An Improvement of Plasma Cleaning Time towards Leadframe Oxidation Performance

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Abstract. Package delamination causing the tendency to absorb humidity which lead to device failure towards Integrated Circuit (IC) packing[1]. Most of the screened unit being analyzed and results showed failure due to popcorn effect. Popcorn effect caused by moisture penetration effecting the packaging to expend causing delamination and cracking during high temperature application. In this paper, delamination had been filtered from Scanning Acoustic Microscope (SAM) towards the failure units and once package encapsulation had been done the root cause being identified as leadframe oxidation problem. The leadframe oxidation can be easily observed during wire bonding and oven curing process since it involved with high temperature process which the indication showed leadframe discolouration appearance. The aim of this work is to evaluate plasma parameter to achieve delamination free product by assessing the plasma cleaning time. Additional plasma cleaning before molding process had been identified as a solution towards free leadframe oxidation process which leads to zero delamination issue for package that using Copper leadframe. Higher plasma cleaning time produced significantly lower leadframe oxidation issue however the Unit Per Hour (UPH) will be effected.

Keywords: Contact Angle, Delamination, Oxidation, Plasma.

1. INTRODUCTION

Package delamination in Intergrated Circuit (IC) becomes critical due to reduction of adhesion quality performance between the molding compund and leadframe. This results to device functioning failure caused by moisture absorption through the gap that being generated. Delamination being indicated as one of failure criteria in assembly which require Scanning Acoustic Microscope (SAM) to identify the delamination unit. Delamination on IC can be detected through SAM which been described per red colour in Figure 1. From delamination, moisture absorbtion will induce package cracking which known as popcorn effect and cause device failure. The device which being identified had delamination being taken out for analysis.
The units then been sent for encapsulation and then encountered some discoloration at the edge of the frame pad and have the same sign of frame oxidation per Figure 2. The area which detected having red colour during SAM on the leadframe die pad being observed to have common delamination in a package which related to adhesion of epoxy mold compound towards the copper leadframes surface[2]. Delamination has a detrimental effect towards the packaging and the copper leadframes which allowed moisture to penetrate and causing reliability issue towards the electronic applications [3] and require action plan to solve the problem.

Further investigation using Transmission Electron Microscopy (TEM) on the reddish area observed the existing of copper oxide which indicates the leadframe oxidation issue which can be refer to Figure 3. TEM is using electron optical performance which been characterized for direct spatial imaging and spectroscopy with the usage of electrons energies as low as 20keV on its application and producing high resolution imaging for better analysis activities[4].

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**Figure 1.** SAM encountered delamination on package through red colour

**Figure 2.** Encapsulation on delamination unit encountered leadframe oxidation

**Figure 3.** TEM result showed copper oxide on the reddish area
The thickness of oxide layer plays a significant effect towards the epoxy molding compound strength on copper leadframe. As mentioned by Muhammad Shirjeel Khan delamination normally associated with the oxygen build up interface[5]. When copper oxide film covering the leadframe surface, the adhesion between Copper leadframe and epoxy molding compound (EMC) reported to have some degradation of adhesion performance. Study from Eiji TAKANO showed that the higher the oxide layer on copper leadframe will reduce the EMC adhesion strength and thickness less than 40nm had lower risk of having cracking issue[6].

The delamination had been identified as leadframe oxidation from the manufacturing process due to high temperature involved during Post Mold Curing (PMC) and wirebonding process. The PMC temperature setting was 175°C while wire bonding temperature was 200°C and due to high count of wire resulting to longer heating process causing the leadframe to oxidize and having discoloration issue. High temperature had been investigated to be the major cause of IC failure due to delamination issue which is common finding by Yumin Liu[7]. It has been observed between PMC and wirebonding process, the leadframe oxidation is more severe at wirebonding due to higher temperature involved. The sample of leadframe oxidation after wire bonding process can be referred to Figure 4 for reference. The leadframe tends to have a purplish colour as indicator that leadframe oxidation had taken place.

![Figure 4. Leadframe discoloration observed after wire bonding process](image)

The process mapping then had been done through the overall manufacturing process flow which can be referred to Figure 5.
The existing process flow observed that oven curing and wire bonding involved with high temperature which caused the copper leadframe getting oxidized. After wire bonding process observed higher discoloration issue on the leadframes though the plasma cleaning being assessed between wire bonding and molding process. The objective of this evaluation is to eliminate the discoloration issue after wire bonding process by assessing the plasma cleaning parameter. Studies had shown that plasma cleaning will improves the adhesion between the molding compound and the leadframe surface which improving the quality of the package itself[8].

2. METHODOLOGY
This chapter will explain briefly about the method that being used to evaluate the plasma cleaning process towards the oxidize leadframe. The experimental setup will be shared to understand the materials and parameters that being evaluated.

2.1 Copper Leadframe
The copper leadframe consists of 140 units per leadframe being fixed during the evaluation. The leadframes were allocated in a magazine which being used during plasma cleaning process. Copper being widely used by the leadframe manufacturer because of the excellent performance of the electrical properties, higher thermal conductivity and the main factor is lower manufacturing cost[9]. However the common problem of copper leadframes is easy getting oxidized when temperature is high. Leadframe oxidation had been identified one of the cause for delamination issue which had been a standard requirement criteria for industrial to have delamination free product for their package[10]. In this assessment, the copper leadframe had been identified to have leadframe discoloration issue when involve with high temperature process such as wire bonding and oven curing process which require process improvement to solve it.

2.2 Plasma Machine
In plasma cleaning, the contaminants will be removed by the ion bombardment[8]. The plasma batch processing being fixed for this evaluation which will be used after wire bonding process. The reason plasma cleaning being allocated after wire bonding process is because to remove the leadframe discoulouration issue which produced by high temperature (200°C) during wire bonding process itself. In this assessment, batch plasma cleaning will be used throughout the whole evaluation activities. Batch processing is a method using chamber loading which require to use magazine for plasma cleaning process as per Figure 6. There were 6 magazines allocation in the batch plasma equipment that being used for the evaluation. All 6 magazines will be slot in during plasma cleaning process however only one magazine will be slot with the Copper leadframes while the other 5 magazines were leave empty. This is because there were limited of leadframes available for evaluation purpose.
Figure 6. Batch processing plasma

The plasma equipment using Radio Frequency (RF) type which used the Argon ion. It combine with electron in the plasma chamber and bombard the Copper leadframes surface by removing the particles on it using physical energy at frequency of 13.56 Hz. The plasma bottom plate acts as cathode and pulls the Argon ion to react with it and generates high power etching capability. The important parameter for plasma process are Power (Watts), Gas type, Gas flow (Sccm), Pressure (mTorr) and Time (seconds). In this assessment all parameters had been assessed and will be fixed except the Plasma time which be evaluated according to 600s, 720s and 1200s.

2.3 Magazine
There are 6 magazines being allocated in the plasma chamber. Each magazine has 6mm gap design which only can allocate 20 leadframes per magazine. For the plasma chamber it consist of 6 allocation slots which per slot can assign only one magazine per slot. In the plasma chamber, there are 3 slots allocation on top area and 3 slots allocation at bottom area. In this assessment, only top center compartment of plasma chamber will be full of leadframes which allocated in one magazine. The setting is same for all the three setting of plasma cleaning time The detail of magazine layout can be referred to Figure 7 for reference.
2.4 Plasma Gas
Argon, Helium, Oxygen, Hydrogen and Nitrogen are the common gases that being used in Plasma process. It can be a single gas or a mixture between gases for the plasma cleaning process which depending on its application. In this activities 99.999% Argon gas had been selected towards the whole of evaluation process. For visual verification, Argon gas will emit purplish colour during the cleaning process. This is one of the identification for Argon gas for user to know the correct gas that being selected and this can be seen through the plasma window pane.

2.5 Contact Angle Measurement
To quantify the wettability on the leadframe surface, numerous method had been developed and contact angle is one of the best approach to analyze it [11]. In this assessment, contact angle being measured using Dataphysics equipment in order to understand the performance of leadframe before and after plasma cleaning process. The contact angle measurements were performed on the 30 die pads for in order to get 30 readings. The water volume setting being fixed at 1.5 µl. The contact angle being measured at each manufacturing process to understand the contact angle performance at each area. The angle of water droplet angle will be measured using Dataphysics equipment and the readings will be collected manually by user for analysis. According to Tianyi Zhao, in general the contact angle measurement towards solid surface with reading less than 90 degree are considered as hydrophilic, while reading measurement more than 90 degree are considered as hydrophobic [11]. The overall results of contact angle measurement then will be discussed in the results portion for monitoring purpose.

3. RESULTS AND DISCUSSION
In this section, all the results and analysis been discussed. The overall contact angle results being monitored before and after the plasma cleaning process. The water droplet for contact angle had been measured on each leadframes for each process to understand the performance of contact angle before and after plasma cleaning process. The leadframe oxidation performance level will be monitored as well towards the plasma cleaning time assessment. The overall results of the contact angle through the
manufacturing process can be referred to Figure 8 for reference.

![Contact Angle Performance Before and After Plasma](image)

**Figure 8.** Contact angle measurement at every process

From the results in Figure 8, before plasma cleaning process took place the average of contact angle being observed with reading more than 70 degree. After plasma cleaning process, the average contact angle reading had been significantly reduced. The three Plasma parameters showed that the longer the plasma cleaning time will reduce the average contact angle. Results showed at 600s plasma cleaning manage to get average contact angle measurement of 55 degree, while 720s had contact angle average of 52 degree and final 1200s cleaning time will get the average value of 43 degree. The contact angle water droplet view before plasma cleaning could be referred to Figure 9 for reference. The rounder the water droplet could be relate to higher contact angle measurement value.

![Sample of water droplet before plasma cleaning](image)

**Figure 9.** Sample of water droplet before plasma cleaning

After plasma cleaning process, the water droplet produced lower contact angle performance which can
be referred in Figure 10 for reference. This had been consistent performance of the water droplet for all leadframes after the plasma cleaning process.

![Sample of water droplet after cleaning process](image)

**Figure 10.** Sample of water droplet after cleaning process

The inspection towards the leadframes discolouration after plasma cleaning had been analyzed as well towards different plasma cleaning time. The sample of leadframe discolouration can be referred to Figure 4 for reference. For control recipe with 600s cleaning time showed the most area with leadframe oxidation area which is about 80% of total leadframe area. With the increment of plasma cleaning time to 720s the oxidation area on the leadframe had been reducing to 60% and doubling the plasma cleaning time to 1200s had significantly removed the oxidation area on the total leadframe area. The overall of leadframe oxidation performance towards plasma cleaning time could be referred to Figure 11 below for reference.

| Plasma Cleaning Time (second) | Leadframe discolouration picture | Leadframe discolouration percentage |
|-------------------------------|---------------------------------|-----------------------------------|
| 600                           | ![Image](image)                  | 80%                               |
| 720                           | ![Image](image)                  | 60%                               |
| 1200                          | ![Image](image)                  | 0%                                |
Figure 11. Results of plasma cleaning time towards leadframe discolouration

From the evaluation results showed that the higher the plasma cleaning time applied, the reduction of leadframe oxidation on the leadframe surface observed. With addition of RF plasma usage it has significant results in terms of cleaning effectiveness towards overall activities[8]. Plasma cleaning had proven that the leadframe oxidation can be removed by applying suitable parameter. However, the higher the plasma cleaning time have a negative impact whereby it will produce higher magazine temperature which in this situation require some precaution of handling procedure during unloading the magazines from the plasma machine. Once the leadframe discolouration had been resolved the contact angle then being measured for 30 samples including the 3 plasma cleaning recipes and results could be seen in Figure 12 below. The results again showed that contact angle have correlation with plasma cleaning time which indicate the higher the plasma cleaning time the lower the contact angle measurement.

Figure 12. Results of plasma cleaning time towards contact angle performance

At 600s plasma cleaning time the average contact angle measurement indicated the average value of 46 degree, while 720s plasma cleaning time at the average of 39 degree and for 1200s plasma cleaning time the average contact angle was at the average of 37 degree. The reduction of leadframe discolouration had same trend with the reduction of contact angle measurement results as well. In this

4. CONCLUSION
Plasma cleaning time plays a vital role towards leadframe oxidation cleaning process. From the evaluation showed that plasma cleaning process can be used as a medium for delamination free process. The longer plasma cleaning time showed reduction of oxidation area on leadframe and the average contact angle will be lower as well. The longer plasma cleaning time however will reduce the UPH performance and make the magazine hotter which safety precaution is required. Doubling the plasma cleaning time from 600s to
1200s had significantly removed the leadframe oxidation which make the objective been successfully achieved.

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