A Chemical and Thermal Resistant Wafer Bonding Adhesive Simplifying Wafer Backside Processing

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Abstract

A variety of adhesives have been demonstrated for use in thinning and backside processing of III-V substrates.[1-4] Each process exhibits certain limitations based on the adhesive's chemical or thermal resistance. As a result, an adhesive's property limitation may drive up costs or reduce throughput by necessitating the use of additional protective aids or special tooling. A new product developed by Brewer Science, Inc. (BSI), WaferBOND™[5] adhesive, eliminates the need for such aids by directly simplifying the process. WaferBOND™ adhesive exhibits an unusually high resistance to process conditions, which enables the use of strong acids and bases, stripping solvents, and temperatures in excess of 200ºC. Applied with conventional spin-on equipment, the material coats with exceptional uniformity (<0.3% TTV), cures and bonds at relatively low temperatures, and demounts in corrosion-safe chemistries in times that are substantially lower than the competition, which allow an increase in throughput. This paper discusses the benefits of the WaferBOND™ adhesive mounting product and the ease of integrating it into an existing process line.

INTRODUCTION

Brewer Science's new spin-on WaferBOND™ adhesive attempts to solve many manufacturing challenges in wafer thinning and backside processing. Using conventional semiconductor wafer coating equipment, thickness may reach 40 µm with a single coat with limited outgassing up to 200ºC (Figures 1 and 2). WaferBOND™ adhesive is an optically transparent material, which allows through-carrier auto and manual alignment. The product is resistant to backside processing chemistries, especially to aggressive strippers such as 85°C NMP (Table 1) held at extended times, as well as to many common electroplating baths. Demount and removal is conducted in a BSI solvent system matched to the chemistry of the WaferBOND™ adhesive to enable rapid dissolution and removal without attacking sensitive metals. This paper presents additional benefits of using WaferBOND™ adhesive as well as in-process benefits from RF Micro Devices' (RFMD) challenging needs in the manufacture of GaN HEMT wafers fabricated on SiC substrates.

WAFERBOND™ ADHESIVE AGENT BENEFITS

The backside process flow has several steps: wafer protection coating, mounting to a temporary carrier, thinning, photolithography, plasma etching (BSV), resist and residue removal, BSV cleaning, metallization, and wafer demounting.[6] The focus of this paper is how WaferBOND™ adhesive and WaferBOND™ remover enable a large variety of chemical and thermal process latitude.

The WaferBOND™ adhesive is a spin-on polymer whose viscosity enables it to be plumbed onto standard photoresist tracks. Spin coating is used to apply the material and planarize the frontside topography, which can be achieved in a single uniform coating (<0.3% TTV) at thicknesses ranging from 10-40 µm (Figure 1). A low total thickness variation ensures that the adhesive thickness from wafer to wafer is repeatable, thus improving the accuracy to wafer targets during thinning.

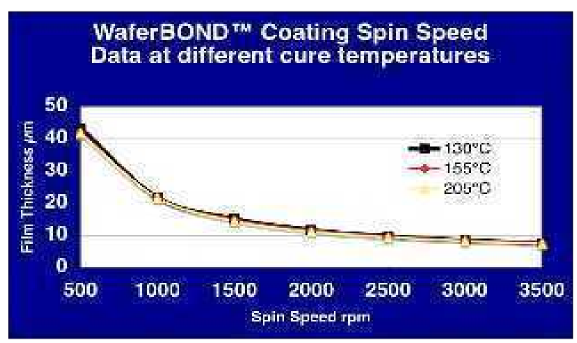

Figure 1. WaferBOND™ adhesive spin-speed curve showing single-coating thicknesses ranging from 10-40 µm. The viscosity is 1050 cP. Coating is on 100-mm silicon using 3 ml of WaferBOND™ adhesive. The spin was for 30 seconds at 5000 rpm acceleration. Films were baked for 120 seconds at 100°C followed by noted temperature for 120 seconds, and measured on an AlphaStep 200 profilometer.

Perforated carriers having a coefficient of thermal expansion that matches that of the base substrate are recommended. The WaferBOND™ adhesive only requires a single 100-120°C bake for 2 minutes for most applications. Once cured, the material is hard and stable for over 2 weeks before bonding. This material stability attribute prevents the need of reworking the coating during times of backside processing delays in the fab. Mounting to the perforated carrier (sapphire for GaAs) to the substrate can be achieved in a temperature- controlled vacuum bonder.

WaferBOND™ adhesive has superb chemical resistance, which allows for a variety of post-thinning chemical smoothing and pre-metal chemical and surface roughing etches.[7] This resistance also enables the use of robust chemicals for resist stripping, via cleaning,[8] and gold etching,[9] whereas these robust chemistries attack many other adhesive systems and leave residues.[10]

TABLE I

WAFERBOND™ ADHESIVE PROCESS CHEMICAL RESISTANCE

Process Chemical	Temp	Time (min.)
n-Methylpyrollidone (NMP)	85°C	>60
Ammonium Hydroxide (NH_4OH) (30%)	25°C	>30
Acetone	25°C	<15
Sodium Hydroxide (NaOH) (10%)	60°C	>30
Nanostrip™ - H_2SO_4 / H_2O_2	60°C	>30
Hydrochloric Acid (HCl) (6N)	60°C	>30
Tetramethylammonium Hydroxide (0.26N)	60°C	>30
Hydrogen Peroxide (1%)	60°C	>30
Sulfuric Acid (6N)	60°C	>30
Dimethylacetamide (DMAC) & Amine	85°C	>60
DMAC & Amine & Ammonium Fluoride	85°C	>60
Potassium Iodide (KI)	25°C	>15

WaferBOND™ coating is coated to 15 µm, cured to 150°C on a 100-mm silicon wafer, and then immersed in the chemistry for the time noted.

Many III-V and SiC devices employ a through-via-hole etching through the thinned substrate. Depending on substrate type and thickness, various etch techniques are used. For GaAs, inductively coupled plasma with a BCl3/Cl2 gas is common, and for InP, a HBr chemistry is referenced.[8,11] ICP uses an electrostatic chuck that is heated to temperatures reaching 200°C. These etch chamber temperatures define a thermal characteristic need for the temporary bonding adhesive. WaferBOND™ adhesive exhibits high thermal stability and thereby enables a variety of higher-temperature dry-etch processes. Thermogravimetric analysis (TGA) is a technique for analyzing thermal characteristics of polymers (Figure 2).

The through-via dry-etch process sometimes yields veil residue that must be cleaned prior to seed layer metal deposition. Depending on the photoresist, substrate, and metal stop layers, various residue removers and wet-etch chemistries are used. DMAC, NMP, HCl, and KI are examples.[8,9] WaferBOND™ adhesive was not observed to dissolve or form residues when exposed to these chemistries.

A common issue with certain polymers used for temporary wafer mounting is that they are compromised when exposed to alkaline or acidic metal plating solutions. In these cases the polymer may leach into the bath, yielding it inactive. WaferBOND™ adhesive's acid and base resistance make it a good candidate for processes utilizing immersion plating techniques.

WaferBOND™ adhesive is released from the perforated carrier by placing it in a heated bath of WaferBOND™ remover.

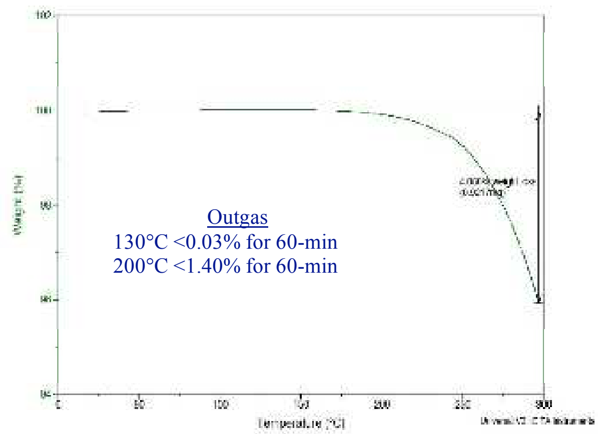

Figure 2. TGA graph of cured WaferBOND™ adhesive run at 10°C min up to 300°C. Additional TGA shows that when temperatures are held at 130° or 200°C for 60 minutes, limited outgassing occurs.

Temperatures from 100°-130°C are used to facilitate the release and cleaning of the polymer. The demounted substrate is then followed up with a rinse in isopropyl alcohol. WaferBOND™ adhesive and remover were designed to work syngergistically. The system is nonpolar and is noncorrosive to sensitive metals such as gold, aluminum, and copper on high-performance devices. Galvanic corrosion is not an issue because no water is used. The WaferBOND™ remover is a non-hazardous air pollutant and is non-flammable.

WAFERBOND™ ADHESIVE AND WAFERBOND™ REMOVER ENABLE BACKSIDE PROCESSING ON SILICON CARBIDE

Wafer bonding is a key process at RF Micro Devices that sets the stage to ensure proper backside processing of gallium nitride (GaN) HEMT technology. GaN HEMT wafers, fabricated on silicon carbide (SiC) substrates, are bonded to sapphire carriers to add the support needed to complete backside fabrication steps. After the wafers are bonded to the sapphire carrier, the wafer/carrier stack is processed through wafer thinning and SiC via etching. The thinning process adds stress to the SiC substrate, requiring a durable bond, while the etching process exposes the bonding adhesive to temperatures in excess of 150°C as well as to aggressive chemistries. These process conditions proved too challenging for the incumbent bonding adhesive and remover platform. Motivated by the need to improve on the current bonding adhesive, the following criteria were set for evaluating a new adhesive:

- Withstand subsequent processes (temperatures, chemicals, etc.) without degradation
- Withstand temperatures in excess of 150°C
- Demount without residual bonding material left on wafer bonding surface after release from carrier
- Release from carrier in a reasonable time
- Integrate easily into existing process/equipment

RF Micro Devices is currently evaluating how WaferBOND™ adhesive and WaferBOND™ remover will perform against the above criteria. Results have exceeded expectations. Experiments show that the adhesive is stable when exposed to process temperatures of 150°-200°C and also compatible with aggressive etch chemistries. Process time for releasing the wafer from the carrier using the WaferBOND™ remover has resulted in a substantial reduction in time over the previous process of record, which allows for an increase in throughput through the backside fabrication area.

CONCLUSIONS

The creativity and problem solving abilities of engineers have yielded many potential polymers for use in temporary wafer mounting. WaferBOND™ adhesive was designed specifically to meet the temperature and chemistry requirements for III-V and SiC wafer thinning and backside processing. WaferBOND™ adhesive–mounted substrates can be processed at temperatures reaching 200°C and exposed to heated resist strippers, alkaline etches, developers, and acidic etches while maintaining the ability to be cleaned completely in WaferBOND™ Remover without leaving residue.

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ACRONYMS

III-V: elements common to groups III and IV of the periodic table, including GaAs, InP, GaN
HEMT: high electron mobility transistor
TGA: thermogravimetric analysis
TTV: total thickness variation