

Optical Profilometry of Substrate Bow Reduction Using Temporary Adhesives

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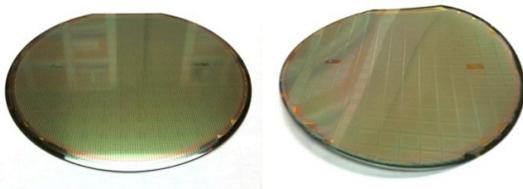
ABSTRACT

Incentives of form factor, performance, and cost reduction are urging the integration of three-dimensional packaging of integrated circuits (3DIC) and promoting thinner substrates. To maintain this trend, new ways of rapid metrology measurement with solutions to achieve substrate bow reduction are needed. FRT's optical profilometry systems offer high resolution and rapid scanning to map a substrate in minutes [1]. When combined with a removable temporary bonding solutions, simple and low-cost options exist for bow reduction to the end user [2].

Key words: profilometry, bow, warp, TTV

INTRODUCTION

It is difficult to predict what variability exists due to thinning semiconductor wafers and die; however, this irregularity commonly increases as thickness is reduced [6]. For example, bow is observed in a LED wafer when its internal stress exceeds the intrinsic strength of sapphire when thinned to 100um (Fig. 1).



Full thickness (~700um) Thinned (~100um)
Fig. 1. Sapphire LED substrate at full thickness (left) and thinned (right) with the presence of bow.

Substrate stress may originate from metal thickness, component design and layout, and thinning. These may be unavoidable, leading to bow and warpage, which contributes to yield loss in 3DIC. Measurement of these characteristics must occur and where necessary, be supported by temporary carriers.

Optical Profilometry

Substrate bow [3], warp [4], total thickness variation (TTV), and flatness [5] are measured to SEMI Standards with either a single sensor or dual, opposed

sensor configuration. The entire substrate or wafer can be mapped or measured by a series of profiles. Non-contact optical profilometry is the preferred method of choice for high resolution, speed, and reliability. FRT's capabilities extend to 450 mm wafers and larger substrates for determining 3D measurements locally or across the entire sample. Detailed images and software driven statistics enable rapid identification of the parameter of interest, enabling critical decisions when searching for solutions that involve handling expensive thinned substrates (Fig. 2).

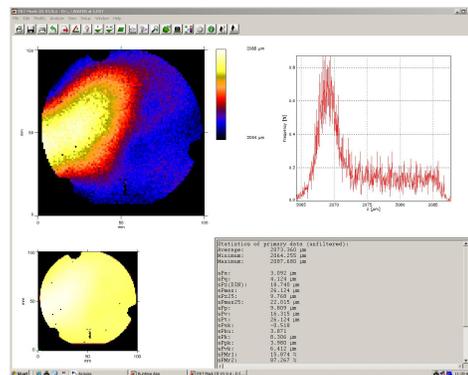
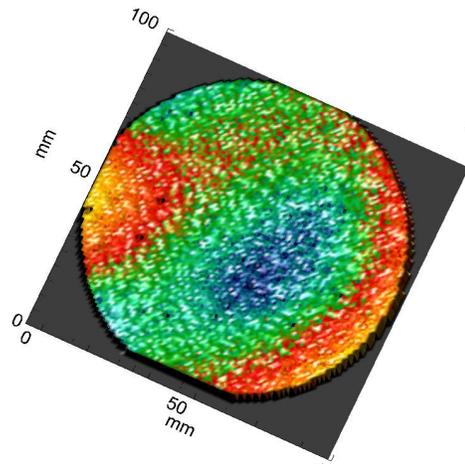


Fig.2. Flatness and TTV scan of a 100 mm wafer.

The equipment sensor resolution can be set in the z range to 3 nm and 1 μm in the x-y direction with a z-working distance to 5 mm. The optical sensor uses a positioning camera, which works as an OM to define the scanning area. Included on FRT's MicroProf® series, they allow rapid and accurate topography measurements at the R&D level or with automation on sample sizes up to 600 mm x 600 mm (Fig. 3).



Manual Operation

Automated – 300mm

Fig. 3. FRT's MicroProf® series of profilometers.

Thin Substrate Handling

Of the common wafer support practices, an adhesive bonded carrier is the most reliable to protect thin substrates and exhibit chemical and thermal resistance necessary for backside work (Table 1).

Table 1. Options for thin substrate handling.

Method of Handling	Substrate Thick (um)	Chem & Therm Resistant	Single or Batch Process	Backside Process Support
Tape	>50	No	Both	No
Vacuum Chuck	>50	No	Single	No
Adhesive Bonded Carrier	<25	Yes	Both	Yes

Temporary Adhesives

All of the current commercialized adhesive technologies use a carrier for temporary support. The carrier enables good surface planarity, low TTV, and reduces both internal stress and wafer bow during grinding [6-9]. Liquid spin-on forms of adhesives offer easy control of TTV with acceptable thinning uniformity achieved with this value at $\leq 0.5\%$ [10-11]. The adhesive supports backside processing, including TSVs, metallization, and dicing. A common feature of temporary adhesives with carriers includes two active stages, namely, bonding and de-bonding (Fig. 4).

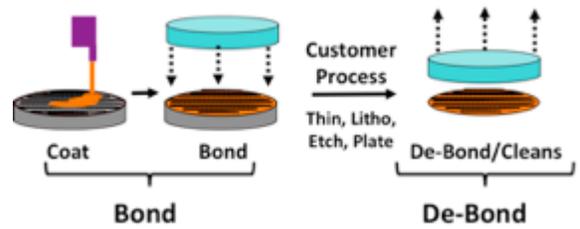


Fig. 4. Two active stages to the use of any temporary adhesive and carrier, bonding and de-bonding. Cleaning is included in the de-bonding practice.

Table 2. Commercial temporary adhesives and their process parameters.

Firm	Chemistry	DeBond Method	Batch or SW	Cleans
BSI	Rubber	Chem. diffusion, therm. slide, peel	SW	Solvent
3M	Acrylic	UV and/or ablate & peel	SW	Solvent
TMAT, Dow Corning	Silicone	Peel	SW	Solvent
DuPont	Polyimide	Ablate/peel	SW	Solvent
TOK	Acrylic/Styrenic	Ablate &/or chem. diffusion	Batch	Solvent
Daetec	Various AQ	Chem. diffusion	Batch	Detergent

Products used in the marketplace include the following: a) rubber/olefinic [12-13], b) acrylic [14], c) silicone [15], d) polyimide, and e) rosin-urethane [16]. Although these chemistries vary, their application is similar by direct wafer coating and carrier bonding (Fig. 4). The main variance in performance and complexity is in their de-bonding (Table 2 & Fig. 5).

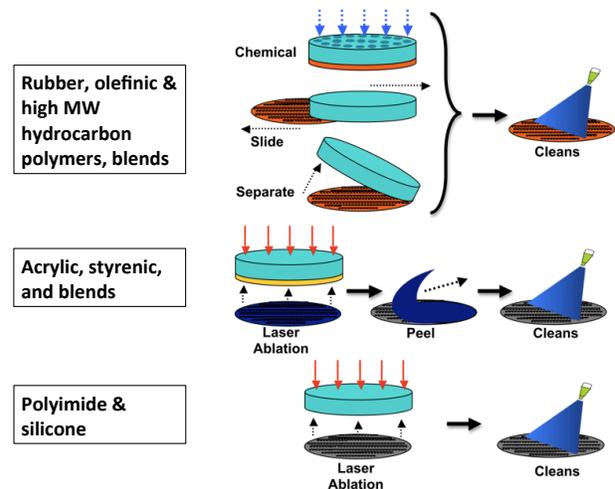


Fig. 5. Temporary adhesives commercially available, exhibiting variable de-bond performance and complexity.

EXPERIMENTAL

Readily available thinned interposer die are acquired by several suppliers in the industry (Fig. 6). Temporary bonding adhesives and other developmental products are readily available [2]. DaeCoat CD300, CS300, and FS300 with detergent DaeClean DP-108 and SL3200, SL1750 cleaning agents. Coatings are produced on a Brewer Science, Inc. CB-100 spin-coater, while spray and encapsulation uses custom tooling. Configuration of interposer die applied to varying carriers with adhesive and measured by optical profilometry (Fig. 7). Metrology data is generated by a FRT MicroProf® optical profiler [1]. Measurement conducted on the diagonal end-to-end, producing thickness profiles with statistics (Fig. 8). Modified thermogravimetric test methodology for outgas is conducted by typical laboratory scales (+/- 0.1mg, Fig. 9). UV cure equipment includes the Intelli-Ray 400 microprocessor controlled light curing system (Uvitron International, www.uvitron.com). Measurement of a thermal deviation from a planar surface by shadow moire', similar equipment to the commercial manufacture (www.akrometrix.com).

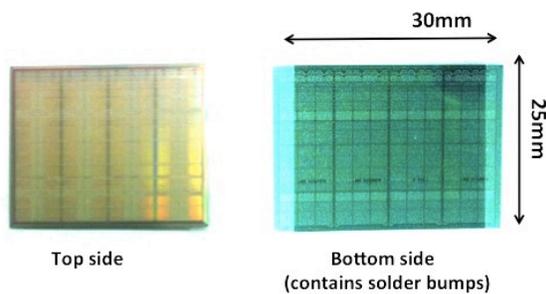


Fig. 6. Interposer die dimensions.

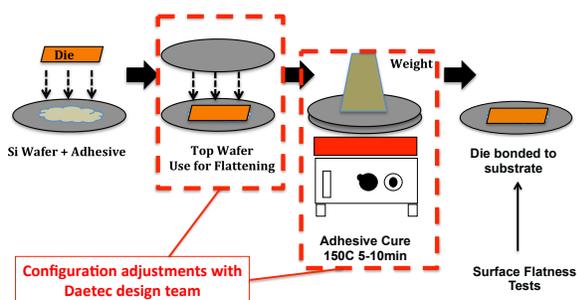


Fig.7. Process flow in bonding interposer die and flatness measurement.

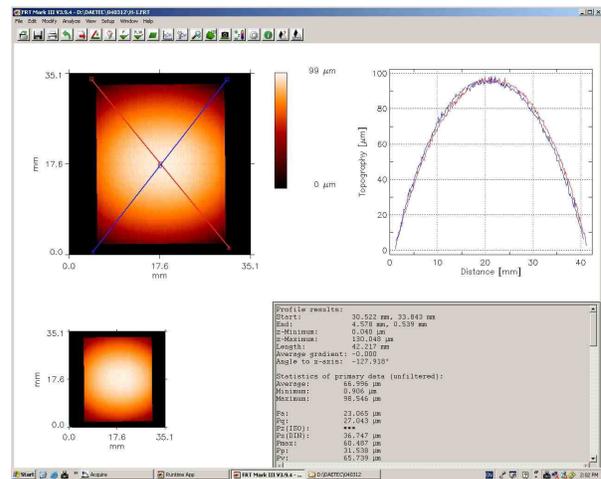


Fig. 8. Optical profilometer output with statistics.

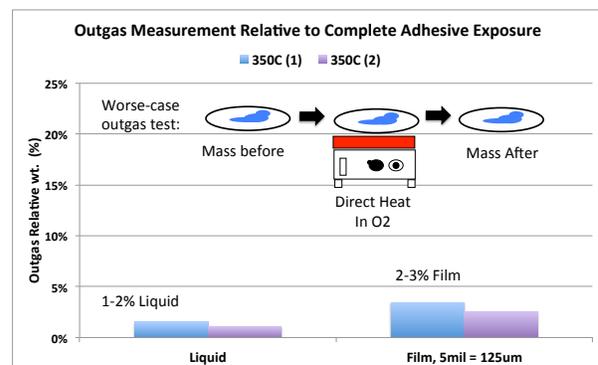


Fig. 9. Outgas data on thermal resistant adhesives.

RESULTS

Thinned interposer die are measured by optical profilometry and are shown to exhibit a bow of >100um as deviation from a planar surface. In the following example, interposer die #5 is observed at the initial condition (Fig. 10), coating on bumped side (Fig. 11), mounted to a carrier (Fig. 12), and then observed for bow in the affixed position to the carrier (Fig. 13).

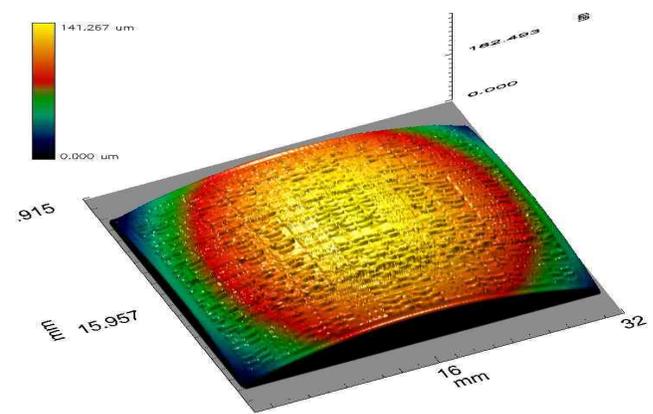


Fig. 10. Initial optical profilometry of interposer die #5, indicating bow extending to >140um.

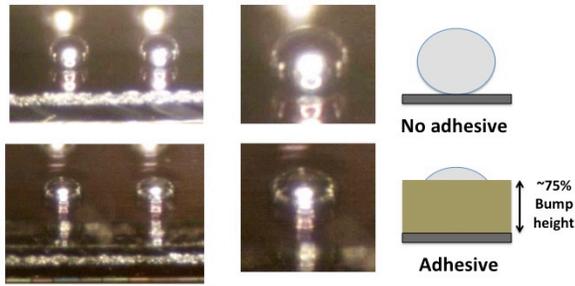


Fig. 11. Adhesive planarization of bumps, $\geq 75\%$.

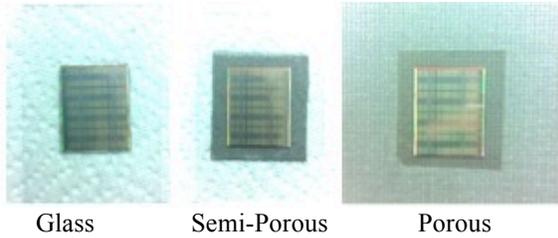


Fig. 12. Bonding interposer die to different carriers as designed internally according to porosity and capillary action during debond.

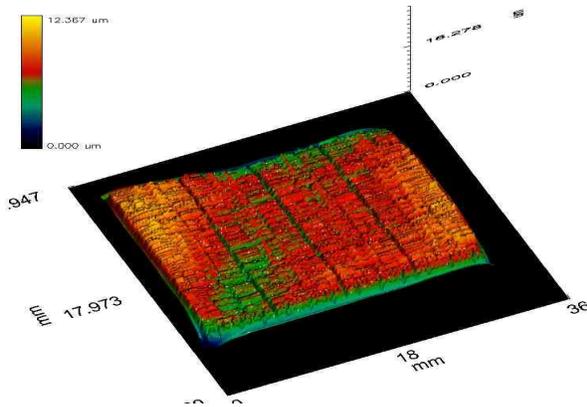


Fig. 13. Post optical profilometry of interposer die #5, affixed by temporary adhesive to carrier, indicating bow reduction to 12um (~90% reduction).

Using multiple adhesive configurations with liquid UV/cure and film forms, interposer die are attached to a range of carrier substrates as solid, semi-porous, and porous (Fig. 10). Once affixed to the carriers, optical profilometry is performed and reporting the maximum and average relative thickness from center (Fig. 14) and percent relative reduction (Fig. 15). Shadow moire' thermal topography results of several interposer die through reflow temperature of 260 °C, achieving a deviation satisfactory to the process (Table 3).

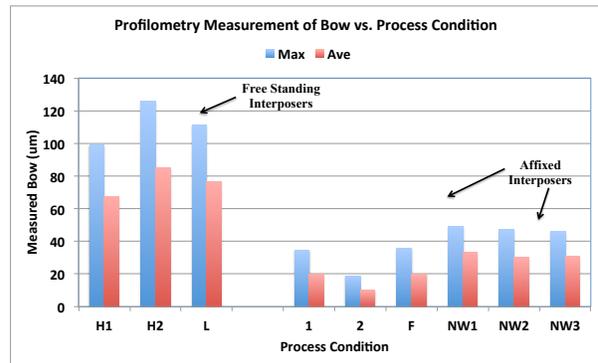


Fig. 14. Bow measurement of interposer die.

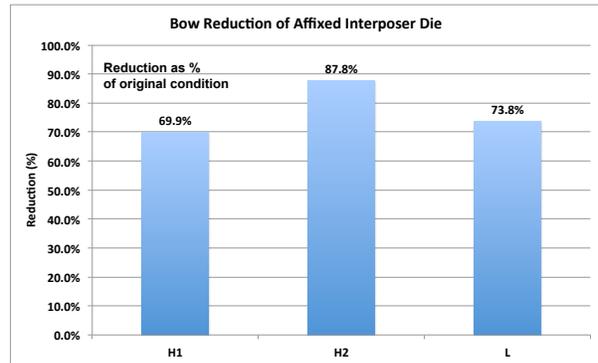


Fig. 15. Bow reduction as percent of original condition.

Table 3. Shadow moire' test condition of adhesive.

Sample #	Adhesive type	Shadow moire'
407	DaeCoat FS300	Pass
#1	DaeCoat CS300	Pass
#2	DaeCoat CS300	Pass
Un-supported	- N/A -	Fail

DISCUSSION

Bow reduction by temporary affixing interposer die to carrier substrates is the beginning to a process development for down stream further 3DIC processing. One such temporary adhesive for coating and planarizing of large features is DaeCoat CS300. Once cured, it can then be affixed to the carrier by a film version of the same chemistry, DaeCoat FS300. A process with porous substrates is given (Figs. 16-17).

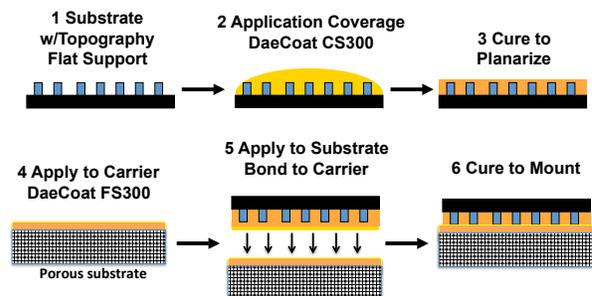


Fig. 16. Process flow for affixing interposer die.

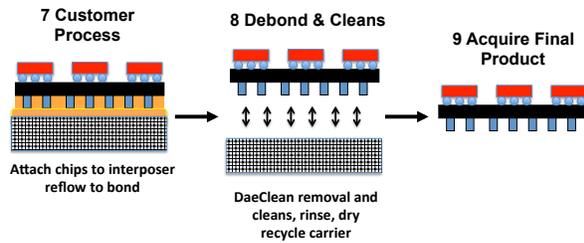


Fig.17. Post-processing of affixed interposer die, demount, and cleans

The tested temporary adhesives in this study are easily removed (cleaned) from the surface, leaving the substrate in a pristine condition. Usual cleans practices involve the application of solvents or aqueous mixtures followed by an alcohol or water rinse. For simple de-bond, it is recommended to use of perforated carriers or capillary diffusion substrates in a batch process.

To support this approach, a new generation of porous substrates is being explored. These substrates are designed to allow greater fluid contact to the adhesive and aid in batch de-bonding. Of the carriers under review, some exhibit smooth surfaces with Rq values of 1um or less and flatness within 10-25um (Fig. 18).

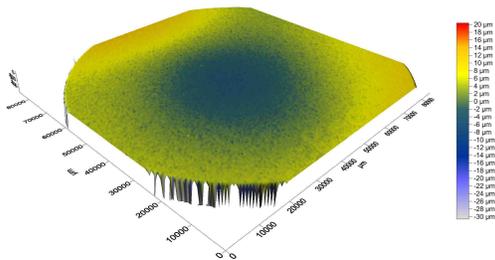


Figure 18. Flatness of a porous carrier, used to demonstrate batch de-bonding processes.

For several decades, temporary adhesives have been used in mounting wafers to carriers, thinning, backside processing, and finishing by a batch de-bonding process [10-12]. Bonded wafers are assembled in a cassette and then immersed into the cleaning solution. Penetration occurs via conduction channels at the side and through a perforated carrier, allowing breakdown of the adhesive. The adhesive gives way and demounting occurs with simultaneous cleaning in the same bath. Customers have designed their own fixtures to separate the carrier from their product without yield loss.

Where wafers are used, it is preferred that de-bonding and cleaning occur while the thinned wafer is supported on a tape (film frame). This practice requires cleaning and process to be fully compatible (safe) with the chemistry of the tape (Fig. 19).

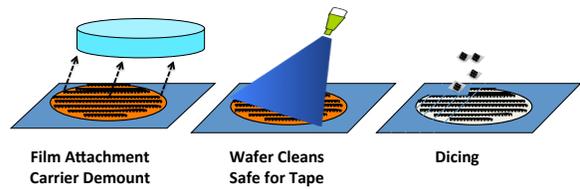


Fig. 19. Process flow for cleans while product wafer is supported on tape (film frame).

Most acrylic-type wafer taping media exhibit limited compatibility to most organic solvents used to clean/remove temporary adhesives, especially those described earlier (Table 2 & Fig. 5). For this reason, it is encouraged to use of aqueous-soluble adhesives, to achieve full compatibility with the film frame without the need of additional equipment would be necessary.

The primary reasons in using aqueous soluble adhesives include process simplification, material compatibility, cost reduction, and environmental safety. Whether it be cleaning with water or detergents, the chemistries are non-flammable, non-toxic, and do not generate evaporative material to trigger air permit requirements. Subtleties exist in aqueous cleans, and many believe it to be more challenging to control than organic solvents. Effective aqueous systems are built with additives that prevent irregularities during processing. Detergents are mixed with purified water. Ingredients in the detergent mix with species from the adhesive to prevent redeposition, inhibit corrosion, and stop scale build-up. These so-called detergents are complex and offer a balance in chemistry to deliver performance at the selectivity that is desired by the process.

CONCLUSIONS

This paper presents data and process suggestions to reduce the occurrence of bow and warpage in thin substrates. By utilizing optical profilometry as a measurement tool with the use of temporary adhesives, a means to reduce bow by nearly 90% is shown to be feasible. This equipment and material options allow subsequent 3DIC processes to occur without yield loss. Using an aqueous soluble adhesive, the process can be planned for batch processing using simple and low cost detergents.

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