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INVESTIGATION OF THIN FILM DEPOSITION BY MEANS OF MICROSCOPY

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Abstract: *The article presents the scanning technology based on scanning with the sensor-surface interaction.It shows the scanning possibilities given by applying such a method within technologies, allowing a measurement at a nano-level, as well as the advantages of implementing this type of investigation method.*

Keywords: *microscopy, investigated, SEM, TEM.*

1. INTRODUCTION

Wire-bonding is a main interconnection process in the packaging industry. Wires are bonded to Al pads using combined thermal and ultrasonic activation. Gold wires are the widely used and well characterized media for this process [1].

Recently, the use of copper wires is of interest to the industry due to its electrical and mechanical properties. Since copper is relatively hard and readily oxidized, the use of copper wires in industrial interconnection processes requires special bonding procedures and equipment. Moreover, due to the relatively slow formation of Al-Cu intermetallics, examination of the as bonded Al-Cu interface by conventional characterization such as optical microscopy (OM) and scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS), provide almost no information related to the deterioration of the wire-bonds as a function of the bond life.

2. PARTICLES SYNTHESYS AND APPLICATIONS

Until today, the Al-Cu wirebond interface was investigated by OM and SEM in samples which were mechanically polished, making it difficult to distinguish between the different Al-Cu intermetallics. Attempts were also made to resolve the intermetallic composition of the bonds via EDS incorporated in SEM [2]. In the present study, transmission electron microscopy (TEM), scanning transmission electron microscopy (STEM) and TEM-EDS were used for quantitative analysis of the intermetallic composition of as-bonded and heattreated Al-Cu wire-bonds. A dual beam focused ion beam (FIB) was used to prepare sitespecific TEM samples. FIB was also used for preliminary analysis of cross-sections by ion-beam and high-resolution SEM. In order to understand the processes that occur at the Al-Cu interface, as-bonded samples and samples annealed in air and argon were prepared. The channeling effect may occur for incident ions if a crystal in the sample is oriented in a low index zoneaxis. In these conditions, the ion beam will penetrate deeper into the target before significant inelastic scattering occurs, resulting in a lower probability of secondary electrons escaping from the sample due to their limited mean-free-path. As a result, grains oriented in a low index zone-axis will have a darker contrast than randomly oriented grains (Figure 1).

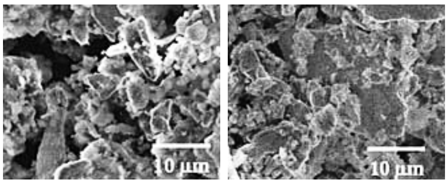

Figure 1: (a) Secondary electron SEM micrograph of the as-bonded Al-Cu interface and (b) ion induced secondary electron micrograph of the same specimen, showing the Cu grain morphology.

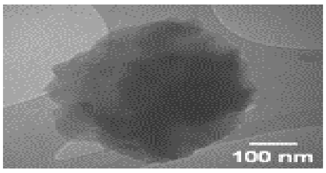

Figure 2: HAADF-STEM micrograph of the asbonded Al-Cu wire-bond cross-section. A nonuniform intermetallic region is evident.

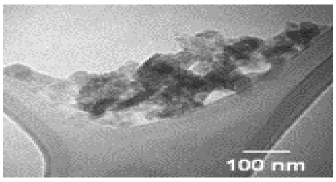

Figure 3: Bright field TEM micrograph of a central region of a Al-Cu wire-bond annealed for 24 hours in argon at 175°C. The inset diffraction pattern is of the dark intermetallic grain.

Figure 2 presents high angle annular dark field (HAADF) STEM micrograph of an area of the as-bonded Al-Cu wire bond, indicating that intermetallic phases are formed in the as bonded samples [3]. EDS analysis confirmed the presence of Al-Cu intermetallics, and that changes in the Cu concentration in the large intermetallic region was not monotonic as a function of a distance from the copper layer.The composition of the intermetallic regions in heat-treated samples was evaluated by TEM-EDS and, wherever possible, confirmed by selected area electron diffraction patterns (Figure 3). 2.Tape Automated Bonding (TAB). They will accommodate the flat TAB tape lead and provide the proper material for a reliable connection to the tape [4]. The bump fabrication process uses a metal deposition and plating process. First a series of barrier and seed layers of metal are deposited over the surface of the wafer. A layer of photoresist is deposited over these barrier and seed ayers. A photomask is used to pattern the locations over each of the pads that will be bumped. An etching process exposes the pads, and the open resist hole defines the shape and height of the bump. The bump, which is typically gold, is then electroplated over the pad and the deposited barrier metals. Once the plating s complete, a series of etching steps are used to protects the underlying materials from being etched. While gold bumping is the most common, copper, tin-lead, as well as layered combinations of these materials are used for bumping. An alternative to die bumping is to create bumps on the tape. For high leadcounts, wafer bumping is more common. Figure 4. illustrates a completed bump and a TAB tape lead.

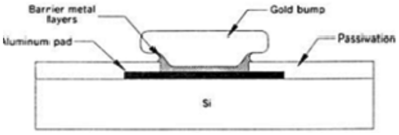

Figure 4. Tab with wafer bumping

Gold top wafer metallurgy had been practiced in the past. With exception of GaAs and TAB, gold had been replaced by aluminum interconnects and then by advanced copper interconnects. Lower material cost plus ultra-fine line capabilities of both aluminum and copper were reasons for the displacement of gold as interconnect. However, to enter high temperature IC applications, to achieve superior reliability or to dissipate greater power, the resurrection of gold as the top metal is both practical and effective. This protective gold top is coined Power Au for the ability of gold to increase power capabilities of ICs, packages and systems. Au wire bonded to aluminum forms many Au-Al intermetallics. This interdiffusion of Au atoms into Al bond pads is well studied. At higher temperature, diffusion and growth rate of intermetallics also accelerate. If the entire thickness of aluminum bond pad were converted into Au4 Al intermetallic, then the poor adhesion of Au4 Al to barrier metal between aluminum layers can result in wire bond separation and electrically open failure. Even as Au4 Al intermetallic is growing, Kirkendall's voids coalesce into hairline crack at intermetallics interface. These weakened interfaces are susceptible to stress failure and again result in electrically open failure. The metal between Power Au and Al is not a perfect barrier however. Under higher temperature testing, barrier metal does eventually break down. Above 250°C plus self heating from 860mA current, gold atoms punch through the barrier metal and then gold diffuse into aluminum. Rapid diffusion of Au into Al Power Au line immediately above contact to aluminum.

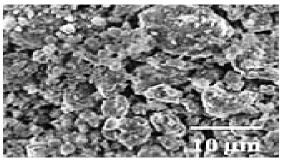

Figure 5. Power Au line with void above contact to aluminum after extremely high temperature testing and 860mA current. Gold diffused into aluminum and left a void.

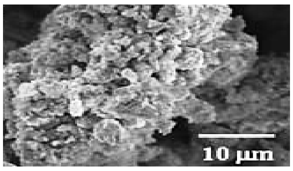

Figure 6. Shows a cross section of a Au-Al bond

The wire pull test is used to measure the strength and failure mode of the wire bond. A small hook is bond to gauge the strength of the 1st bond or next to the wedge at the 2 nd bond to ensure a reliable weld. Generally, if the hook is placed at the mid span of the wire, then the test will show the weakest link of the bond. This is typically either the neck of the ball bond (right above the ball) or at the heel of the wedge bond. The Pull test is basically a function of the wire diameter. Loop height & wire span are the most significant factors that determines the strength of a wire for a given wire diameter. Shorter span & a lower loop will result in a lower pull strength. As opposed to a longer span & a higher loop height which will result in higher pull strength. Copper wire bonding is normally formed by a copper ball onto an aluminum based bond pad in microelectronic package. However, copper oxidation at the interface of Cu- Al bonding area causes the cracks, decreases the interfacial shear strength, and weakens the Cu-Al bonding. Surface analysis of ball-peeled pad of Cu-Al bonding using XPS demonstrates the copper oxidation in the Cu-Al interface after autoclave test (at 121oC and 100% relative humidity). The binding energy scans for Cu 2p on the specimen after 0, 192, 384, and 576 hours in autoclave test chamber is carried out. After 576 hours corrosion, the chemical change of copper in a few atomic layers of surface from Cu to CuO. Furthermore, there are two major copper oxides peaks observed in the study, CuO and Cu(OH)2. Cu2O is not table in air and change to CuO immediately. Therefore, CuO2 is not expected to be detected at the specimen [7].

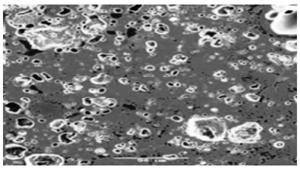

Figure 7. SEM pictures show corrosion and a crack after test hour increase (X1000)

Low cost, high thermal and electric conductivity, easy fabricating and joining, and wind rang of attainable mechanical properties have made copper widely used in electronic packaging, such as lead frames, interconnection wires, foils for flexible circuits, heat sinks, and WPB traces. However, unlike the aluminum oxide, the copper oxide layer is not self-protect. Therefore, copper is readily oxidized, especially at elevated temperature. Copper oxidationinterface of Cu-Al bonding area causes the cracks, decreases the interfacial shear strength, and weakens the Cu-Al bonding. Also, Copper oxidation in the area of the lead frames die pad and mold compound causes the delamination of packages. Furthermore, the moisture penetrates through the crevices because copper oxidation induces poor adhesion in the area of the copper lead frames and molding compound, creating corrosion problem in the packages.

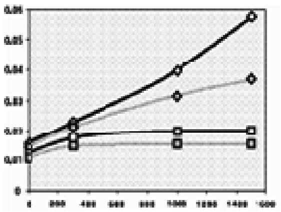

Figure 8. Intermetallic thickness vs. exposure for 6 hrs at respective temperature b) effect of wire material & substrate metallization on electrical resistance after aging

Tests show that, after exposure at various temperatures, intermetal I ic growth is significantly slower in copper wire bonds than in gold wire bonds. and device performance. Tests also show that despite a lower amount of intermetallic penetration, pull force and shear testing show values that are equivalent to, or greater than, those obtained with gold wire. Potential for maximum conductivity, device performance (tact frequencies of <500 MHz) and resistance to degradation in a mono-metallic system are the driving forces for the use of Cu wire in packages with Cu pads. DHF and iCu wire have been successfully ball-bonded to bare Cu lead frames and also AlSiCu metallized pads [8].

3. CONCLUSIONS

Recent studies have shown that, in many applications, copper wire bonding can provide better performance and reliability than gold wire bonding. While copper wire and ribbon have been used in discrete and power devices for many years, these latest studies also show that successes in ball bonding thin copper wire to aluminum, silver-nickel plating and even bare copper, provide the potential for its use in high-end, fine-pitch packages with higher lead counts and smaller pad sizes. For these reasons, along with the lower inherent cost of copper material, Kulicke & Soffa Bonding Wire [8] has developed and optimised two copper wire products: DHF copper wire for ball and wedge bonds in power devices and discrete packages; and iCu for fine-pitch or high-end IC applications.

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