Aluminium Oxide Thickness impact on Wire Bond Shear

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Abstract

The extensive usage of electronics devices in automotive applications, where high reliability and long life is required making wire bond shear test a mandatory. Tremendous progress has been made to improve the quality and reliability of the semiconductor chip. However, the quality of interconnect seems to have been overlooked and lagged behind than other processes. Internal outgoing inspection on bond pads triggered this study of wire bonding to ensure our reliability before shipping to customer. This experiment mainly focuses on stained pads and metal grain on polyimide module. The introduction of Oxygen Plasma step before polyimide coating was carried out to mitigate the occurrence of stained pad phenomenon. In this paper, we discuss mainly on the impact of Oxygen plasma to aluminium oxide thickness and wire bonding reliability. TEM data indicates that the oxide thickness is acceptable and wire bond shear results will also be shown.

1. Introduction

Wire Bond Shear (WBS) test is a method to demonstrate the integrity of metal bond pad, the backend scheme as well as the bond pad or via design. Wire bonding is still considered the most widely used package interconnect method where ninety percent of the connections are made [1]. In this paper, Wire Bond Shear (WBS) test setup for 0.18 & 0.35 technology bond pads with different bond pad issues were investigated. The experiment focuses mainly on investigation of stained pads and metal grain on polyimide module. The polyimide module generates several types of defects including stained pads during visual inspection step, which will not be accepted by customer though sometimes it can be deemed as cosmetic defect (see Figure 1 and Figure 2). Polyimide is usually used as buffer coating layer onto the chip and as passivation layer for bumping process. Polymide is a coating layer of polymide on the wafer and pattern it with resist mask , and last curing it in Curing at 375 C in nitrogen atmosphere. Typical process flow for semiconductor polymide process as illustrated in Figure 3.

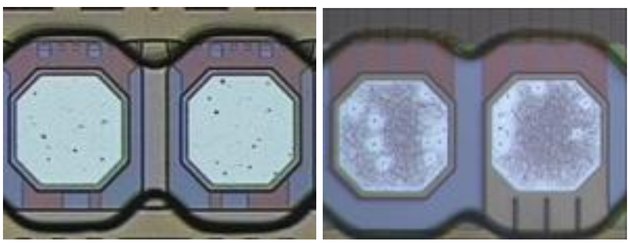

Figure 1: The optical images for normal bonds pad (Top) versus stained bond pads (bottom).

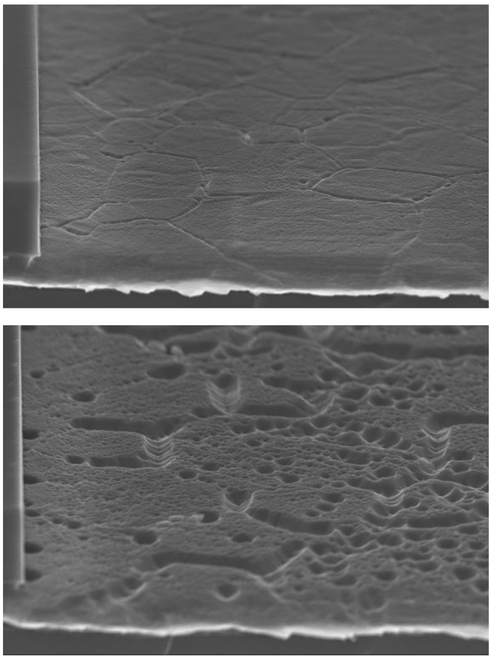

Figure 2: The SEM images for normal bonds pad (left) versus stained bond pads (right).

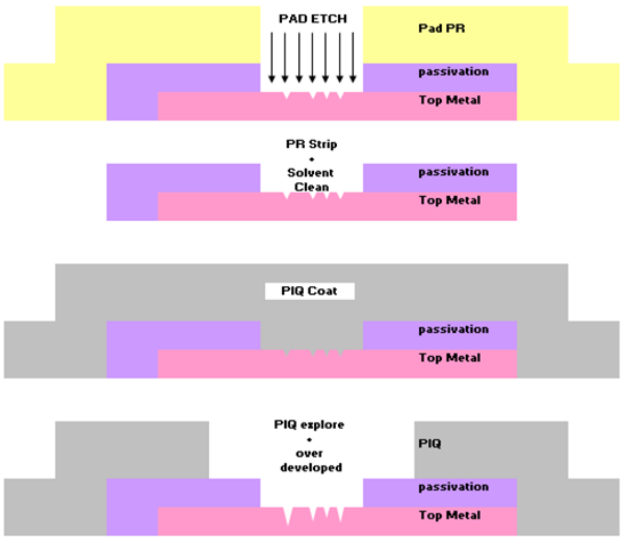

Figure 3: Process flow of polymide module

Stained bond pads as shown in the Fig.1 and Fig.2 is resulted from TMAH (Tetra-Methyl-Ammonium Hydroxide) developer attacked on aluminium bond pad surface during polyimide development process. It results in rough bond pad surface and more prominent at Al grain boundary. This is believed to be due to enhanced reaction rate when copper is present (near grain boundary) in the AlCu metal layer through galvanic process. The introduction of Oxygen Plasma step before polyimide coating was carried out as it is believed that more uniform Al2O3 layer protective layer will be formed on bond pads.

Experiences from outsource laboratory was reported and shear strength performances were analysed. Affected pads shows lower shear strength value compared to non-affected pads.

Factors affecting shear quality on bond pads design, metal property, bond pad surface topology were studied. Setting parameter such as wire diameter, bond force, temperature, ultrasonic power, the bonding time capillary were taken into account in Wire Bond Shear setup. The methodology setup was described in an article [2].

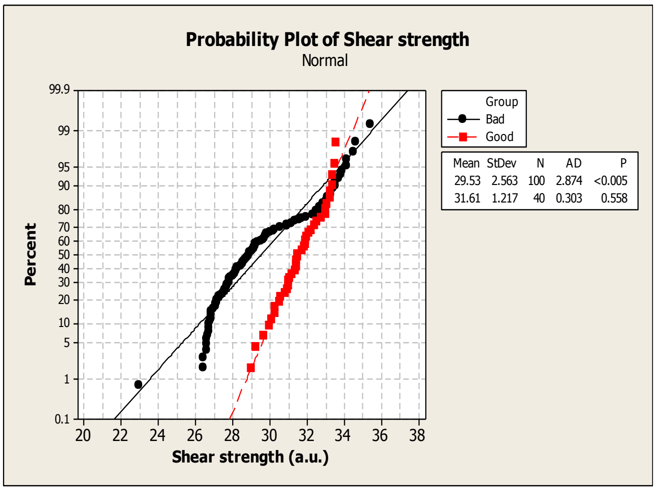

Figure4 : Shear strength comparison between affected (stained) and non-affected (normal) pads.

2. Experiment

In order to prevent the attack of the aluminium bond pad by TMAH developer during the patterning of the polyimide (PIQ) window, downstream oxygen "ashing" plasma process is introduced prior to polyimide coating to ensure complete passivation of the aluminium surface by Al2O3 depsite native Al2O3 is laready present on bond Al surface. It is known that excessive aluminium oxide thickness can inhibit and result in bonding reliability problems.

Full flow engineering wafers were prepared to study the impact of the oxide thickness on aluminium pads against the wire bonding impact. The test wafers were prepared as listed in table 1.

Table1. DOE split for oxygen plasma condition.

Condition	Time
Standard	No plasma treatment
Oxygen plasma 2x	120 seconds
Oxygen plasma 4x	240 seconds

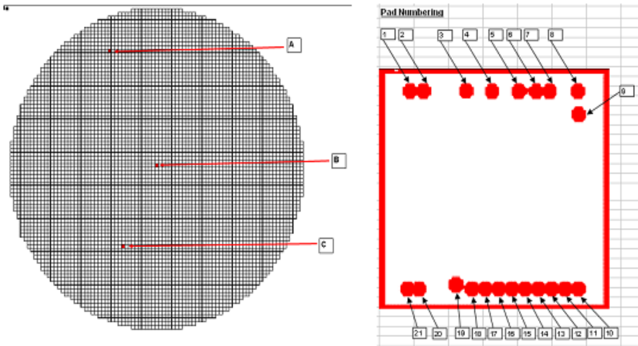

Figure3 show map location and wafer map sites identified for TEM analysis.

Wafers sent to external contractor for TEM analysis to determine oxide thickness. Pad 20 was used for TEM analysis and the aluminium oxide thickness is compared among wafer top, center and bottom of the wafer. The TEM data indicates that the oxide thickness for the control wafer is as expected (5nm). The TEM data indicates that the native oxide thickness for aluminium oxide thickness is comparable for all three processing conditions. The TEM data also indicates that the oxide thickness is significantly less than our accepted limit of 20nm, as illustrated in Figure 4.

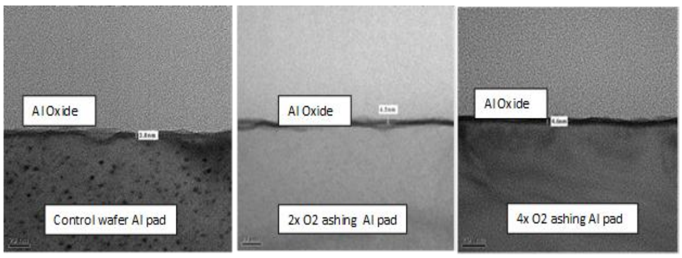

Figure 4 :TEM analysis on Al oxide thickness on Al pads on control wafer, 2x O2ashing , 4x O2 ashing.

Meanwhile another three processed wafers wafers were sent for wire bond shear testing. Wafers received argon plasma cleaning prior to bonding to remove any containmination. All bond pads were wire bonded with 1 mil diameter gold wire detailed in (Seng, 2011) and underwent ball shear testing (EIA, 1998) using a Dage 4000 shear test equipment per settings in Table2. All testing carried out using standard JEDEC procedure.

Test method: Wire Bond Shear Standard: AEC – Q100-001-REV-C (Method – 001Wire bond shear test) EIA/JESD22-B116.

Table2. Ball Shear tester input parameters

Parameter	Units	Setting
Test speed	um/s	250
Test load	gf	50
Land speed	um/s	50
Shear height	um	3.4
Overtravel	um	150

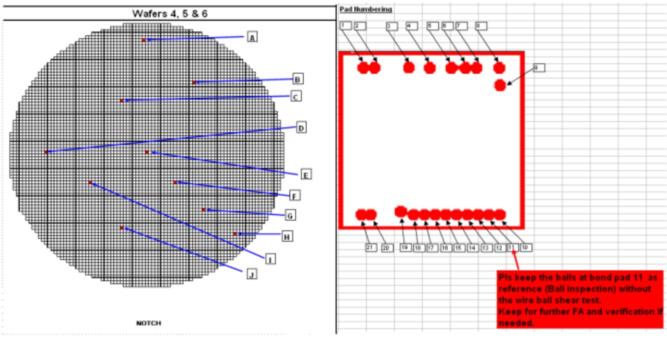

Figure 5 : Map location and site identified for Wire bond shear test.

3. Results and Discussions

The TEM shows native oxide thickness for aluminium oxide thickness is comparable for all three processing conditions as displayed in Table 3.

Table3. Oxide Thickness from TEM analysis (a.u.)

Process Condition	No additional processing (control)		2 X ashing plasma (proposal)		4 X ashing plasma (extension)	
Wafer location	Top	Centre	Top	Centre	Top	Centre
Die No.	1-A	1-B	2-A	2-B	3-A	3-B
1	5.6	4.4	3.5	4.5	3.5	4.6
2	5.6	3.8	3.5	3.8	4.1	5.4
3	5.1	3.8	3.8	4.1	4.1	5.3
Average	5.4	4	3.6	4.1	3.9	5.1

P value from ANOVA > 0.05 implies that there is no significant difference in mean oxide thickness. Visual inpscetion done on these pad shows pad is clear of staining defects.

One-way ANOVA: Control, Proposal, Extension

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Source  DF     SS     MS     F      P
Factor   2  2.341  1.171  2.51  0.115
Error   15  7.002  0.467
Total   17  9.343

S = 0.6832   R-Sq = 25.06%   R-Sq(adj) = 15.07%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level      N    Mean   StDev   -----+---------+---------+---------+----
Control    6  4.7167  0.8353              (---------*---------)|
Proposal   6  3.8667  0.3830   (---------*---------)
Extension  6  4.5000  0.7457            (---------*---------)
                               -----+---------+---------+---------+----
                                  3.60      4.20      4.80      5.40

Pooled StDev = 0.6832
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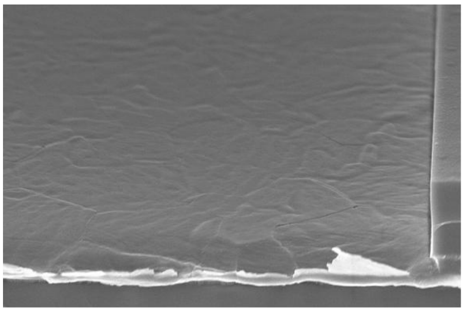

Figure 6 :No visual staining defect found on the plasma passivated bond pad.

No significant differences in mean shear strength value were observed from DOE splits, as showed in Figure 7. All of the 200 individual bond shear tests meet the Jedec specification of minimum individual shear strength 15.6 grams. All of the 20 dies meet the Jedec specification of average shear strength of 24.4 grams. Based on the wire bond shear data, no impact seen from implementing additional O2 ashing plasma treatment on the bond strength.

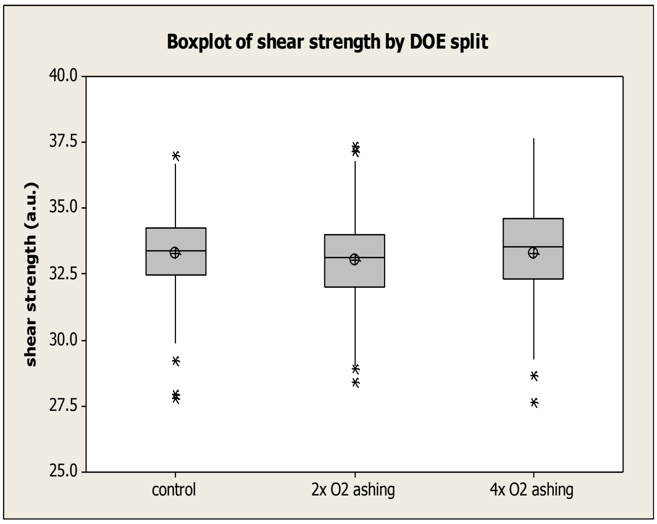

Figure 7 :Shear strength comparison between control wafer , 2x O2 ashing and 4x O2 ashing as per JEDEC (EIA, 1998), the Minimum Individual Shear Reading is 15.6 gf whereas the Minimum Shear Average is 24.5 gf

4. Conclusions

In conclusion, the use of downstream oxygen ashing plasma has no impact on the thickness of the inherent native oxide on aluminium bond pads. The wire bond shear result shows comparable shear strength across plasma ashing split. Ever since introduction of O2 plasma ashing pre-treatment, stained pad defect counts have been reduced significantly in production line. AVI Statistical shows stained pad defective die is reduced significantly after Oxygen plasma in placed.

References

1. Chen, William, W. R. Bottoms, Klaus Pressel, and Juergen Wolf. "The next Step in Assembly and Packaging: system level integration in the package (SiP)." ITRS White Paper V 9 (2008)
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