# Wafer Backside Coating (WBC) of Die Attach Adhesives

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## Abstract

*Traditionally, the most common types of die attach materials used in the semiconductor industry have been solder or adhesive. Both have been applied to the substrate, immediately before die attach. Recently, the benefits of applying the adhesive to the back of the silicon wafer have been recognised. If the adhesive is in the form of a dry coating, the wafer can be sawn and individual dies picked and placed together with their adhesive. This eliminates variation in dispense quantity and location, and thus allows much more controlled fillet height and bond-line thickness. In turn, this allows for the use of thinner chips, with lower electrical resistance and lower package height. As the adhesive is now a solid, flow and resin bleed-out beyond the outline of the die are negligible, allowing smaller package outlines. Additionally, processing time (UPH) may improve as the adhesive or solder application step is eliminated from the assembly process.*

*This paper examines the benefits and disadvantages of applying wafer backside coating via a printable paste process as compared to a dry film lamination process.*

*The paper describes the development and use of electrically conductive and non-conductive adhesive pastes that can be applied by screen or stencil printing to the backside of silicon wafers. The paste is then dried, and the wafer can be stored until the time of assembly. The formulation of the adhesive can be tailored to special applications or requirements.*

Key Words: Die Attach, Printing, B-Stage, Wafer Level

**Introduction**

Die attach adhesives have traditionally been formulated to allow dispensing through a needle or dispense head. For very small dots (less than 0.3 mm diameter), pin transfer is also commonly used. However, it is challenging to maintain consistent fillet size and shape, due to variables in the adhesive dispense process. Variability in parameters such as dispense time and needle height can cause significant variations in dispensed volume. Add to this the inevitable variations in adhesive rheology caused by lot-to-lot differences, temperature fluctuations and the changes occurring during the adhesive worklife, and significant variability can be observed in size and shape of dots. Finally, differences in bond force and time during the chip placement process can create further variations in fillet size.

With a die thickness around 300 to 400 microns mounted in a large package, this does not usually cause practical problems. In fact the fillet can be considered the "buffer" which accommodates all these material and process variables. Unfortunately, with the introduction of much thinner die (to reduce internal electrical resistance, or to reduce height in die-stacking applications), there is a need to control the fillet height and width much more tightly. One solution to this is to use a solid adhesive which exhibits minimal flow.

It is possible to fabricate the adhesive as a film, and laminate it to the back of a wafer. Technically this is attractive, but the cost of producing a film, and the capital equipment needed to apply it is prohibitive in some applications.

An alternative approach is to screen or stencil print the adhesive onto the wafer, and dry (or "B-Stage") it so the wafer can be processed as with a film adhesive.

Figure 1 shows a section through a small die. It serves as an example to indicate some of the issues that can arise with the use of paste adhesives. The

die fillets are not uniform, and in the larger fillet, an air bubble is visible. The fillet extends about 0.3mm outside the die. Figure 2 shows a view of a similar size die, attached using “wafer backside coated” (WBC) die attach. The fillet width and height are negligible (about 30 microns) and are uniform all around the die.

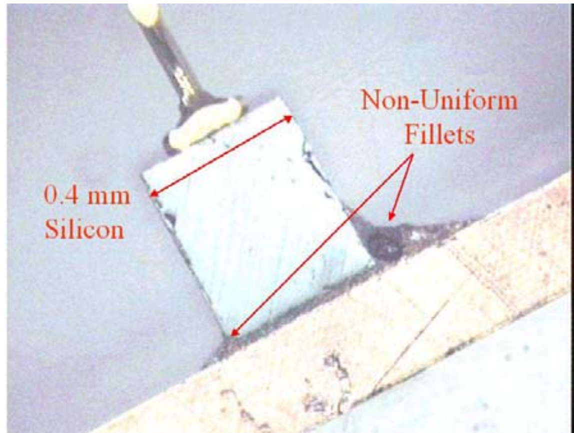


**Figure 1**
**Die Bonded with Paste Adhesive**

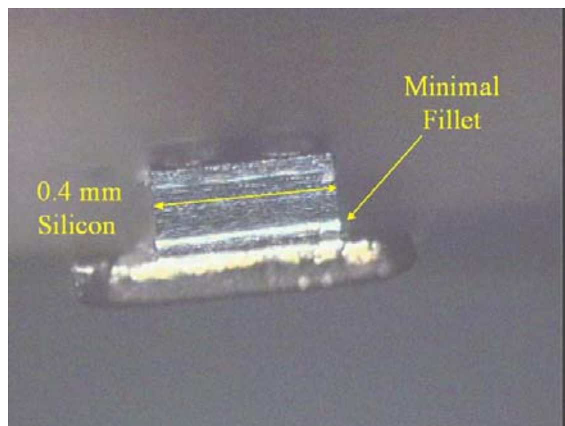


**Figure 2**
**Die Bonded with Solid Adhesive**

One aspect of this wafer level technique is that the adhesive usage is different from a conventional dispensed paste. With a dispensed paste, and relatively small die, most of the adhesive resides in the fillets. With WBC adhesive, there is no adhesive in the fillet, so material usage is much less. However, with larger die, the effect of the fillet is not so significant, and other factors, such as reject die and presence of test structures dominate. So with larger die, the WBC process can consume more adhesive than conventional dispensing. This is indicated schematically in Figure 3. The actual die size at which the “cross-over” point occurs depends on the bondline thickness, fillet height and several factors. Typically, with a 25 micron thickness bondline and 50% fillet height on 500 micron thickness die, the cross-over point will occur at a die size around 5mm x 5mm.

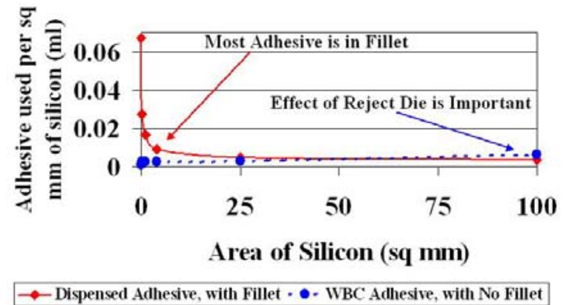


**Figure 3**
**Example indicating adhesive usage with Dispensed paste and WBC Adhesives**

Another impact of the wafer backside approach is that the adhesive dispensing operation can be eliminated from the die bonder. As this is often a relatively slow step, it is likely that implementing WBC would increase the UPH (units per hour) for the assembly line overall. Conversely, the time needed to print adhesive on a wafer is less than 1 minute. With a 150mm wafer comprising about 15,000 die (at 1mm x 1mm), this equates to about 1 million UPH.

## Non-Conductive Adhesive Development and Application

Adhesives have been formulated for application by printing for many years. Hybrid electronics for automotive use, such as engine management and anti-lock brakes utilise conductive epoxy screen printed onto large ceramic tiles. A Non-Conductive epoxy formulation (Adhesive “E”) was developed with suitable characteristics for screen printing large areas. See Figure 4. Adhesive “C” will be described later in the paper.

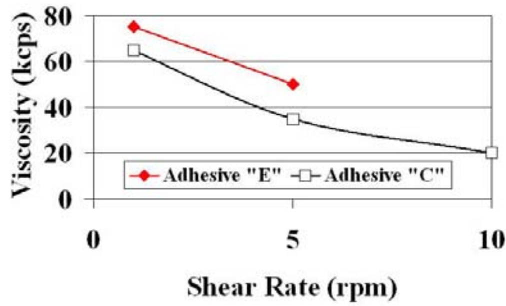


**Figure 4**
**Rheology Curve for WBC Adhesives**

Initial evaluation work determined the selection of screen type and print parameters to achieve a consistent print thickness of approximately 25 microns.

Three stainless steel screen meshes were tried, as indicated in Figure 5.

| Wires per Inch | Mesh Opening | Wire Diameter | Mesh Thickness | Open Area | Wet Deposit Thickness |
|---|---|---|---|---|---|
| | (micron) | (micron) | (micron) | (%) | (micron) |
| 200 Mesh | 90 | 40 | 90±2.5 | 48 | 43 |
| 105 Mesh | 160 | 75 | 162±4.0 | 46 | 75 |
| 180 Mesh | 95 | 45 | 102±2.5 | 46 | 47 |

**Figure 5**
**Screen Meshes Evaluated**

The adhesive transferred well through conventional stainless steel mesh screens onto silicon wafers. Average print thickness is shown in Figure 6. The thickness variation across a 150 mm diameter wafer is around +/- 2 microns.

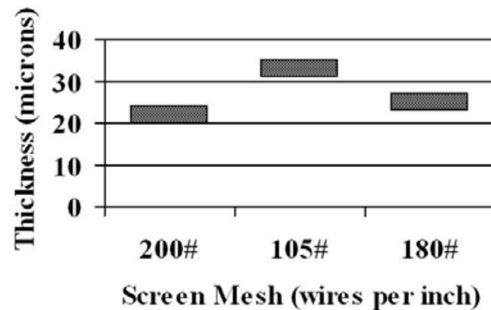


**Figure 6**
**Dry Print Thickness for Non-Conductive Adhesive "E"**

Next, the surface roughness of the print was assessed. Normally, wafer mount tapes or dicing tapes are designed to retain wafers with very smooth backsides, so it is important to have a suitably flat surface on the printed adhesive.
Prints were measured after B-Stage, using Surfcom 130R on-contact profilometer. The Rz value is quoted, measured in microns. This represents the typical "peak to trough" height of the surface. Data was collected from 5 runs per wafer, in different directions. Each evaluation length was 15 mm and the cut-off distance set at 2.5 mm.

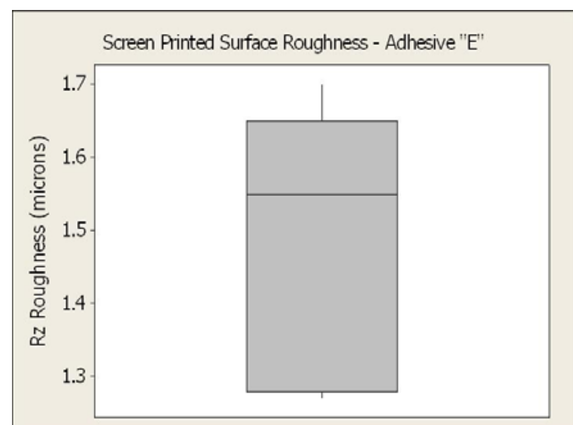


**Figure 7**
**Surface Roughness**

Sawing trials were performed on Adhesive "E", using an industry standard dicing machine and a commonly used type of pressure-sensitive dicing tape, in order to determine optimum parameters. It appears that the Silicon + Adhesive layer can be diced using standard equipment and typical throughput speeds. However, for small die sizes (below 2mm x 2mm) a dual cut process gives the best performance. No "die fly" was seen at die sizes

down to 0.25mm x 0.25mm, indicating adhesion to dicing tape is adequate.

| Wafer | 150 mm x 200 micron Silicon | |
|---|---|---|
| Adhesive | Non-Conductive Adhesive "E" | |
| Dicing Tape | PSA – 75 microns thickness (10 micron adhesive) | |
| Blade Height | 110 micron | 50 micron |
| Blade | NBC-ZH<br>1030-SE<br>27HCDD<br>(Width 20-25 micron) | NBC-ZH<br>126F-SE<br>27HABB<br>(Width 30-35 micron) |
| Blade Speed | 40k/min | |
| Cutting Speed | 50 mm/sec | |
| Die Size | 0.25 mm x 0.25 mm | |
| Fluid | Water (19C) | |

**Figure 8**
**Dicing Parameters used for Non-Conductive Adhesive "E"**

**Conductive Adhesive Development and Application**

The formulation of the paste was modified to incorporate a silver filler. The viscosity was adjusted to be as low as practical, to maintain adequate edge definition of the print around the wafer. This material is designated Adhesive "C".

Print trials indicated that dry thickness was 18 microns with 200# screen, and 21 microns with 180# screen. The roughness of the surface was visibly greater than the non-conductive material – with an Rz around 30 microns, which would negatively impact dicing performance. Trials with stencil printing gave encouraging results. A 50 micron thick laser cut metal stencil proved easy to use, in conjunction with rigid metal squeegees. Improved tooling is under development to provide consistent deposition on the conductive WBC material. Meanwhile, in order to assess the adhesive properties, the printed wafers were passed between laminator rollers (Calendering) under heat and pressure to smooth the adhesive surface. A 6 bar roller pressure, with a feed speed of 0.2 m/sec gives good results at a temperature of 100°C – just below the onset temperature of the adhesive cure reaction. Figure 9 indicates that the calendaring process reduces the roughness to a level similar to the stencil printed surface.

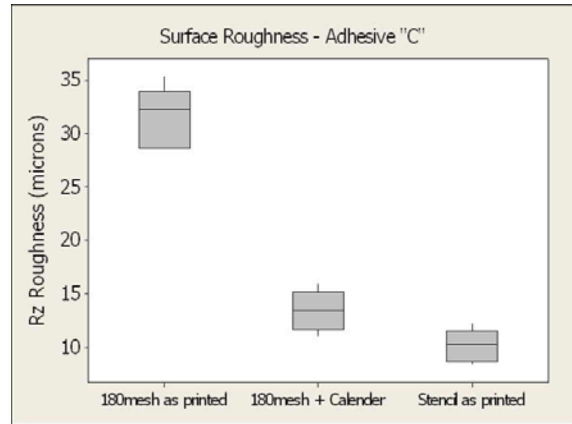


**Figure 9**
**Screen and Stencil Roughness Conductive Adhesive "C"**

Trials confirmed that this material can also be attached to wafer mount tape and diced successfully.

Pick-up and attachment trials were run on high speed equipment. As the adhesive is solid at room temperature, some heating is needed to allow the adhesive to wet onto the substrate. Using a chip size of 0.28mm x 0.28mm, optimum parameters were established as:

Bond Force: 42 grams
Bond Time: 10msec
Substrate Temperature: 100°C to 120°C

Results were positive, with visual appearance of adhesive wet-out very consistent when observed with a high speed camera.

**Reliability**

Additional samples were prepared to determine hot die shear strength. These used gold backed die with size of 2.4mm x 1.7mm. Parts were cured, and then shear tested at 260°C. This temperature was chosen as it is commonly used for attaching the finished semiconductor package to a circuit board with Pb-Free solder.

Results summarised in Figure 10 indicate good compatibility with three metals commonly used in semiconductor packages.

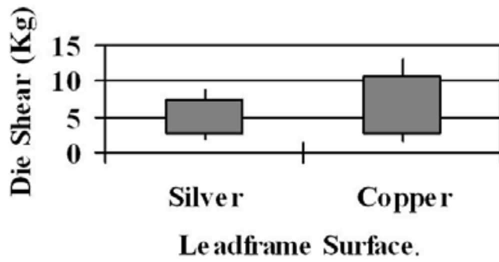


**Figure 10**
**Hot Die Shear (260°C) of Adhesive "E"**
**on Two Metal Surfaces**
**Die are 2.4mm x 1.7mm, with Gold Backside**

Current materials are suitable for assembly of reliable packages up to Moisture Sensitivity Level MSL L1, indicating that the package is not sensitive to moisture and can be stored and shipped without special dry packaging.

The reliability tests were performed on a Micropack XSON6 at Philips Semiconductors Nijmegen. An extensive qualification program was executed to verify the quality of the package, using Adhesive "E". The following tests were performed:

**TMCL** – Temperature cycling
Temperature cycling (air to air, -55°C ↔ 125°C) with preconditioning. This test is particularly suitable to evaluate the moisture resistance and the thermal stress of the package.

**PPOT -** Unbiased Pressure Pot Test
Unbiased Pressure Pot Test - autoclave (121°C, 100% R.H.), with preconditioning. This test is particularly suitable to evaluate the moisture resistance of the package.

**HTSL -** High Temperature Storage
High Temperature Storage of devices (150°C). This test evaluates the reliability of the product after long term storage.

**HAST -** Highly Accelerated Steam Test
Highly Accelerated Steam Test (130°C/85% R.H.), with electrical bias (Vcc,max ) and preconditioning. This test stresses both the electrical endurance of the design/process, as well as the resistance to moisture of the package.

**Qualification Results Overview of 4 lots:**

| | requirement | lot 1 | lot2 | lot3 | lot4 |
|---|---|---|---|---|---|
| **HTSL** | 1000 hrs | 0/46 | 0/78 | 0/78 | 0/76 |
| **precon**[1] + **HAST** | 192 hrs | 0/46 | 0/46 | 0/46 | 0/46 |
| **precon**[1] + **TMCL** | 500 cycles | 0/78 | 0/78 | 0/78 | 0/78 |
| **precon**[1] + **PPOT** | 168 hrs | 0/78 | 0/78 | 0/78 | 0/78 |

1: Preconditioning to MSL level 1 according JEDEC A113.

**Future Work**

Improvements to adhesive rheology and the printing process should allow stencil printing to be introduced, and the calendering step currently needed on conductive adhesive to be eliminated.

Conventional (solvent free) dispensable adhesive pastes are limited to around 85% maximum silver (by weight). Higher filler contents generally increase the viscosity to an unacceptable level. But the use of solvent in the WBC concept allows higher silver contents (over 90%) in the bond line. Therefore relatively higher thermally and electrically conductive adhesives are theoretically possible. We anticipate that the next generation of WBC products will have significantly better conductivity than Adhesive "C" evaluated in this trial.

We anticipate developments to produce snap curing adhesives, capable of curing "in-line" in approximately 20 seconds. This will remove the need for batch cure ovens, and allow packages to be assembled on lines configured for eutectic solder die attach.

**Conclusions**

Wafer backside coating offers advantages over paste to enable construction of chip scale packages. There are benefits in terms of bondline uniformity, and control of height and width of fillets.

First generation products are for small die, as this offers benefits in terms of materials usage as well as technical advantages.

On-going development will make the process more cost-effective, and therefore make the WBC concept increasingly attractive for larger size die.