Plasma Cleaning Methodology for Stain Removal in Electronic Packages

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Abstract- Various packages being used for electronic card assemblies and flat pin as well as dual inline packages are mostly employed. The package pins are coated with nickel followed by gold layer and thicknesses ranging from 1-3 um. The coating not only prevents corrosion due to environmental effect but also takes care of scratches. As the coating thickness is less so the storage conditions plays an important role in keeping the packages intact. Due to improper storage or handling, various contaminants can deposit and stuck due to humidity resulting it in stain which in result may affect long term reliability of packages. The stain can be due to volatile or organic contaminants and needs to be cleaned so as to utilize the component for high reliability applications. Traditionally the stains are cleaned with Iso-propyl Alcohol (wet method) and abrasive cleaning (dry method) through powder which poses lot of constraints as it is performed manually. Apart from that as packages comes with multiple pins having small pitch and width so extra precaution to be taken so as to avoid Electrostatic discharge (ESD), roughness, breakage. This leads to higher time consumption and sometime multiple abrasion which can be detrimental to device long term reliability. To circumvent the same, microwave plasma technique is introduced which leads to stain removal totally avoiding manual operations.Optimization of the power and time is needed so as to remove the stains completely. This article details the recipe optimization of the microwave plasma and the detailing various observations using optical microscope.

Keywords- Plasma, Etching, Packages, lectronic.

1. INTRODUCTION

Contaminations are basically categorized as: ionic contamination, airborne molecular contamination and defect density. Ionic contamination comprises cations and anions that are physically adsorbed or chemisorbed. Organics particles sources are wet processes, lithography, dry etch polymers, chemicals and gases whereas inorganic sources are material outgassing, resist strips etc. So surface contaminants in packages can be categorized as:

- Molecular contamination (organic or inorganic)
- Anionic and Cationic contamination (ionic)
- Various impurities such as metals, chemicals,gases (environmental effects)

Contamination due to environmental resulting from storage condition of the electronic packages are the major source introducing stains [1]. Removal of the corrosive stains is the key challenge as the stain can increase in size if the remedial actions are not taken to stop or eliminate it. The non-removal of impurities can lead to pin holes, cracks, material voids and various dislocations of the deposited films. Main step is to remove the stain and conformally coat the place so that it will not propagate further. This methodology introduces lot of challenges such as handling, removal of metal coating, pin breakage, ESD failure as it is performed manually.

Plasma cleaning is a dry-cleaning method & better option as the non-reactive gas is employed for generating plasma [2]. Argon plasma is the preferred technique as it is cost effective and clean the surface by breaking the bond and carried out of the chamber. Monolayers of hydrocarbons which sticks on the package surfaces are removed with the energetic plasma reaction to form the gaseous products. Argon gas is preferred in case of stain on the metallic portion as plasma activated atoms behave as molecular sandblast resulting in the removal of organic contaminants.

2. STANDARD METHODOLOGY

Discoloration or stain is the phenomena associated with the deposition of the hydrocarbon on the metallic surfaces. Standard procedure for its removal is the usage of abrasive powder (pumice powder) which is non-reactive as well as considered hazardous. This powder is having hardness of 5.5 Mohs so as to scratch stains and having mostly SiO(75%), AlO(15%), K_2O, Na_2O, FeO etc. As the material is having crystalline silica dust so it is considered as hazardous material. Further handling small packages with multiple pins also poses severe constraint due to manual operations. Author group tries microwave plasma

for the cleaning process by employing Argon gas. This methodology eliminated manual operations as well as completely safe for the package and operator.

3. PLASMA CLEANING METHODOLOGY

Plasma is partially ionized gas containing an equal number of positive and negative charges, as well as some other number of non-ionized gas particles (Neutral atoms/ molecules and radicals) [3]. In plasma systems positive ions are the key players. Plasma cleaning is often referred as dry cleaning process used in the fabrication of Hybrid microcircuits prior to component assembly & wire bonding process [4]. Surface contamination on bonding pad causes intermetallic formation issues which impacts the bonding strength of bonded interconnect and eventually affects its long term reliability. Plasma removes all types of contamination and oxide layers from the desired surfaces and helps in executing respective processes with desired bonding strength with high reliability. Physical plasma can be obtained with a noble gases / inert gas like Argon, Krypton etc [5]. A plasma system consists of Microwave generator (2.4 GHz) and a vacuum chamber with a parallel plate arrangement that keeps the lower electrode at a negative voltage bias with respect to the upper electrode (Figure 1). Typical vacuum pressures are set at 0.2 mbar. The electric field helps accelerate the free electrons to collide with the argon atoms. Ionization occurs as a free electron dislodges an electron from the Ar atom, resulting in a positively charged Ar+ ion plasma

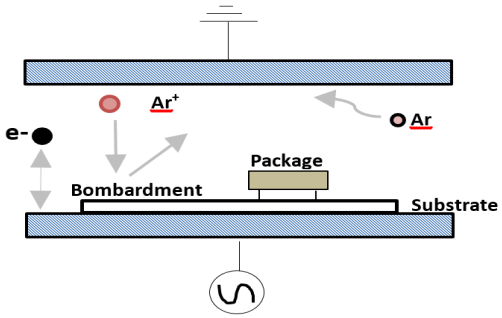


Fig. 1 Plasma Chamber working principle

Initially gas molecules (Argon Gas) in chamber are electrically neutral. However, a few can be ionized by high collisions, interactions with protons or other phenomena. This will lead to the creation of free electrons.

$$Ar\ (g) \longrightarrow Ar^{+} + e^{-}$$

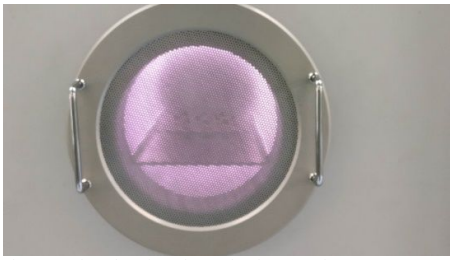
If we now apply an electric field through an electrode plate, the free electrons and the positive ions will respond by accelerating towards the anode (+) and Cathode (-) respectively. In a plasma, gas atoms are excited to higher energy states and also ionized. As the atoms and molecules 'relax' to their normal, lower energy states, they release a photon of light which results in the characteristic "glow" or light associated with plasma. Different gases give different colors. Microwave signal breaks the process gas into various reactive species. These species react with organic creating volatile by products. The resulting surface is ultra-clean.

Electronic Plasma Prep 5 Microwave plasma cleaning (2.4GHz) equipment (Figure 2a & 2b) is used for intended package cleaning. Prep 5Microwave plasma equipment can deliver max. 600W (100%) microwave power [6].

Table 1 Typical PLASMA Parameters of Plasma PREP 5 With Microwave

SN.	Gas	Power	Gas Flow	Pressure
1	O_2/H_2	20%	80%	0.3 mbar
2	O_2	20%	80%	0.18 mbar
3	He	20%	100%	0.4 mbar
4	H	20%	100%	0.2 mbar
5	Ar	10%	100%	0.25 mbar
6		40%	60%	0.07 mbar
7	CF_4	**This gas is forbidden for the machine!**		

Fig. 2a



Package under cleaning through Plasma Glow

Fig. 2b Plasma Equipment with Plasma Glow

4. RECIPE OPTIMIZATION

Stain or discoloration due to organic impurities is tried by running and optimizing the recipe.

Keeping the power as minimal, the time duration of the plasma is varied. The argon plasma is created from the microwave source (2.45GHz) and cleaning time is varied resulting in various observations as shown in Figure 3.

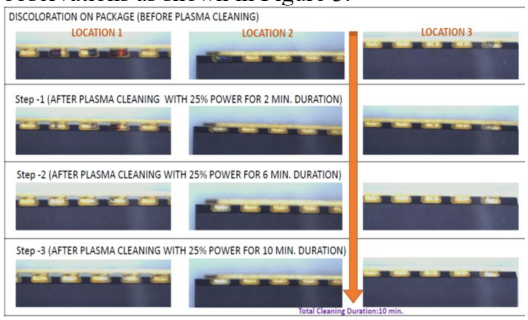


Fig. 3 Effect of time duration on stain removal (side view)

5. RESULTS

Optimized recipe for cleaning with 25% power for 10 minutes resulting in the cleaning of the stains as shown in Figure 4. Two different trials are tabulated in which single shot cleaning and in next trial three step approach is adopted keeping power and total timing same i.e 10 minutes. Stain or discoloration due to organic impurities is tried by running and optimizing the recipe. Keeping the power as minimal

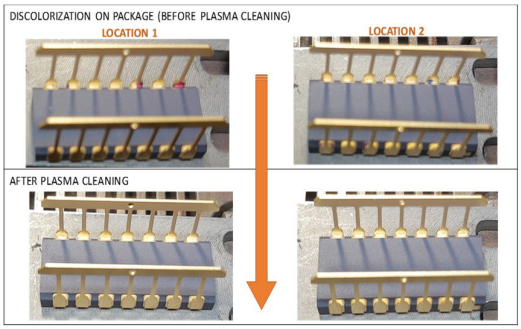


Fig. 4 Stain removal trials on samples with optimized recipe

6. EDAX ANALYSIS

Discolored samples after cleaning were subjected for EDAX analysis to check elemental composition on the discolored surface at the lead emerging area (bottom side) of the leads Figure 5. EDAX carried out on lead emerging area of discolored pin (bottom side) after cleaning. All elements have been analysedand obtained elements are Al=0.72%, Ni=2.22%, Au=97.06% (Spectra-1). And all samples show same results and did not reveal in presence of any corrosive elements or C and O.(Table 2 & Figure 6)

7. CONCLUSION

Argon based plasma cleaning is effectively employed for the stains removal which are even difficult to remove with the standard techniques. Microwave plasma is used which need recipe optimization for the specific application. It is observed that for both trials discoloration vanishes with plasma cleaning within 10-12 minutes time duration with 25% Power. As the microwave power can lead to arcing so the recipe is optimized for the process time keepingminimal power. Presented article demonstrate the effectiveness of this methodology without compromising or damaging the electrical or mechanical integrity of the electronic package. Also EDAX analysis post cleaning confirmed unavailability of any corrosive elements or C and O, presence of which would have impacted long term reliability of packages.

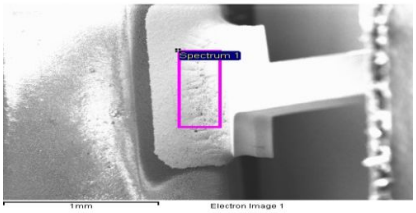


Fig 5 Spectrum 1 – EDAX Analysis

Table 2 Spectrum 1 – EDAX Analysis for all elements

Element	Weight%	Atomic%
Al K	0.72	4.78
Ni K	2.22	6.78
Au M	97.06	88.44
Totals	100.00	100.00

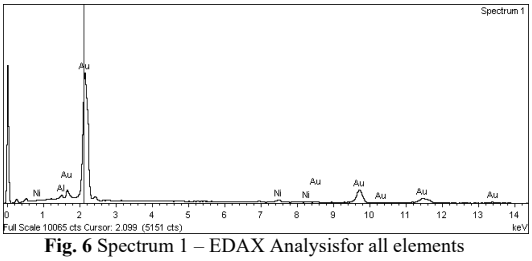


Fig. 6 Spectrum 1 – EDAX Analysisfor all elements

8. ACKNOWLEDGEMENT

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