The effect of roughening characteristics nickel-palladium-alloy plating on copper substrate to mold compound adhesion

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ABSTRACT – The current study was aimed to investigate the effect of surface roughening of Nickel-Palladium-Alloy plating on copper-based substrate with thermoset resin compound on the adhesion strength. Three type of textured roughness substrates conditions were evaluated. A surface roughness of the samples was identified using Atomic Force Microscope (AFM) and Field-emission Scanning Electron Microscope (FESEM) and adhesion strength was evaluated using mold button shear tester. Grainy structures on the highly textured surface was believed to increase the adhesion strength. This morphology was postulate to create resin compound to have great penetration into cavities and surface irregularities, hence it was contributed to the mechanical interlocking and resulted in changes of it physical and chemical properties, thus was affected in increasing of adhesion strength.

1. INTRODUCTION

A high reliable performance of IC package is critical in electronics applications. The product especially in automotive requires high quality and robust packaging solution requires for critical system application for instance braking system, door lock and power train. Therefore, improvement in reliable package is compulsory. A common failure in manufacturing assembly packaging is delamination. Delamination is weak adhesion between copper substrate and mold compound. In plastics packages, popcorn cracking usually happens during reflow process because of vapor pressure and delamination caused thermal stress resulting from mismatch in coefficient of thermal expansion (CTE) occurs among package component in pre-conditioning moisture sensitivity level 1 (MSL 1) and thermal cycling testing [2, 3]. Popcorn and Interface delamination failure between substrate frame and resin compound shows in Figure 1, vertical cracking happen within mold compound and delamination occurs between interfaces of dissimilar materials.

Conventional silver plated (Cu/Ag) on copper metal substrate usually has poor adhesion with epoxy mold compound (EMC) [3]. Interface delamination between silver-copper alloy substrate and EMC induced by thermos-mechanical load and creates a major risk for package reliability and lifetime failure [4]. Song et.al. in his paper present extensive study on oxidized surface layers of Cu-Fe-Zn-P (C194) and Cu-Ni-Si-Mg (C7025) substrate frames under different oxidation conditions and influence on the adhesion of EMCs to substrate [5]. An interfacial adhesion bonding was improved by formation of thin Cu_2O on substrate frame. Cu_2O was formed on copper surface and then CuO slowly generates through inter-diffusion of oxygen into oxide with optimal oxide layer 20-30 nm of thickness [5, 6, 7]. The Adhesion/shear bonding can be improved using Micro-oxidation and micro-etching surface techniques. The study had showed that micro-oxidation call "needle-like grain structure having more effective and higher shear strength as comparing with micro-etching substrate [8]. However, these approaches may not suitable and difficult to control when it comes to real manufacturing due to involved many processes related to temperature. A Nickel-Palladium-Alloy plating on copper substrates has excellent electrical and thermal conductivity becoming very important as substrate frame materials [1].

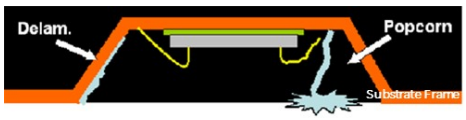

Figure 1 Popcorn and interface delamination failure of transistor outline semiconductor package

2. METHODOLOGY

Material

In this recent work, a Nickel-Palladium-Alloy plating (Ni/Pd/AuAg) on copper alloy substrate and biphenyl epoxy with phenolic hardener compound were used.

Surface Roughening Process

The copper substrate frame surface was going through surface treatment and roughening by using electro-plating process. The substrate continues with deposited into Ni solution to form intermediate layer. The second layer of Pd was electroplated on top of Ni. The top layer that was Au-Ag layer was then plated on Pd layer. The thickness of each layer 0.5 µm, 0.012 µm and 0.005 µm respectively. The deposited-on substrate frame (copper)

parameter as well as additives employed were proprietary. Three types of substrate frame with different level of texturing has been prepared including one without roughening.

Morphology and Surface Characterization

The textured of substrate samples were characterized using atomic force microscope (AFM; SPA300HV) and Field-emission scanning electron microscope (FESEM).

Adhesion Shear Testing

Commercial thermoset resin compound then was molded onto substrate frame in circular truncated cone shape button with height of 5.00 mm and diameter top and bottom 4.0 mm and 4.37 mm respectively. All samples were subjected to pre-conditioning moisture sensitivity level 1 follow (IPC/JEDEC STD 020) prior to mold shear testing.

3. RESULT AND DISCUSSION

The surface morphology of Up-grade Nickel-copper alloy (Cu-Ni-Pd-AuAg) with different roughness density was illustrated in Figure 2.

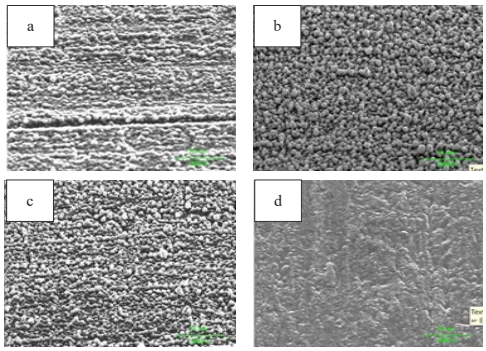

Figure 2 Surface morphologies of textured substrate-frame (a) Textured 1/low, (b) Textured 2/medium, (c) Textured 3/high and (d) No textured/standard by FESEM

Measured surface roughness (SR) of substrate surface using AFM was depicted in Figure 3. The morphologies structure shows flatten for low and medium texturing treatment of substrates and meanwhile high texturing treatment shows grainy structure. High textured substrate looks more rugged with combination of roughness sizes as compared with the other low and medium substrate textured.

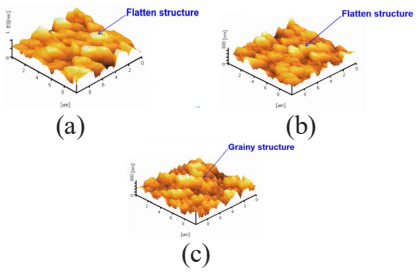

Figure 3 Surface morphologies of textured substrate-frame by AFM. (a) Textured 1/low, (b) Textured 2/medium and (c) Textured 3/high

Shear strength of different substrate texturing roughness shows in Figure 4. An adhesion strength shows a significant correlation with surface texturing density of substrates due to the penetration effect by thermoset resin compound into surface irregularities of textured substrate surface. This condition was led to the formation of mechanical interlocking thus contributed to the adhesion strength.

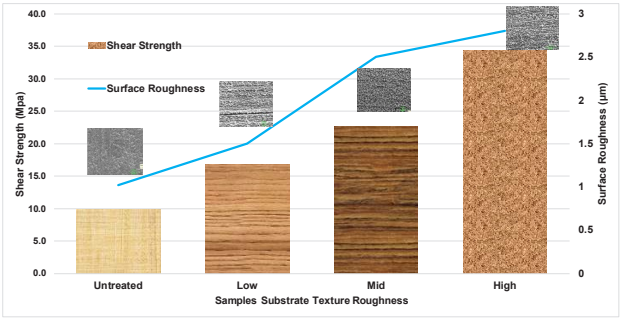

Figure 4 Average shear strength and surface roughness of substrate subjected to different texturing

4. CONCLUSIONS

High surface roughness of the plating on copper substrate was believed to contribute in adhesion strength due to formation of mechanical interlocking within the molecules and changed chemical and mechanical properties of bonding strength force.

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