Dicing Die Attach Films for High Volume Stacked Die Application

Annette Teng Cheung, Ph.D.
CORWIL Technology Corp.
1635 McCarthy Blvd.
Milpitas, CA 95035
Tel: 1-408-321-6404 E-mail: Annette@CORWIL.com

Abstract

The usage of die attach film (DAF) is rapidly growing propelled by stacked die and 3 dimensional packaging. The die attach film is integral in facilitating the growth of wafer level packaging and stacked die packaging. Currently stacked layers of 7 and more dies are possible using DAF. The adhesive on these tapes have the double function of providing adhesion for the wafer during dicing and also providing the adhesive for die attach to substrate. The die attach film (DAF) applied to the backside of wafers prior to saw offers a breakthrough in die attach technology by eliminating the epoxy dispense process step in the assembly line. DAF has many advantages including no die tilt, no voids, consistent bond-line, no bleed-out, no fillet which improves the real estate on the substrate. Dispensing adhesive paste on top of another die can be problematic especially for highly thinned dies. Yet very little information has been published on DAF by the manufacturers and by the users. This paper reveals some of the advantages and shortcomings of integrating DAF into the assembly process. Adhesion of die with DAF to various substrate materials is compared. Dies thinned to thicknesses of 75 and 50 micrometers mounted with DAF are found to show improvement in stackability and die shear strength over paste adhesives. Die shear strength and wirebondability of the very thin stacked die with 0.635mm of overhang is evaluated. Also the effect of the backside roughness by backgrind, chemical mechanical polish and dry polish methods on shear strength is compared. It was found that the most important factor for stacked die strength is sidewall chipping. For high volume stacked die assembly, dicing parameters are critical to minimal side wall chipping and minimal DAF whiskering.

Background

Stacked die packaging has created a necessity to get away from paste type die attach to film type die attach material. With the multitude of die sizes in existence, the inventory and handling of tape preform sizes can get very hairy. Dicing die attach films (DAF) bypasses all these handling issues at the die level. The die attach material is affixed at the wafer level. The front end assembly flow is illustrated in Figure 1. Mounting the DAF at the wafer level at the front-end of the assembly process offers many advantages listed here.

Process reduction by bypassing the paste dispense step and even bypassing the oven cure step which have always been a bottle neck in assembly lines.

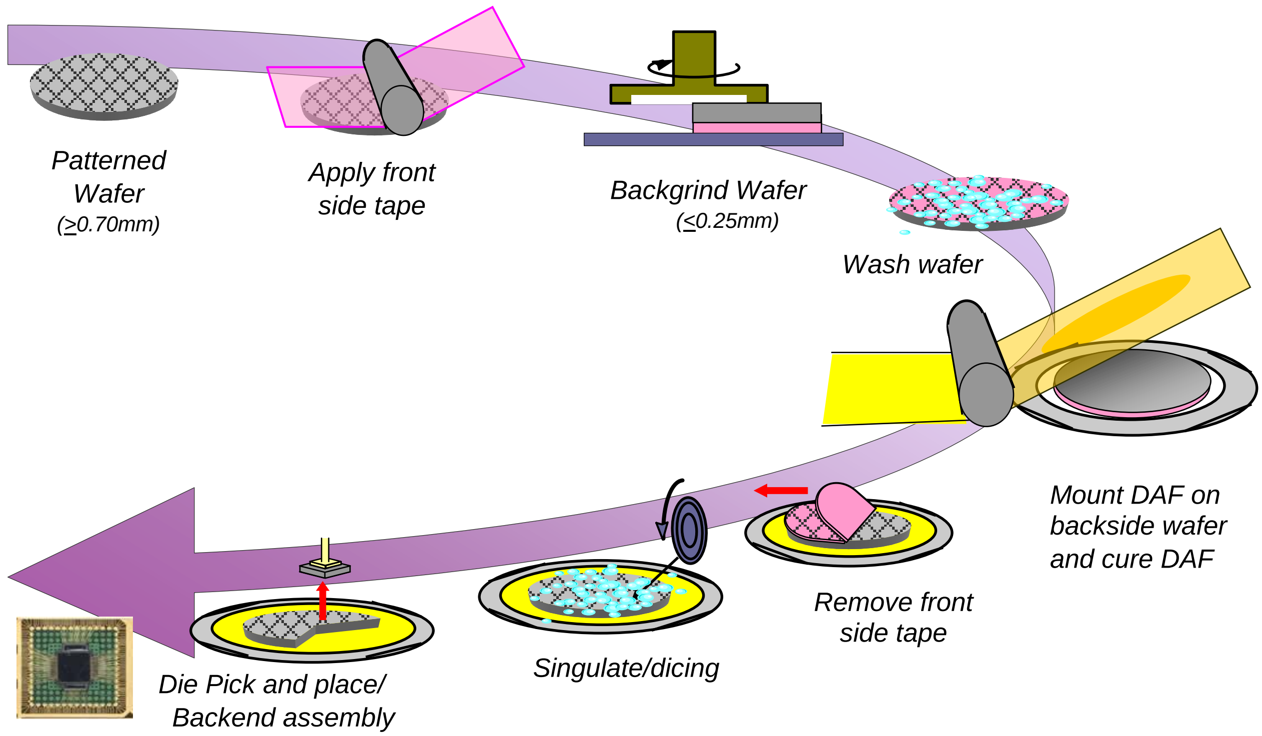
1. Consistent bondlines. The thickness variation of DAF is extremely low. Uniform thicknesses can be selected from 10, 20, 30 40 and 50 micrometers.
2. Skip curing step after die attach. The DAF is tacky enough to hold the die intact through wirebonding. Cure can occur during wirebonding. This is a major advantage since die attach cure is always a bottleneck in assembly lines.
3. No resin bleed. Since DAF is solid rather than a liquid paste, resin bleed is non-existent. This is another important advantage since the die attach processing period can be increased from minute/hour range to day/week range.
4. No voids. The DAF when applied properly creates continuous interfaces with the die as well as the substrate. The die attach paste with pattern dispense cannot achieve voidless interfaces between die, adhesive and substrate.
5. No fillet around the die sidewall. DAF creates a filletless attachment of the die to the substrate maximizing die size to die pad size ratio.

DAF tapes are available in precut rolls for various wafer diameters and require proper storage in freezer. The rolls have limited shelf life similar to single component paste die attach materials. There are several suppliers mostly from Japan of DAF[1, 2, 3]. High volume implementation of DAF in assembly lines does require some capital equipment commitment.

DAF adhesives are available in two forms, namely DAF with dicing tape and DAF without dicing tape. DAF with dicing tape are termed as 2-in-1 tape and do not need to be mounted onto a separate dicing tape. DAF without dicing tape must be additionally mounted to another dicing tape before the wafer is mounted on. For this paper, the 2-in-1 DAF was used.

Introduction

Stacked die are constructed in several configurations. The pyramid style consists of dies with decreasing size stacked on top of each other with no overhang. The staggered style comprises of oblong dies stacked alternatively at 90^o angles with overhang on both ends (or one end). Pagoda style has overhang on all four sides separated by smaller spacers in the center. The most vulnerable area on a stacked die is the overhang joint over the bottom die. This is especially true for very thin dies where the ledge is subjected to downward force during wirebonding. It has been known that very thin wafers must be de-stressed by polishing the wafer backside to mirror finish by mechanical, chemical or plasma methods



[4]. This study looks at die strength with and without DAF of very thin dies with different backside finishes. Samples were designed, fabricated and tested for die strength at the ledge of the overhang.

Sample Preparation

Blank 100mm and 150mm diameter silicon wafers are procured at a standard thickness of 0.725mm and thinned down to 75□ and 50□□µm using DISCO DFG850 backgrinding machine at CORWIL. The roughness after 2000 grit backgrind is 0.2□ µm. Wafers are subsequently split to be chemical mechanically polished (CMP) and dry polished (DP) for stress relief. This additional polishing smoothens the backgrind surface by removing the damaged topmost 2□µm layer. The final roughness is 0.11 µm for the CMP finish and 0.003µm for the DP(or mirror) finish. Additionally, patterned and non-patterned silicon wafers were thinned to 50□µm for die strength comparison and for wirebond evaluation. The dry polish process provides a mirror finish to minimize stress build-up and wafer breakage during handling. Dry polish is done on a Disco DFP8140 machine with a non-diamond wheel at CORWIL. The residual polishing dust is blown off by high pressure cyclone action[5]. The final thickness is verified by a thickness drop gage. All wafers are mounted on DAF tapes and cured prior to sawing. One particular DAF tape was exclusively used for this evaluation. The total tape thickness of this particular DAF is 110 µm and it requires ultra violet light exposure for curing prior to dicing. The ultraviolet light cures the adhesive and increases adhesion between the wafer backside to the DAF. These wafers were subjected to proper UV curing to avoid issues like dies flying off from the wafer during dicing, adhesive whiskering and adhesive merging after dicing. The taped wafers were then diced using a Disco DAD340 saw at CORWIL with various diamond blades from 20 to 30□µm thick. The blade height is set to cut through the adhesive layer and into the base film or 60□µm below the wafer backside. Both single and double pass dicing was performed to evaluate process problems with die strength, adhesion and whiskering, The rectangular die size after singulation was 3.5mm X 12.7mm. These dies were mounted on glass slides with half of the length hanging over the edge of the glass slide, and the other half bonded to the glass slide. The dies were cured in an oven at 150^{o}C for 1 hour within the manufacturer's recommendation range. A control group of test dies with no DAF was glued on the glass slide with a non-conductive die attach paste from Ablestik. Both sets of dies have overhang that is 6.35mm long. The glass slide was firmly clamped by vacuum while the overhang was subjected to shear testing. A flip chip bonder with a 500 gm load cell (SEC860) was slightly modified for this shear test. The width of the tool tip is slightly wider than the die overhang width or 3.6mm. The tool pushes the tip of the overhang at 5.0 mm from the edge until break point at 1.15mm/minute speed. The force at fracture is recorded for sample sizes of 6 and shown in Table 1. The details of the die shear test set-up is shown in Figure 2.

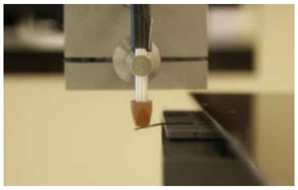


Figure 2. 50µm thick die with overhang under load

Results

Table 1 shows a 20% die shear improvement for die bonded with DAF over dies bonded paste. This is true for the 2000 grit 75µm dies and the mirror finish 50µm dies. For the mirror finished dies, DAF surprising does not provide die strength improvement. Another distinct trend is that the rougher 2000grit die has higher strength than the highly polished die in both categories. It should be noted that these dies were diced by the single pass method resulting in random sidewall chipping causing random crack initiations sites. This may be the cause for the wide range in fracture strengths. Figure 5 shows a test sample with presence of sidewall cracking from single pass dicing.

Table 1. Relative die strengths of 75µm thick die (single pass dicing).

Wafer Backside finish With / without DAF	Breakage force (gm)	Actual die thick. (µm)
2000 grit with DAF	78.4+9.4	.083-.086
CMP with DAF	68.8+14.3	.084-.087
Mirror finish with DAF	58.8+21.9	.082-.083
2000 grit without DAF	65.2+10.0	.083-.086
CMP without DAF	59.2+2.8	.084-.088
Mirror finish without DAF	59.7+7.1	.081-.083
Mirror finish with DAF	33.4+ 12.8	.050-.054
Mirror finish without DAF	27.8+ 6.3	.050-.054

Wirebonding on Very Thin Stacked Dies

A patterned wafer with bond pad matrix was thinned to 50 µm and mounted on DAF and diced. This die was stacked over a thicker die to create an overhang 0.50 mm long over the edge of the bottom die. The top die with the overhang was subjected to 25 µm diameter gold stud ball bonding. A top view of the stud ball bonds is shown in Figure 4. Wirebond results show that 25 µm gold wire can be wirebonded on the ledge of a 50µm die with DAF for a distance of up to 0.26mm from the ledge. Non-sticking is observed beyond this distance as the bond pad becomes too floppy to allow gold ball to aluminum pad welding. The die fractured at the joint under the force of the capillary beyond 0.3mm. The ball bondable region beyond the ledge of the overhang is greater than 15 times the thickness of the 50µm die. This overhang length to thickness ratio can be even higher for dies with no sidewall chipping through well optimized dicing parameters to relieve stress [6, 7] and to prevent blade loading caused by the DAF [8]. The chipping size on some of the test dies (an example shown in Figure 5) was greater than 50% of the die thickness (50µm) and would be rejectable per Mil. Std. 883 [9]. The Mil. Std. indicates that any cracks extending above the midway lateral line of the die is rejectable.

Figure 4. The area between the solid and the dashed line on the overhang indicates ball bondable region.

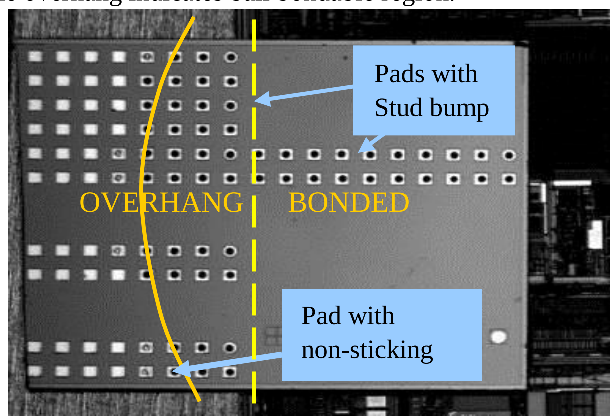
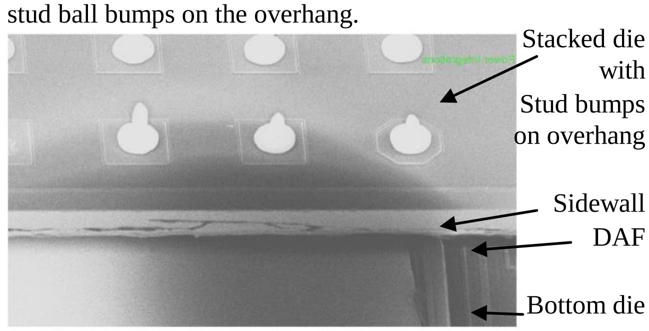


Figure 5. Scanning electron micrograph of stacked die with stud ball bumps on the overhang.



Adhesion Testing

For die adhesion strength of the DAF to various substrate materials, 2.6mm x 4.24mm x 180 µm thick test dies with DAF were used. Curing of the DAF prior to dicing was optimized to avoid DAF tearing. These dies with DAF were picked off the tape and placed onto five different types of substrates commonly used in stacked die applications including polyimide passivation, silicon nitride passivation, silicon wafer, solder mask and plated gold. Care was taken avoid samples with incomplete DAF coverage such as shown in Figure 6. .

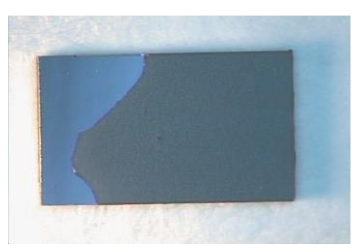


Figure 6. Torn DAF on die backside

The dice were pressed onto the various substrates and cured in an oven at 150°C for 1 hour. An Anza Model 560 die shear tool was used to measure adhesion and the results shown in Table 2. It can be observed that the DAF selected for this study has high adhesion to substrate materials used in stacked die applications and is particularly strong for topside silicon nitride and polyimide passivation surfaces as well as bare silicon surface.

Table 2. Adhesion of DAF to various substrate materials.

Substrate material	**Die shear (Kg)**	**Main Failure interface**	**Pass**
Bare silicon	18.12±2.46	DAF to die backside	Pass
Polyimide passivation	16.16±4.2	Even Split between DAF to die & DAF to polyimide	Pass
Silicon nitride passivation	18.19±2.3	DAF to die backside (Fig. 7)	Pass
Solder mask	8.01±3.59	Solder mask	Pass
Plated gold	12.44±2.79	DAF to gold substrate	Pass

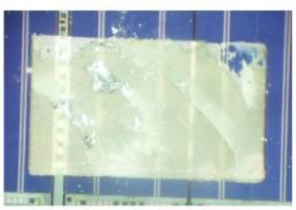


Figure 7. Exposed DAF interface after die is sheared off.

Various blade types and varying dicing parameters were performed on different wafers. The undesirable presence of whiskering (Figure 8) and sidewall chipping was empirically noted and the results shown in Table 3. From these results, it can be observed that wider dicing blades create more whiskering due to higher volume of DAF material removed. The depth of cut also has a role in whiskering incidence. Very thin wafers have higher a tendency for lateral sidewall chipping. However it is possible to achieve chipless dicing (Figure 9) usually at the expense of productivity and throughput. There are many dicing parameters[10] affecting side wall chipping which will not be included in the scope of this study.

Figure 8. DAF whisker over die.

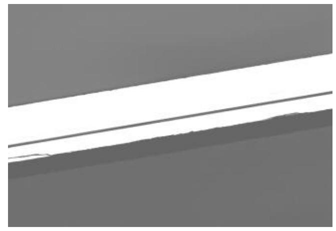


Fig. 9. Sidewall of die & DAF from optimized dicing parameters with no chipping.

Table 3. Observation of sidewall chipping and whiskering from various dicing parameters.

Thickness of Blade / of wafer (μm)	No. of dicing passes	Cut depth into DAF (μm)	% of dies with whiskers (Fig. 8)	% of dies with no sidewall chipping (Figure 9)
15 / 50	2	60	0	10-40
15 / 50	1	60	0	0-20
25 / 50	2	60	0	50-100
25 / 50	1	60	0	0-20
45 / 180	2	70	0-3	70-90
65 / 180	2	70	0-5	70-90
100/180	2	70	0-8	70-90

Backgrind vs. Polished Wafer

50 μm thick wafers with various backside finishes without DAF were mounted together on a Disco DAD340 saw and diced with same blade and machine parameters simultaneously. The DAD340 is a single spindle saw so the same blade was used to cut into the street first at 50% of the wafer thickness followed by 100% of the wafer thickness. A step on the sidewall cannot be seen by same blade dual pass but chipping is nontheless minimized when compared to single cut. Table 4 shows the results of the backside roughness effect on sidewall chipping. The percent of dies in a wafer with sidewall chipping is categorized by the size of the chipping with respect to the die thickness (T).

Table 4. Comparison of backside condition on sidewall chipping.

Backside condition	% with no chipping	% 0.1T chip	% 0.2T chip	% ≥ 0.3T
Backgrind 2000 grit	80	20	0	0
CMP finish	80	20	0	0
Mirror Polish finish	31	50	13	6

It is noted here that mirror finished wafers have an unexpected higher incidence of sidewall chipping when compared to less polished finishes. Earlier in this paper, lower die shear strength on stacked dies was observed on the polished wafers. This is attributed to the higher incidence of sidewall chipping on highly polished wafers causing cracks to initiate during shear testing (Table 4). The reason for this surprising observation is that a mirror finish backside has lower adhesion to the adhesive during dicing compared to the 2000 grit finish where the adhesion is higher. High adhesion or high grip of the wafer to the chuck is critical to minimize vibration during conventional blade dicing. Another possibility is the higher energy it takes to break a smooth surface versus a rough surface causing more damage along the blade path. New dicing methods are currently available as alternatives to conventional dicing which will reduce lateral chipping of very thin and highly polished wafer.

Conclusions

Die attach films applied at the wafer level prior to dicing is the ideal adhesive material for high volume stacked die application.

Stacked dies bonded with DAF has 20% higher die strength than stacked dies bonded by paste material. 50 μm dies attached with DAF can have an overhang of 16X length to thickness ratio that is wire bondable.

Side wall cracking from the wafer singulation process is a major factor affecting the strength of stacked dies. A proper dicing process must be established as stacked dies becomes thinner and as more dies are piled on top of each other.

Wafer backside finishes of various roughness affects sidewall chipping during dicing. It was found that sidewall cracks are larger and more frequent in highly polished wafer versus 2000grit wafer. Highly polished finish is actually detrimental to stacked die packaging as it increases sidewall chipping when processed by the conventional blade dicing process.

Acknowledgments

The author wishes to thank Finn Wilhelmsen Ph.D., Robert Corrao, Raymond Wong, Dan Miranda, Nghia Truong, Hiu Lam, LinhChi Pham and Dennis Ho of CORWIL for facility support and sample preparation support; and to Bill Chen for his encouragement.

References

1. www.Nitto.com
2. www.Mitsuichemicals.com
3. www.Lintec-USA.com
4. T. Harder, W. Reinert, "Low-profile and flexible electronic assemblies using ultra-thin Silicon" Technology & Production for Flexible Electronic System, Nov. 26, 2002
5. www.Discousa.com
6. Annette Teng Cheung, "Dicing Advanced Materials for Microelectronics", in *Proc. IEEE/CPMT 10th Intl. Symposium on Adv. Packaging Materials Processes, Properties and Interfaces*. Mar 16-18, 2005
7. M. Gerber and N. Arguello, "A Comparison between Single Versus Dual Spindle Processes for Copper Metallized Wafers," *Proceedings of Electronic Components and Technology Conference*, San Diego, CA, May 2002, pp. 1167-1171.
8. H.H. Jiun, I. Ahmad, A. Jalar and Omar, "Effect of Laminated Wafer Toward Dicing Process and Alternative Double Pass Sawing Method to Reduce Chipping," *IEEE Transactions on Electronics Packaging Manufacturing.* vol. 29. no. 1, pp. 17-24, Jan. 2006
9. Military Standard 883, Method 2010, "Internal Visual"
10. Annette Teng Cheung "Dicing Advanced Materials for Microelectronics" MEPTEC lunch presentation, Sunnyvale, Apr. 27, 2005