The Use of Temporary Bonding in Manufacturing Flexible and Rigid Substrates

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Abstract

Thin substrate manufacturing is one of the highest growth areas in electronics. Fragile substrates of 100um or less supported by a carrier until the process is complete and are removed by simple and reliable means. The demands for temporary bonding of electronics vary from rigid wafers, flexible films, to components with solder bumps. Substrate type, topography, thermal budget, processing, and removal, all influence the choice of bond & de-bonding. The handling of wafers and the choice of adhesive commonly operate within single-wafer processing equipment. Batch processing exists with perforated carriers or DaeBond 3D™ whereby debond occurs by passive means in a *green* chemical bath while thinned device wafers remain affixed to film frames. Flexible display manufacturing uses thin substrates as polyimide (PI) and metal foil. Much is focused on transparent materials with high thermal resistance. Adhesive choice depends upon the substrate being a liquid casting or solid film; removal is by peeling. Tuning adhesion enables simple removal without challenge to substrate integrity. Daetec will discuss our challenges in handling 4um Si, interposers with bumps, and flexible PI, as well as thermal resistance to 600C.

Introduction

A wide range of adhesives has been reported in temporary bonding practices for electronics. Adhesives are available to temporarily bond a range of substrates (Table 1).

Table 1: Applications of DaeCoat™ products.

Work Unit	Market	DaeCoat™	Method
Organic Film	OLED, flexible displays	355	Cure on carrier, bond w/pressure
Organic Film (cast)		355	Cure on carrier, cast & cure liquid
Thin glass	TFT LCD	355	Cure on carrier, bond w/pressure
Metal Foil	OLED, flexible displays	355	Cure on carrier, bond w/pressure
Wafer	3DIC	355, 365, 615, 625	Planarize coat, bond w/pressure
Die (chip)		355	Cure on carrier, bond w/pressure

Temporary bonding is mostly about debonding. Namely, the handling of a thin and fragile substrate is governed by debonding. Intermolecular adhesion such as van der Waals forces, can limit simple removal by peeling, sliding, or pulling. Models help tune adhesion force while protecting the efficacy of a bonded stack (Fig. 1) and determine external tensile or shear forces for debonding (Fig. 2).

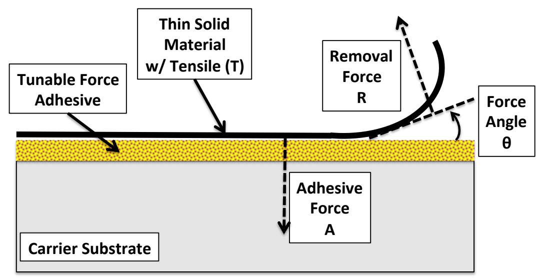

Fig. 1: Model for tuning adhesion (A) according to a material's property (T) and process (R & Ø).

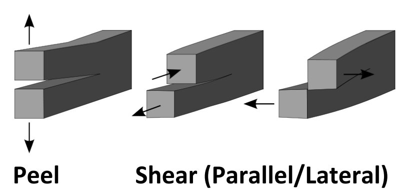

Fig. 2: Description of external forces on two adhered masses to effect tensile (peel) and variable direction shear.

Wafers

Temporary wafer bonding involves two active stages (Fig. 3), the mechanics of which are similar.

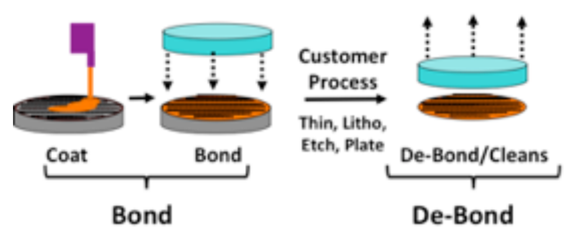

Fig. 3: Two active stages to the use of any temporary adhesive and carrier, bonding and de-bonding.

Many technologies exist, all differentiated by debonding where some chemical or mechanical change at the interface has occurred (Fig. 4). For example, laser demount or peeling requires highly transparent carriers or plasma treatment to create a phobic interface. Many processes encourage low temperature processing to minimize bow and warp due to CTE mismatch.

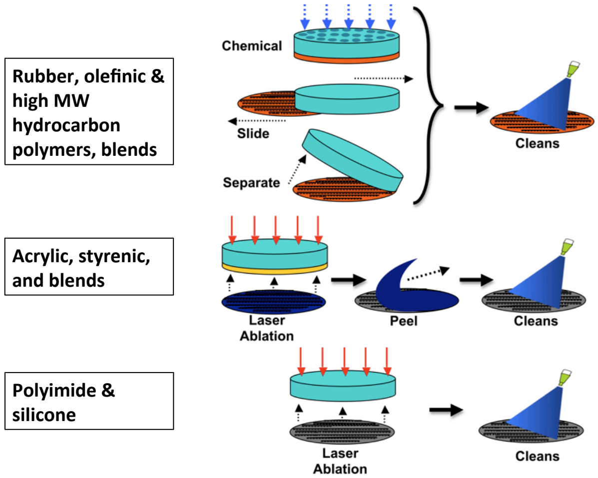

Fig. 4: Leading practices of wafer debonding.

Wafers are ground and polished to at least 100um while front side devices are protected during backside processing. Carriers offer surface planarity at ≤2um TTV and reduce bow from internal stress during grinding. Spin-on adhesives control TTV and seal the wafer. Many adhesive chemistries are used for thin wafer handling, including: a) rubber/olefin [1-2], b) acrylic [3], c) silicone [4], d) polyimide [5], e) rosin-urethane [6], and BCB [7]. Bonding is similar by coating on the device wafer, curing, and bonding to a carrier.

Batch Processing

DaeBond 3D™ describes a novel batch-processing thin wafer handling system. Device wafers are planarized with DaeCoat™ 515, bonded with DaeCoat™ 355 (tunable adhesion force) to a carrier, and processed through the customer's line [8]. Carrier de-bonding occurs by capillary diffusion into the bond line while the device wafer is supported onto a taped film frame. A tape-safe chemistry, DaeClean™ 300, is used in a simple wet bench tool offering low cost and throughput defined by the size of the cassette and tank (Fig. 5).

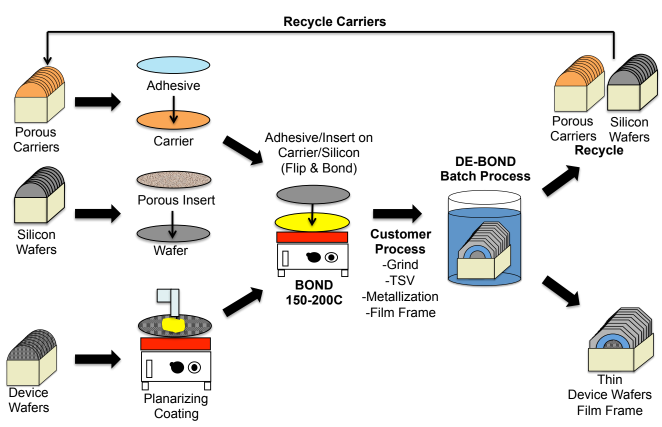

Fig. 5: DaeBond 3D™ technology flow.

Carrier de-bonding occurs in Tank 1 by liquid penetration to break the edge seal and migrates swiftly through the porous coating until saturation causes a drop in adhesion. Cassettes of film frames holding device wafers proceed to tank 2 for final washing (Figs. 6 & 7).

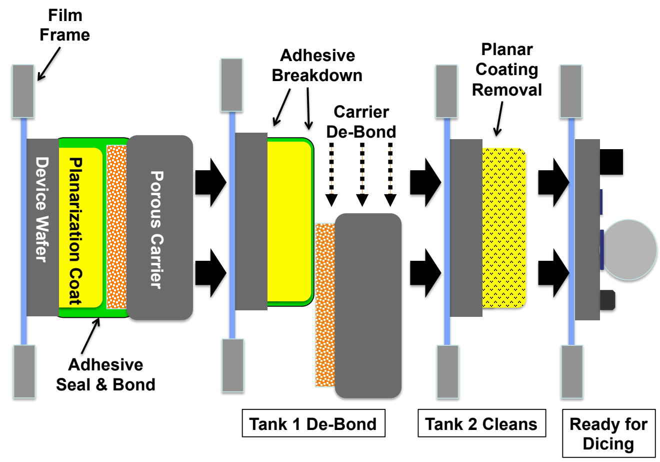

Fig. 6: Step-wise carrier de-bond & wafer cleans.

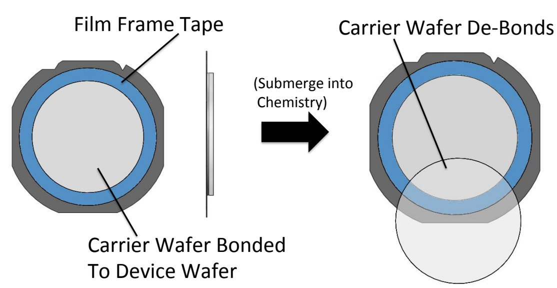

Fig. 7: Carrier de-bond from the taped film frame.

Displays

In display processes, temporary bonded substrates are removed by peeling practices without the need for adhesive cleaning. The process flow applies DaeCoat™ 355 to the carrier (glass) prior to liquid PI curing. It is processed to device completion and peeled after laser cutting it by laser cutting (Fig. 8).

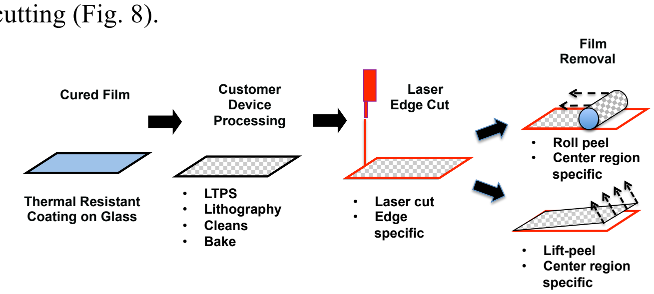

Fig. 8: Process flow for displays.

The removal of large-area substrates use peel methods where its physics are force vectors and adhesion is measured over removal distance. These configurations follow modified ASTM D3330 methods using a 90 or 180 degree orientation. Practices should use such modified approaches in order to achieve the desire of the process without damage to the part (i.e. wafers, thin PI, or devices, Fig. 9).

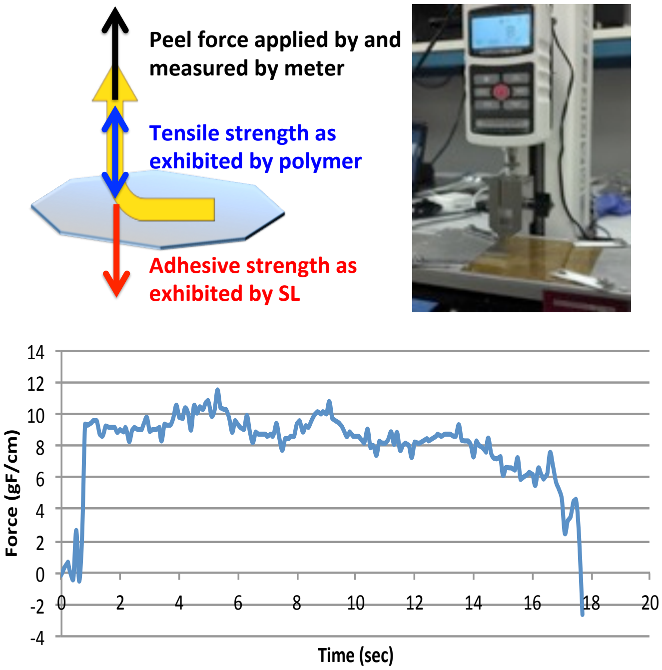

Fig. 9: Vector modeling and measurement (top) and graph of peel force (bottom).

Small Components

Temporary bonding of small die and packages are applied to elastic adhesive, processed, and subsequently pulled away without residue. DaeCoat^{TM} 355 adhesive supports a PVD process and allows carrier recycling by using DaeClean^{TM} 300 [9]. Similarly, DaeCoat^{TM} 365 reduces Interposer bow during post-bonding of micro-bumped chips by encapsulating existing bumps (Figs. 10-12) [10].

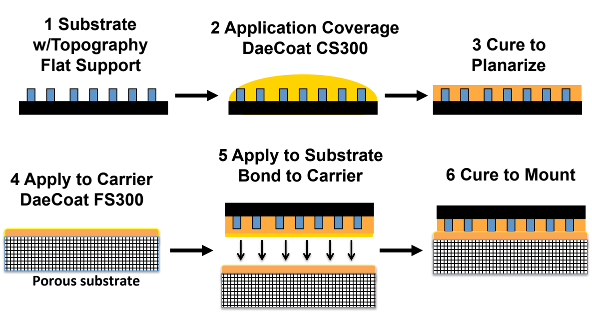

Fig. 10: Process flow for affixing interposer die.

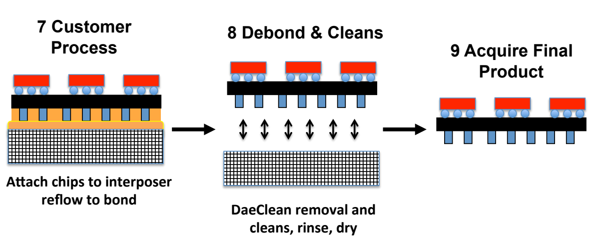

Fig. 11: Die processing, demount, and cleans (option).

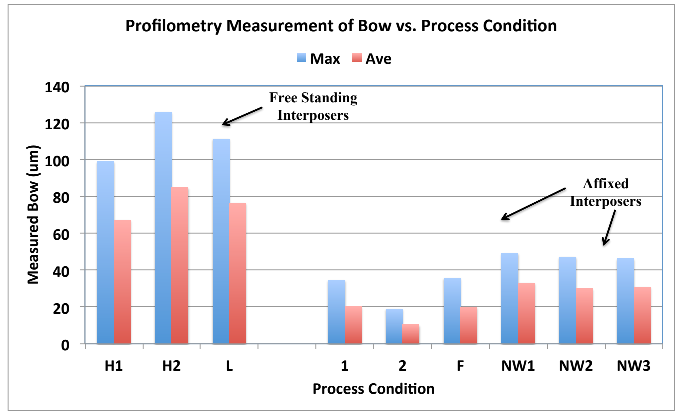

Fig. 12: DaeCoat^{TM} 365 bow reduction of Interposers.

Green Products

The electronics market continues to reduce risk by minimizing the use of chemicals. Daetec creates products that are 100% solids (solvent free) or use water to apply or process. DaeCoat^{TM} 515 is a planarizing coating that washes with DIW prior to dicing (Fig. 13). The same coating eliminates laser HAZ debris (Fig. 14) [11].

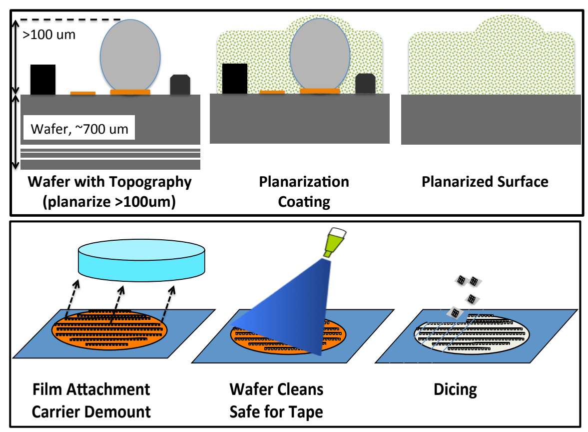

Fig. 13: DaeCoat^{TM} 515 washable planarizing coating.

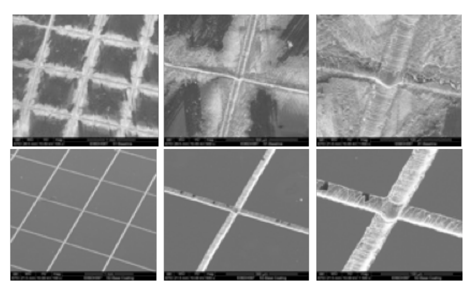

Fig. 14: SEM photos of laser processing without DaeCoat^{TM} 515 (top) and with coating (bottom).

The washable adhesive, DaeCoat^{TM} 615 with varying thermal resistances from 70-250C (Fig 15), is used to process wafers and electronic parts and subsequently washed away with detergent. The pH-driven system is inert for grind/polish slurries and accepts all dicing tapes.

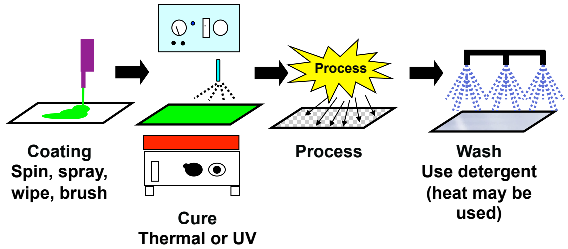

Fig. 15: Process description for using detergent washable adhesive DaeCoat™ 615.

Experimental

For subsequent analytical testing, quartz substrates as are chosen and prepared at Daetec along with 100-200 mm (4-8") silicon wafers (1-0-0, ~525 µm) re-manufactured from Wollemi Technical, Inc. (Taiwan, www.wollemi.com.tw). Materials used include commercially available spin-coated adhesives and other developmental products produced at Daetec. UV-cure applications are conducted with free-radical resins available from BASF. Solvents and other chemicals considered to be common to a development laboratory are available.

Coatings are produced on a Brewer Science, Inc. CB-100 spin-coater, while spray and encapsulation uses custom tooling designed at Daetec. Metrology data is generated by a XP-1 stylus profiler, AFP-200 atomic force profiler, and a Xi-100 optical profiler. Where applicable, equipment settings include a 5 mg stylus load, minimum 4 mm distance, and speed of 0.5 mm/sec. Modified thermogravimetric test methodology for outgas is conducted by typical laboratory electronic gauges (+/- 0.1mg). UV cure equipment includes the Intelli-Ray 400 microprocessor controlled light curing system (Uvitron International, www.uvitron.com). Adhesion is measured by force gauge with measurement software (www.mark-10.com) using traceable method (Daetec SOP #45, ASTM D3330).

Results

PI temporary bonding from liquid castings requires the adhesive DaeCoat™ 355, a mixture of two resins A & B. The PI varnish, DaeCoat™ 215, is applied to adhesive pre-treated carriers (Fig. 16), where A & B exists 10-50% relative to each other, creating an adhesion force from 15-90 g/cm^2 (Fig. 17). External force location (Fig. 18) creates improved peel results of thin glass from DaeCoat™ 355 on carriers (Fig. 19).

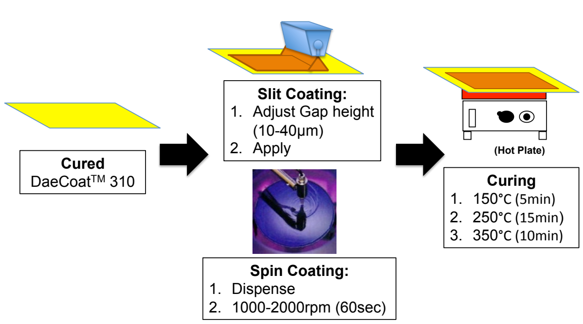

Fig. 16: DaeCoat™ 215 PI coating process.

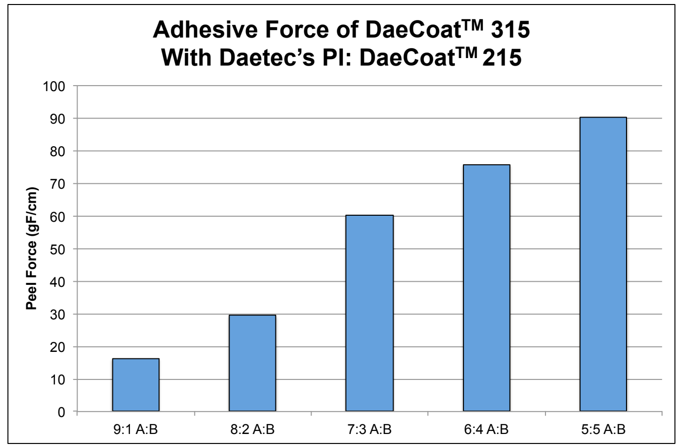

Fig. 17: PI adhesion tuning using DaeCoat™ 315.

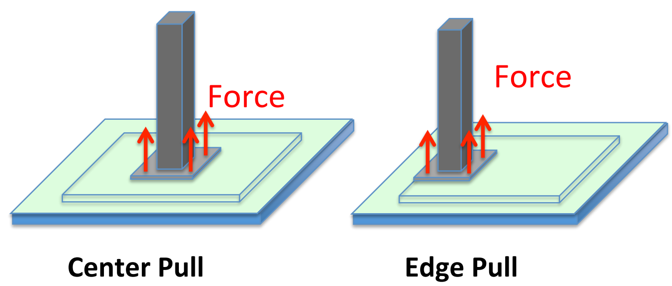

Fig. 18: Configuration of thin glass peel configuration.

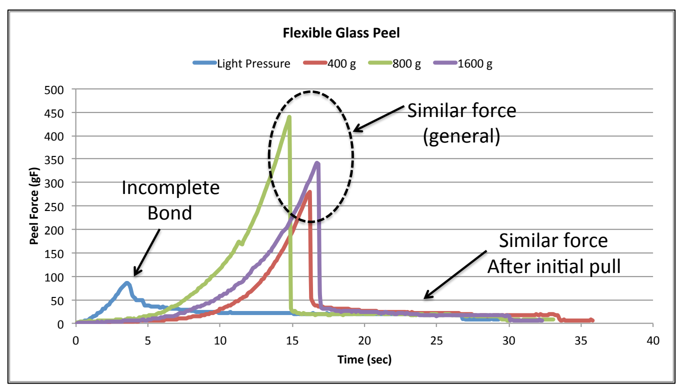

Fig. 19: Thin glass peel results showing adhesive spike.

Small devices are bonded to thermal resistant adhesive, DaeCoat™ 355. Adhesion force is tuned by mixing different resin molecular weights (MW) and activator levels shown to have a direct effect on peel force. Adhesion appears to follow MW with the highest actually tearing apart as activator is driven down, leaving unwanted residue (Fig. 20). Products have been created that allow rapid bonding of small components with topographies exceeding 100um with rapid removal and no residue.

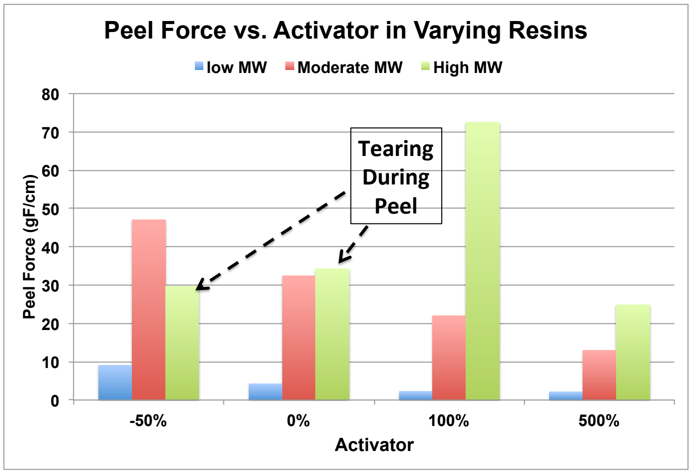

Fig. 20: Adhesion vs. resin MW of DaeCoat™ 355.

Thermal Resistance

Thermal stability of DaeCoat™ 355 in oxygen/air environments with post baking at the desired high temperature will confirm this stability (Fig. 21).

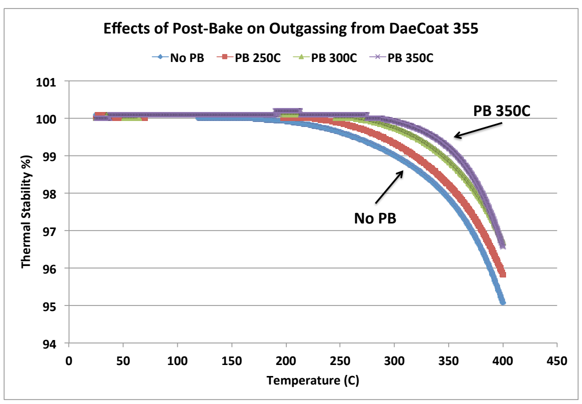

Fig. 21: Thermal stability DaeCoat™ 355 with PB.

For simple grind/polish with limited backside processing or directly proceeding to dicing, a detergent soluble adhesive, DaeCoat™ 615 exhibits resistance >200C (Fig. 22) or <100 ºC for rapid debond in hot DIW.

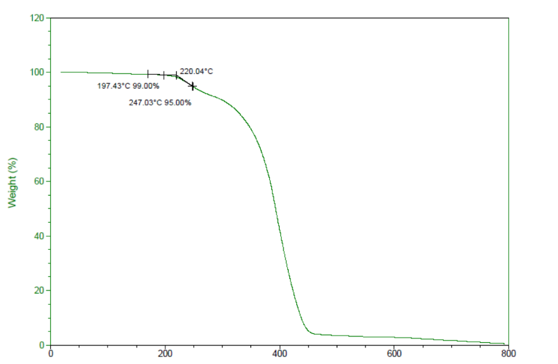

Fig. 22: Thermal stability of DaeCoat™ 615 detergent washable adhesive.

Conclusions

Temporary adhesives are used to affix one substrate to a carrier and allow handling and processing of thin fragile materials. Adhesion chemistry and force is tuned to bond wafers, displays, and small components to allow simple cleaning or no-cleans during removal. Adhesion is tuned using DaeBond™ 3D for wafers, DaeCoat™ 315 for thin PI, and DaeCoat™ 355 for components.

Responding to the rapid growth in display manufacturing, a cost effective solution was investigated to create flexible substrates for OLED applications. Tuning adhesion force with PI and the carrier is possible by using resin mixtures comprising materials of opposing hydrophobic and philic interactions. The process was created to support the use of low temperature polysilicon (LTPS) applied directly to the PI after it has been thermally treated to temperatures in excess of 400C. Adhesive force depends upon several factors, including glass carrier surface, PI chemistry, thickness, and the process conditions. Specific areas of the carrier may be treated with varying ratios of DaeCoat™ 355 to provide adhesion gradients (Fig. 23).

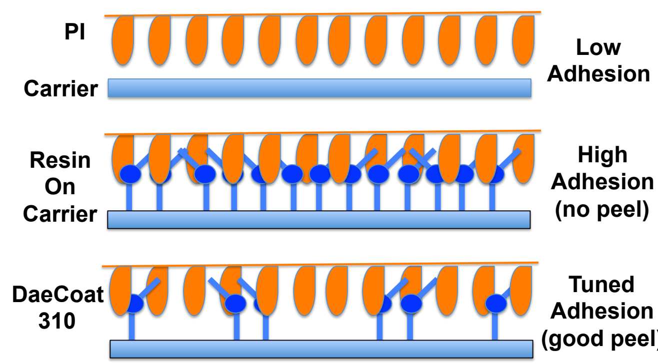

Fig. 23: Adhesion tuning of DaeCoat™ 355 using a resin system offering opposing interaction with PI and the carrier.

Tuning adhesion for wafers, displays, and components is dependent upon several factors, including materials, topography, and the process. Adhesion success requires proper characterization of the interface, the wetting of that surface with adhesive, and ability to create a process around these materials that sustain the target work product. The ability to vary surface energy defines many removal practices in the market, including peel, pull, slide, and passive capillary diffusion between adhesive and the carrier.

Acknowledgments

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