LOW-PRESSURE DC PLASMA CLEANING ON LEADFRAME SURFACE

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Abstract

The surface cleaning of semiconductor by low-pressure plasma is intended for the removal of organic contaminants. Plasma treatment of the surface increases the wettability of the surface as measured by the contact angle. The decrease of contact angle correlates directly with improved adhesion. For improving the wire bond strength of leadframes, low-pressure dc plasma cleaning processes were carried out in a plasma chamber using Ar or Ar/H_2 mixture with various ratios as the working gases. The treatment time was 5 minutes. The cleaned and uncleaned leadframe surfaces were investigated by contact angle measurements, wire pull and stitch pull strength tests. The experimental results show that contact angle decreased from 83.12 degree to 12.70-27.90 degree depending on the cleaning condition. Wire pull and stitch pull strength increased from 4 grams to 7.75-10.94 grams and 6.85-9.35 grams, respectively.

Keywords : leadframe, plasma cleaning, contact angle, wire pull, stitch pull

Introduction

A leadframe is a metal frame to which an integrated circuit (IC) is attached during the package assembly process. Wire bonding is an important technology used for making electrical connection inside microelectronics packaging. Wire bond carries power and signals between IC and leadframe. Wire bonding process is one of the most critical processes in IC packaging. At present, over 95 percent volume of the manufactured packages are being wire bonded [1].

There are a few common type of leadframes on the market; silver (Ag)-plated copper (Cu) leadframes are the most common leadframes used for gold wire bonding devices in IC packages [2]. Gold-wire bonding to silver-plated leadframe has been successfully used in the package assembly process for many years. The quality of the leadframe surface is critical for overall package performance.

Bondabillity problems can be caused by contaminants on the band pad surface. Contamination of metallic leadframe surface through the presence of oxides and organics may degrade the interface causing premature debonding. Removal of oxide and organic layers from bond pad surface prior to wire bonding process helps to improve the quality of wire bondabillity and reliability of package.

Plasma is able to physically and chemically micro-sized remove surface contamination and impurities. Plasmas of gases such as argon, hydrogen, oxygen and mixtures of these are often used for cleaning the surface of leadframes before wire bond processes to improve the wire bonding performance [3-5].

In this study, plasmas of Ar or Ar/H_2 mixture with various ratios were applied to die-attached leadframes to remove oxide and organic layers on surface prior to the wire bonding process. The cleaned and uncleaned die-attached leadframe surfaces were investigated by contact angle measurements and wire bond ability after plasma cleaning was evaluated by wire pull and stitch pull strength tests.

Methodology

Processes in production line

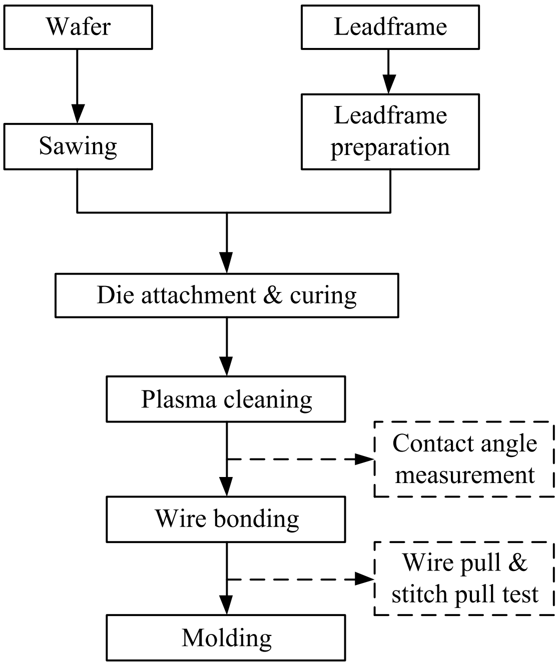


Figure 1 Processes in production line

Figure 1 shows the processes in production line used in this study. Wafer was sawed and epoxy was dispensed at the die-attach pads area for die attachment on the leadframe. Dies sawed from the wafer were attached on the pre-dispensed die-attach pads. After dies was attached, the leadframes were loaded into a magazine and transferred into a plasma cleaning system. Cleanliness of the surfaces was investigated by contact angle measurement. In wire bonding process, gold wire was used to make an electrical connection between die surface and bond pad on the leadframe by a method of ball-stitch bonding. Wire bond strength was evaluated using destructive wire pull and stitch pull tests.

Materials

A commercial leadframe material, called QFN FR0067, is provided in sheet form. The dimensions of leadframe are 70 mm x 250 mm and the thickness is 0.1 mm. The wire-bond and die-attach pads of quad flat no lead (QFN) leadframe are print-formed on pretreated copper substrate using silver paste. Each leadframe consists of 315 die-attach pads. The dies used in this study are called Al-dummy dies. They are prepared by cutting an aluminium-coated silicon wafer to die size of 3.5 mm square. An Al-dummy die attached leadframe used in this experiment is shown in figure 2.

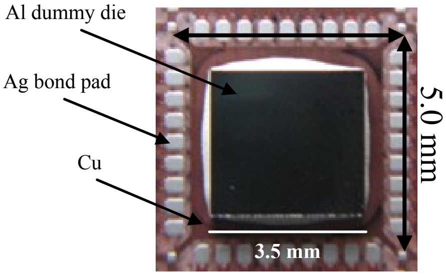


Figure 2 Top view of a piece of QFN FR0067 leadframe with Al-dummy die.

Table 1 Plasma parameters used in the experiment.

Condition	Working Gas	Flow rate (sccm)	Pressure (mbar)
1	Ar	35	1.2
2	Ar/H_2	20/15	3.2
3	Ar/H_2	10/25	1.5
4	Ar/H_2	10/40	2.8

Plasma cleaning

Ar or Ar/H_2 mixture plasmas with various ratios generated in DC plasma system were used to apply plasma treatments on the leadframe. The leadframes with Al-dummy dies were loaded into magazines and transferred into the plasma chamber for cleaning step. Four conditions of working gases used in this study are shown in Table 1. Filament current and arc current of plasma generator were fixed at 190 A and 60 A, respectively. The treatment time for all conditions was 5 minutes. Figure 3 show the bond pad area before plasma cleaning precess.

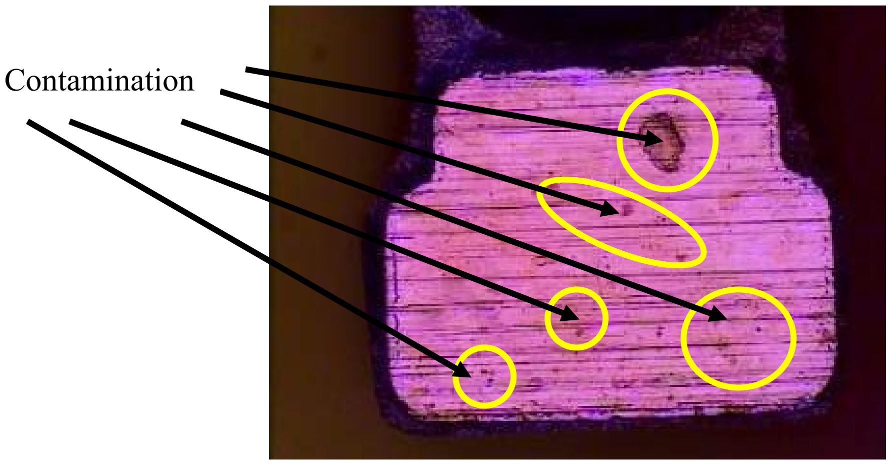


Figure 3 Top view of bond pad area before plasma cleaning.

Contact angle measurement

Static contact angle data were collected with goniometer at a room temperature. A drop of deionized water was placed on the treated and untreated Al-dummy die surface as shown in Figure 4. Then the contact angle of each droplet was observed. A drop with a smaller contact angle means that the surface is more hydrophilic, reflecting better wettability, better adhesiveness and higher surface energy.

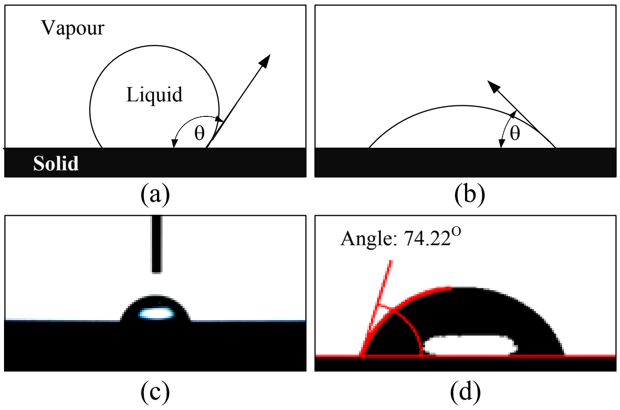
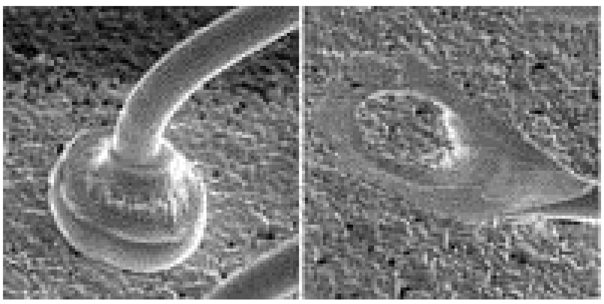


Figure 4 Contact angle measurement (a) bad wetting, (b) good wetting, (c) liquid droplet on the tested surface and (d) measured contact angle.

Wire bonding

The type of bond methods used in this experiment is ball-stitch bonding. By this method, temperature, ultrasonic power and force are used to form a metallurgical bond. A fine gold wire is used with a ball bond formed on die surface and a stitch bond at the wire-bond pad on the leadframe. A gold wire of 1 mil (25 µm) in diameter was used in wire bond process. A typical ball and stitch ball are shown in Figure 5.



(a) (b)

Figure 5 Examples of typical ball (a) and stitch (b)

Wire pull & stitch pull strength tests

Wire pull and stitch pull test are kind of destructive testing. This method is used to evaluate the bond strength by hooking and pulling the bonded wire until failure occurs and then the force was measured by wire pull & stitch pull strength test machine. Figure 6 shows the difference in hook location of wire pull test and stitch pull test. For the reliability of data in wire pull and stitch pull strength test, 30 data were collected of each plasma condition. The minimum, maximum and average values of wire pull and stitch pull strength were recorded. The acceptable minimum value of wire pull and stitch pull strength for the IC packaging process are 4 grams-force (gfs).[6]

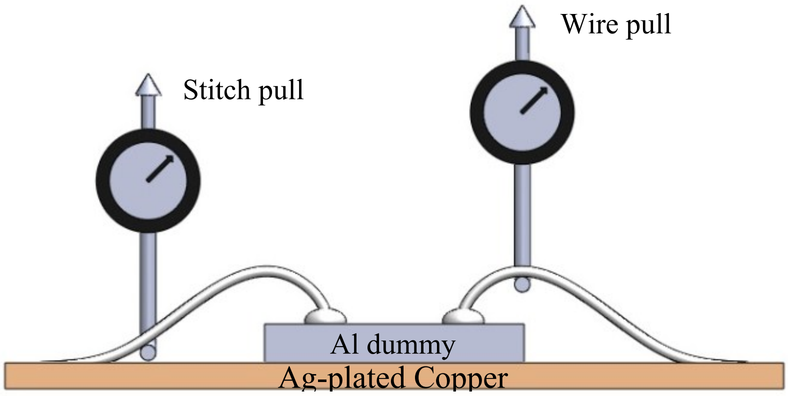


Figure 6 Wire pull and stitch pull strength test

Results

Contact angle measurements

Table 2 shows the contact angles for Al-dummy dies before and after plasma cleaning, which were measured immediately after plasma cleaning (at time 0 hr.). The typical measured contact angle of Al- dummy die before plasma cleaning is 83.12^o. This is because oxide and organic layers have accumulated on the surface of Al-dummy die, resulting in high contact angles. Measured contact angle values after plasma cleaning are shown in Table 2. The data clearly demonstrate that the contact angles decrease drastically after plasma cleaning. This indicates that some parts of die surface contaminates were removed. The contact angles were reduced to 14.90^o for plasma condition 1 and to 12.70^o, 21.70^o and 27.90^o for condition 2, 3 and 4, respectively. The highest acceptable value of this experiment is 30^o.

Table 2 Contact angles of Al-dummy dies before and after plasma cleaning.

Condition	Contact angle (degree)
Untreated	83.12
1	14.90
2	12.70
3	21.70
4	27.90

Wire pull strength test

Table 3 shows the values of wire pull strength after plasma cleaning process under various conditions. By comparison with pure Ar plasma (condition 1) cleaning, we found that the Ar/H_2 mixture plasma (condition 2-4) for cleaning process provided the better overall performance of wire bond. The minimum value of wire pull strength increases with increasing in ratio of hydrogen. It reaches a highest of 8.18 gfs when leadframes were cleaned with Ar/H_2 mixtures of 10/40 ratio.

Table 4 shows the stitch pull strength after plasma cleaning under various conditions. It can be seen that a change in plasma conditions is insignificant to the stitch pull strength of wire bond.

Table 3 The data of wire pulls strength tests.

Condition	Wire pull strength			
	Min (gfs)	**Max (gfs)**	**Avg. (gfs)**	**SD**
1	7.59	10.94	9.54	0.88
2	7.75	10.21	9.34	0.68
3	7.94	10.13	9.13	0.58
4	8.18	10.52	9.21	0.69

Table 4 The data of stitch pulls strength tests.

Condition	Stitch pull strength			
	Min (gfs)	**Max (gfs)**	**Avg. (gfs)**	**SD**
1	7.33	9.07	8.00	0.38
2	7.40	9.12	7.99	0.47
3	6.85	9.12	7.66	0.48
4	7.39	9.35	8.31	0.48

The reason of the increasing ratio of hydrogen to make the better quality of wire bond is that Ar plasma cleaning was used sputter process (physical mechanism) for cleaning the surface. This sputter process results in rough surface of die and leadframe. The higher surface roughness related to the lowering of contact angle. In the case of Ar/H_2 mixture plasma, the surface was cleaned by sputtering process from Ar plasma together with chemical processes from hydrogen plasma. The increase in hydrogen ratio caused the surface roughness to decrease. This result was observed from the increase in contact angle. However, the efficiency of the contaminant layer removal can be improved by chemical mechanism of hydrogen plasma without increasing in surface roughness, which leads to the better wire bond quality.

Discussion and Conclusion

In this study, Ar or Ar/H_2 mixture plasma was used to remove the oxide or organic layer from the Al-dummy die and silver-plated copper leadframe surfaces. After cleaning the surfaces by Ar plasma or Ar/H_2 mixture plasma, we found that wire pull and stitch pull strength values are greater than the acceptable value of 4 gfs. This result suggests that the Ar/H_2 mixture plasma with hydrogen ratio of ¼ should be used in the process of IC packaging. However, all of plasma conditions can be accepted.

Acknowledgments

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