MEETING THE FABRICATION CHALLENGES FOR BACKSIDE PROCESSING ON THIN SUBSTRATES WITH ULTRAHIGH DEVICE TOPOGRAPHY

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Abstract:

TriQuint manufactures devices on ultrathin substrates (100 µm) with ultrahigh topography (>80 µm). The development of a mounting process to thin the substrate to the required thickness for such devices is presented with consideration to critical process requirements including total thickness variation (TTV), grind thickness uniformity, damage removal, etch resistance, and electrical parameters.

INTRODUCTION:

As wafer thickness decreases to 100 µm and thinner, manufacturing challenges arise. Ultrathin wafers in the 100-µm thickness range with ultrahigh topography (>80 µm) are less stable and more vulnerable to stresses, and the die can be prone to breaking and warping—not only during grinding but also at subsequent processing steps.

One of the major requirements of mounting ultrahigh device wafers to carriers is to protect the active device during the thinning process. Protection must be provided by means of a consistent process that meets tight total thickness variation (TTV) requirements across the stack. Previously, large volumes of mounting material have been required to protect these ultrahigh devices. Mounting materials can be quite expensive; therefore, reducing the amount of material used per wafer is vital to minimizing cost. Methods for developing a process that uses less material while still meeting all of the basic requirements are presented.

BACKGROUND:

TriQuint manufactures semiconductor devices that require thinning of the 6-inch device wafer to as low as 100 µm while supporting over 80 µm of topology. TriQuint currently uses a material and process that require multiple coating and baking steps to sufficiently cover device topography. In an effort to reduce costs and simplify the mounting process, TriQuint has started collaboration with Brewer Science, Inc. A coating and bonding process has been developed which allows achievement of 100-µm post-grind substrate thickness and sufficiently covers TriQuint topography in a single coating step using a Brewer Science bonding material (Brewer Science® WaferBOND® HT-10.10 bonding material).

Tests for feasibility were first conducted at Brewer Science facilities using its equipment. These tests were then followed up with several additional tests at TriQuint using Brewer Science bonding material and TriQuint processing equipment.

METHOD:

For the initial demonstration, 10 product wafers and carriers were bonded and mounted at Brewer Science with an additional 10 device wafers coated (but not bonded) at Brewer Science. The bonded pairs were returned to TriQuint for device wafer thinning to 120 µm. The unbonded wafers were bonded and thinned at TriQuint.

All bonded pairs were initially scanned for voids using the Sonix® Fusion® scanning acoustic microscope (SAM). The carrier identification number was used to track each pair in this state. Figure 1 displays one of the scans. Each of the bonded pairs showed uniform bond lines regardless of whether they were bonded at TriQuint or Brewer Science.

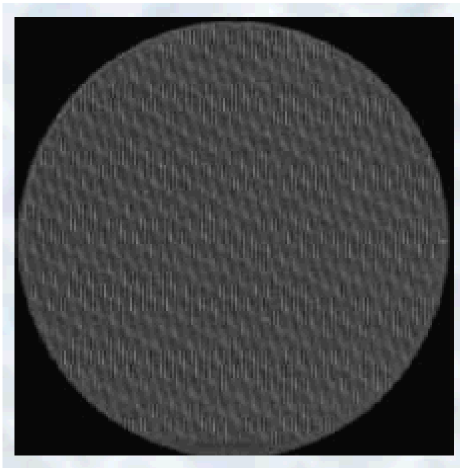

Figure 1: SAM Map

A 100-µm single-coat process was implemented at TriQuint. Using a single coat instead of multiple coats was the key to significantly decreasing chemical usage and costs. It was critical to properly bake the WaferBOND® material-coated wafers to avoid outgassing and to be able to achieve a reliable bonding process. The wafers had to undergo a ramped bake at temperatures up to 190°C. The wafers were then bonded to uncoated carriers and ground to as thin as 100 µm.

The next challenge was to determine a manufacturable debonding process for the thinned wafers. Initially, a very manual process was established. Although several wafers were successfully debonded, it was not dependable enough to release for manufacturing due to a high wafer breakage rate.

In early 2013, an automated Brewer Science® Cee® 1300CSX debonding tool (see Figure 2) was purchased and installed at TriQuint to improve reliability of the debonding process. The Cee® 1300CSX debonder uses top and bottom heated vacuum chucks set at 190°C, which allow the bonding material to soften, followed by a slide-off debonding.

One important aspect of the Cee® 1300CSX debonding tool is that it requires a topside edge bead removal (EBR) process on the mounted wafers to keep the heated platens from being contaminated with WaferBOND® residue. The reason for this is because at such high temperatures, WaferBOND® material begins to soften, and any excessive material along the wafer edges will melt onto the heated platens. The topside EBR process was therefore performed on the coat track using the same chemicals that are required to clean the wafers.

After debonding, the thinned wafers had to be attached to taped film frames and cleaned. WaferBOND® Remover proved to be an effective chemical in cleaning the WaferBOND® material-coated wafers. Several cycles of a dynamic dispense were used, followed by an isopropanol (IPA) rinse. Formation of puddles was avoided to keep the saw tape from "sagging" and causing vacuum errors on the cleaning tool.

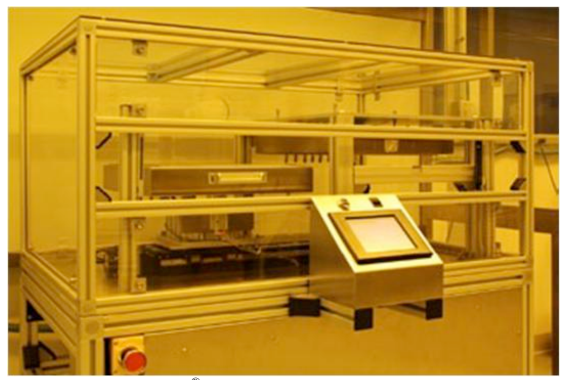

Figure 2: Cee® 1300CSX Benchtop Debonder

In addition to cleaning the product wafers, it was also important to clean the carrier wafers after debonding. Several different methods were considered and tried. Initially, the carriers were cleaned on the coat track using WaferBOND® Remover and IPA. The cleaning process required several dispenses, which amounted to an excessive amount of chemical usage. Therefore, a tank clean was attempted. The carrier wafers were batched in 24 wafer boats and dipped in a WaferBOND® Remover–filled tank, heated to 70°C, for 10 minutes followed by an IPA tank for 10 minutes. The wafers were then dried in a spin rinse dryer (SRD). Early trials showed minor residue on the carriers after the cleaning process. Future trials will add a second "clean" WaferBOND® Remover–filled tank for the wafers to be dipped in after exiting the first "dirty" WaferBOND® Remover–filled tank. It will also be important to monitor the number of uses of each tank before chemical replacement is needed.

Several test lots were run to compare the performance of WaferBOND® material versus the standard mount process. These lots were split between WaferBOND® material and the standard process using TriQuint coating, mounting, grinding, demounting, and cleaning processes. For the initial test lots, a manual debonding method was used. Additional verification lots were run to confirm the new debonding process.

RESULTS:

TriQuint has created an algorithm to measure post-mount thickness uniformity in terms of wedge, bump, dip, and photo bump (bump in the center of the wafer), as shown in Figure 3. Green represents “good,” yellow represents “marginal,” and red represents “rework.” The odd numbered wafers were processed with WaferBOND® material, and the even wafers used the standard mounting process. The image shows that WaferBOND® material gave superior uniformity, especially in the “dip” category. The positive results were expected due to a better coat uniformity achieved with WaferBOND® material because it does an excellent job of planarizing over the topology on the wafers.

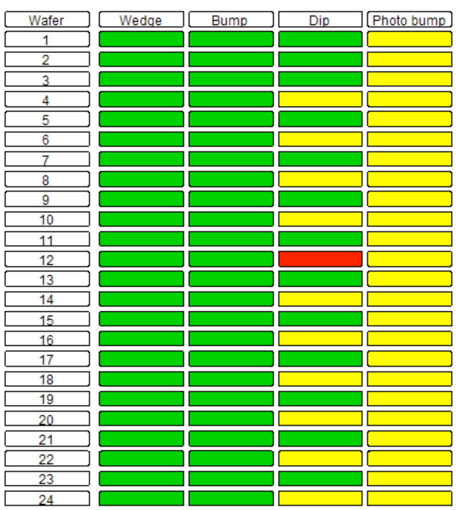

Figure 3: Post-Mount Thickness Uniformity

Adhesion data for the 80-µm topography showed no degradation from either of the splits. Final electrical data and Automated Optical Inspection (AOI) data also showed no change in performance due to WaferBOND® material. Bond pull data was collected on the WaferBOND® material splits with no failures. Final wafer thickness uniformity was significantly improved with the WaferBOND® material process in comparison to the standard wax process, as shown in Figure 4. The odd numbered wafers (WaferBOND® material) show much better uniformity across the wafer, while the even numbered wafers (standard process) have a thick ring around the edge and thin center areas as indicated by the color-coded charts. Consequently, wafer yield was significantly improved due to much fewer die failing thickness requirements.

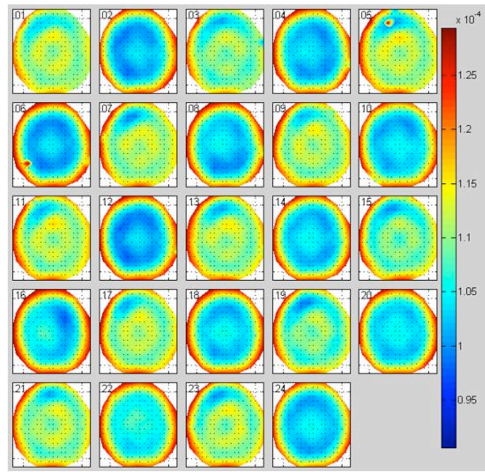

Figure 4: Final Substrate Thickness Uniformity

Verification lots for the Cee® 1300CSX debonder showed equivalent electrical, adhesion, and thickness uniformity results compared to the manual debonding process. The wafer breakage was greatly reduced with the new debonding process.

CONCLUSIONS:

The Brewer Science® WaferBOND® HT-10.10 temporary bonding material showed excellent results while decreasing the amount of the material used compared to the standard bonding material. The new process also helped to reduce cycle time, significantly reduce costs, and improve wafer reliability and yield. While the first trial was to implement the WaferBOND® material process for 6-inch acoustic wave wafers, there are plans to expand the changes to 4-inch GaAs and GaN wafers and eventually to all devices that are processed at TriQuint.

ACKNOWLEDGEMENTS:

Numerous individuals were involved in the success of this project. Noteworthy parties include several process engineers, applications engineers, product engineers, equipment engineers, quality engineers, manufacturing operators, sales managers, supply chain specialists, and more. Special mentions go to engineering technician Cory LaFoy for his efforts in developing and testing new and innovating process ideas, Darrell Lupo for reviewing all product parameters including electrical, AOI, and yield data, Joe Raposo for providing a reliable link between TriQuint and Brewer Science during the development process, and Molly Hladik and Matt Rich for installing and qualifying the debonding tool at TriQuint and providing endless tool and process support. Joel Peterson also deserves considerable credit for his creativity and prompt timing in supplying and modifying process equipment used to develop and qualify the processes at TriQuint. Additionally, Angela Franklin deserves mention for her work as part of the Supply Chain team to ensure that costs, chemical and equipment usage, and quality standards were maintained and optimized.

REFERENCES:

ACRONYMS:

AOI: Automated Optical Inspection
BSI: Brewer Science, Incorporated
EBR: Edge Bead Removal
IPA: Isopropanol
SAM: Scanning Acoustic Microscope
SRD: Spin Rinse Dryer
TTV: Total Thickness Variation