 200-mm wafers. The rheology plot (Figure 4) shows that WaferBOND™ HT 220 adhesive starts softening at 140°-150°C, which allows it to reflow at the recommended bake temperatures into any structures on the wafer surface to allow **void-free coverage**. The material rapidly loses modulus as well as viscosity beyond the softening temperature, which allows the wafers to be separated easily by sliding the substrate wafer against the carrier at elevated temperatures (240°-250°C).

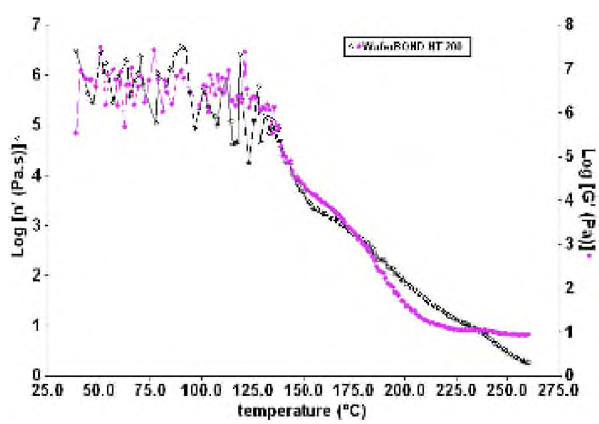

FIGURE 4
RHEOLOGY BY RDA OF WAFERBOND™ HT 220 ADHESIVE

Various WaferBOND™ HT platforms offer the chemical resistance needed for backside processing. The direct exposure of the adhesive to process chemicals is reduced by the use of non-perforated carriers. In addition to the process and material design considerations of WaferBOND™ HT 220 adhesive, this material is easily cleaned up in simple solvents such as acetone, SafeStrip™, or standard positive photoresist strippers. These solvents are plumbed directly in the EVG®850DB tool.

In some applications, backside alignment lithography is necessary. To enable this process, the carrier wafer and the intermediate layer must be transparent to visible light. For infrared (IR) alignment, all included layers and materials (device and carrier wafer, intermediate layer, and eventually protective coating) must be transparent to IR light. Figure 5 presents **transparency** data for WaferBOND™ HT 220 adhesive [8].

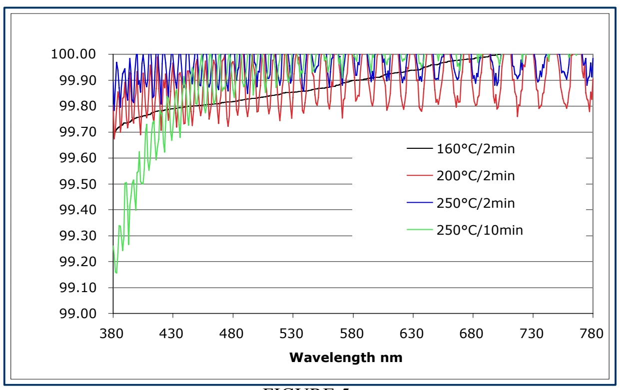

FIGURE 5
TRANSMISSION OF WAFERBOND™ HT 220 ADHESIVE AT 10 µM

Another critical and necessary criterion for a robust bond system is the ability to form a **void-free bond**. Voids in the bondline can lead to many potential defects including poor grind finish, poor uniformity, stress to thinning wafer during high-vacuum processes, and others. The combination of WaferBOND™ HT 220 adhesive and the EVG tooling platform achieves perfectly void-free bonds (Figure 6).

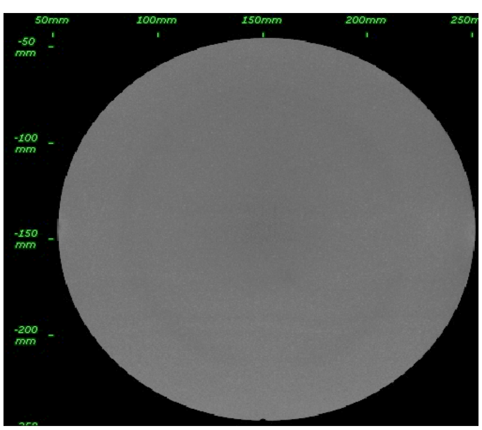

FIGURE 6
CSAM IMAGE OF 200-MM BONDED PAIR

The primary design for **debonding** the wafer package is to use a thermal slide- or wedge-off approach (Figure 7). For this material, the debonding method involves heating the wafers to the debonding temperature (in most cases, typically above 200º-250ºC) while they are locked into a rigid frame with top and bottom heaters. Then, the wafers are slid apart in a controlled manner such that the wafers stay parallel to each other until completely apart. Using two heaters is critical. If only one heater were used, then as the wafers separate, the influence of air would cause one substrate to cool, increasing the viscosity of the adhesive at the boundary between newly exposed surface and the still-covered surface. This situation would create a shear force variation, which can lead to wafer breakage [6].

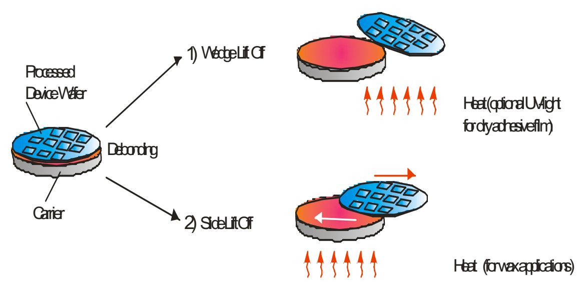

FIGURE 7
DEBONDING PROCESS FLOW FOR SLIDE-OFF AND WEDGE LIFT-OFF

After the debonding process, the thin wafer is transferred with a dedicated thin wafer handling technology to a single wafer cleaning chamber, where the remaining adhesive is removed. Finally, the thin wafer is transferred to the dedicated output format. For the output format, various types of storage reservoirs can be selected. Usually, thin and brittle substrates are moved, via a film frame, onto single wafer carriers, coin-stack canisters, or dedicated wafer cassettes (Figure 8) [7].

FIGURE 8
DEDICATED OUTPUT FORMATS FOR THIN WAFERS

The actual throughput onto an automated system mainly depends on the process conditions as well as the actual system configuration. An EVG®850TB system, dedicated for processing Brewer Science HT materials, typically consists of send/receive cassette stations, coating and bake modules, and one or multiple bond chambers as well as a robotic unit for transferring the wafer to the individual process modules.

An EVG®850DB system, dedicated for debonding Brewer Science HT materials, typically consists of a high-temperature debonding module, a single wafer cleaning chamber, and a process module to bring the thin wafer into the dedicated output format. EVG's unique handling tools for safe and reliable transfer of thin wafers to and from the individual process modules are implemented as well.

The measured throughput of this process is 12 wafers per hour (wph) for a single head bonder and demount module, or 24 wph for a dual head bonder and demount module on the EVG®850TB and EVG®850DB tools. Table 2 provides the breakdown of the time needed for each step as performed on a 150-mm wafer with the WaferBOND™ HT 220 adhesive.

TABLE 2
TYPICAL PROCESSING TIMES FOR AUTOMATED MOUNT/DEMOUNT

Tool	Process Description	Time (sec)
EVG850TB	Coat WaferBOND™ HT 220	60
EVG850TB	Cure WaferBOND™ HT 220	400
EVG850TB	Reversible Mount	300
EVG850DB	Wafer/Carrier Demount	300
EVG850DB	Carrier Clean	60
EVG850DB	Thinned Device Wafer Clean	120

CONCLUSIONS

The authors have described a chemically robust mounting adhesive that is stable at high temperatures and works synergistically with an automated high-throughput wafer processing equipment solution to yield up to a 24-wph throughput. The tooling and material process offers a package where the coat through debond steps are automated. The WaferBOND™ HT 220 adhesive is a material that can be used in future high-temperature, high-throughput wafer fabrication processes.

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ACRONYMS

HBT: Heterojunction Bipolar Transistor
TTV: Total Thickness Variation
TGA: Thermogravimetric Analysis
PHEMT: Pseudomorphic High Electron Mobility Transistors
MMIC: Monolithic Microwave Integrated Circuit