Temporary Bonding and Debonding Study with the Newly Developed Room Temperature Mechanical Debonding Material

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The wafer thinning process and making backside redistribution layer (RDL) process were key technologies for assembling 2.5D and 3D IC the low profile device manufacturing. It was widely studied about temporary bonding material (TBM) for those advanced device packaging. The key issues here were void free, bonding, thermal resistance without having delamination and defect free cleaning after debonding. To minimize the cost effective 3D IC manufacturing, we have developed single layer temperature bonding material designed for room temperature mechanical debonding process. The materials have a high thermal resistance over 230 °C for 4 hours without having any void formation, delamination and no residue on the device after solvent cleaning.

Keywords: Temporary bonding adhesive, Wafer bonding, Wafer thinning, Mechanical debonding

1. Introduction

The temporary bonding materials were widely used for TSV, the wafer thinning and back side RDL process in various kinds of 2.5D and 3D IC manufacturing, where various kinds of debonding method were utilized, such as thermal release, solvent removal, laser assisted, and mechanical debonding [1,2].

The most of temporary bonding debonding material required releasing layers which were laser sensitive for laser irradiation, and/or adhesion control between glue and substrate boundary [3-5]. However this release layer may cause a defect issue after debonding and may cause a difficulty of cleaning and ashing carrier wafer and device rework process.

Moreover, in case of laser debonding, the handling glass wafer substrate and the laser induced damage on device would be issued at the current manufacturing process. The decomposed compounds were generated from the material by laser which gave additional contamination issue on both device surface and carrier wafer recycling process.

In general, the temporary bonding materials were utilized more than two layers or sometime three layers to make a coating on carrier side and

or device side. Using various kinds of chemicals in TBM process would be an issue to achieve low CoO and high wafer throughput.

To overcome those issues, we have newly developed single layer TBM having no release layer for room temperature mechanical debonding [6,7].

The TBM was coated on one time at carrier wafer, which is usually bare Si wafer, with 2 steps baking process, that could be enhance process throughput. No laser and no heat in debonding process might reduce both laser induced damage on wafer, residue and surface contamination that could be reduced the manufacturing cost.

The TBM chemistry did not use any cross-linking type component to minimize residue at a high thermal process for both RDL and solder reflow.

2. Experimental

The temporary bonding material thermal properties were measured by TGA, Q-500 TA instrument. The temporary bonding material (TBM) was coated on 8 inch Si substrate with EVG 101 coater. The coated wafer was baked at 100 °C for 180 seconds first, and then applied 180 °C for 180 seconds to obtain 20 μm of film

thickness with EVG 105 hotplate. The film thickness and TTV was measured by Pocket design's in-house made scanning stage measurement tool having KEYENCE spectral interference laser displacement meter.

The wafer bonding was made with EVG 540 bonder with 15kN under vacuum condition where the bonding temperature was applied 200 °C for 300 seconds at both carrier and device sides. The mimic thermal process was utilized at 230 °C for 4 hours and 260 °C for 5 minutes $\times$ 2 times, which could be simulated polyimide curing process and solder reflow process, respectively. Thermal stability and void formation after bonding were inspected by Hitachi FineSAT FS-100, scanning acoustic tomography. The wafer edge was cleaned before debonding by applying edge bead rinse with mesitylene solvent to remove unnecessary part of TBM at the wafers bevel edge. Bonded wafer was attached on Nitto ELF PF-02 dicing tape. Then wafer debonding were made with Süss MicroTec DB12T with 8 inch compatible unit. TBM cleaning process was carried out by applying solvent with EVG 101 spin coater

3. Results and discussion

3.1. Temporary bonding material properties

The TBM materials decomposed temperature was measured with TGA under a) in nitrogen and b) air atmosphere (Fig.1).

a) in Nitrogen

b) in Air

Fig. 1. Decomposed temperature measurement by TGA.

The material thermal stability was determined at ca. 360 °C with -0.5 % of weight loss by changing heating temperature. Additionally, the thermal durability was studied by fixing temperature at 230 °C with changing duration time (Fig. 2). There is no significant weight loss was observed for 4 hours (240 minutes) with this temporary bonding material.

Since none of significant weight loss of TBM components were observed during 230 °C for 4 hours, it was suggested that the newly developed TBM could have a potential for high thermal resistance without having any chemical decomposition after bonding.

The TBM peeling force strength could be controlled from 4 N/m to 84 N/m against various kinds of customer's device substrate and surface topography for mechanical debonding, where TBM mechanical peeling force was unchanged before and after 230 °C of thermal process for 4 hours.

Fig. 2. TGA weight loss measurement at 230 °C for 4 hours.

3.2. Wafer bonding and debonding study

Since the materials consist of thermally stable components above 230 °C thermal process, this optimized formulation could be accepted for the usage of polyimide curing process after TBM wafer bonding.

To obtain TBM film on the carrier, the TBM solution was coated on 8 inch Si carrier side with EVG 101 spin coater. Then the wafer was baked at 100 °C for 180 seconds and 180 °C for 180 seconds, respectively.

The film thickness and TTV was investigated using scanning spectral interference laser displacement meter (Fig. 3).

It would generate a large height of edge hump where the film thickness was thicker than the center area because of the manual coating with spin coater. That was a general issue of spin coating material. Then high TTV value was 5.8 μ m at edge exclusion of 2 mm on 8 inch sized wafer.

a) Film thickness: 20.45 μm

b) TTV: 5.8 μm @EE 2 mm

c) 8 inch wafer coating uniformity

Fig. 3. TBM coating uniformity, a) film thickness from center to edge, b) TTV, and c) coating uniformity.

c) Warpage

North: 3.1 mm

East: 0.9 mm

South: 3.2 mm

West: <1mm

Fig. 4. a) RDL side, b) mold side, c) wafer warpage at 4 positions.

3.3. Wafer warpage

The 8 inch wafers having 300 μm of thickness was used in this study (Fig. 4). This wafer has about maximum 3 mm of warpage.

3.4. Temporary bonding and thermal test

The TBM coated wafer was bonded with wafer RDL side, where TBM was contacted with a) side of device surface in Fig.4, by using EVG 540 bonder with 15 kN pressure at 200 $^{\circ}\text{C}$ for 300 seconds (Fig. 5).

Fig. 5. Si carrier coating, bonding and thermal resistance test.

The wafers were subsequently applied 230 $^{\circ}\text{C}$ for 4 hours under nitrogen and 260 $^{\circ}\text{C}$ for 5 minutes $\times$ 2 times in inside of bonding chamber to applying mimic thermal process. The wafer warpage was inspected again after thermal test (Fig. 6). There was no delamination and no warpage enhancement observed after bonding and thermal process.

a) North: <1 mm

b) East: <1 mm

c) South: <1 mm

d) West: <1 mm

Fig. 6. Warpage inspection after bonding and thermal test.

3.5. Scanning acoustic tomography inspection

A Scanning Acoustic Tomography (also called C-SAM) inspection had been done after both the bonding and the thermal test using Hitachi FinSAT FS-100.

There was no void formation observed after bonding. And void was not generated during 230 °C for 4 hours and 260 °C for 5 minutes with 2 times process. The edge delamination would not be observed in both cases (Fig. 7). A white signature at south place was hand written wafer numbers on mold surface in the images.

Fig. 7. SAT images of a) after bonding and b) after thermal test.

Fig. 8. SAT images of a) after bonding and b) after 50 μm wafer thinning and thermal test.

The second lot of the same wafers sets, we had performed the wafer thinning from 585 μm to 50 μm to confirm adhesion property under 230 °C for 4 hours and 260 °C for 5 minutes with 2 times of heating condition after 50 μm wafer thinning.

The SAT images of bonded wafer thinning to 50 μm and after applying the thermal test images were shown in Fig. 8. A black curved line was seen at center, which was hand cleaned written inks on mold side (Fig. 8a), which ink attached layer could be thinning down to obtain clear images (Fig. 8b). There was no significant void and delamination was observed in this study.

3.6. Room temperature mechanical debonding

Then bonded wafer of first lot was placed on ELF PF-02 (Nitto-denko) dicing tape with ring frame, the room temperature mechanical debonding process was performed with SÜSS MicroTec DB12T debonder (Fig. 9).

The bonded wafers were held on the debonding stage together with dicing tape and ring frame with vacuum chucked stage holder at room temperature under the ambient clean room condition. The tool had a mechanical initiator to insert the blade at the edge of bonded wafers between Si carrier wafer and TBM boundary (Fig. 9a).

Then vacuum chucked Si carrier wafer was pulled toward upside together with the blade initiator to make the room temperature mechanical debonding. Typical debonding time at the debonding stage was less than one minute, which might give a high throughput for the high volume manufacturing. The room temperature mechanical debonding was successfully done without having any damage on device substrate

Fig. 9. Room temperature mechanical debonding results of wafer, a) mechanical debonding method, b) after debonding and c) after dicing tape removal.

3.7. Cleaning process

The after releasing the wafer from dicing tape, the TBM cleaning was performed with EVG 101 coater with applying solvent spin puddle on device wafer (Fig. 10).

Since our temporary bonding material did not contain any cross-linking reaction components, TBM compounds would be soluble against solvent after passing thermal test process.

Cleaning process	
Solvent	mesitylene
Dynamic	450 rpm / 20 sec
Static	10 rpm / 93 sec

Fig. 10. Device wafer cleaning with EVG 101 coater.

The TBM residue on both Cu pad and dicing line were inspected with optical microscope. There was no residue found on both critical patterns. There was also no significant solvent damage on device wafer (Table 1).

Table 1. TBM residue inspection at Cu pad and dicing line.

Position	Residue
North	None
East	None
South	None
West	None
Center	None

3.8. Solder ball shear test

After cleaning process, the solder ball was attached on Cu pad, then reflow at 260 °C for 5 minutes with 2 times. To confirm adhesion property, the solder ball shear test was performed on this TBM cleaned wafer.

The solder balls were SAC 305 having 300 μm diameters, attached on Cu pad size which was 280 μm diameters. The shear force was measure by DAGE 4000 tool with 200 – 300 μm / sec of shear force speed. Since Cu pad was cleaned completely by solvent and no residue was remained on the top surface of pads, the bulk solder were remained on pad-solder ball interface after shear test. No pad

lift was observed on Cu pad. It was passed the solder ball test after TBM debonding and cleaning process (Table 2).

Table. 2. Solder ball test results.

Ball Shear 45 bumps (gf/mil ²)		
Ave.	Max.	Min.
3.90	4.56	3.24

4. Conclusion

The room temperature mechanical bonding and debonding performance was evaluated with newly developed single layer temporary bonding material having high thermal resistance. The wafer thinning process could be applicable down to 50 μm after bonding. The adhesion property of temporary bonding materials was stable without having any void and any delamination under 230 °C with holding time 4 hours in nitrogen and 260 °C for 5 minutes with 2 times heating process in air atmosphere.

After polyimide cure mimic process and solder reflow process were passed, the bonded wafer was successfully debonded with room temperature mechanical debonding equipment.

The solvent cleaning process could remove the remaining temporary bonding material from device surface. Solder ball shear test indicated that Cu pad could be cleaned effectively after temporary bonding and debonding process.

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