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# Ag-alloy Stud Bump for IC and LED Packages

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## Extended Abstract

Gold has been commonly used as the interconnection material for IC and LED packaging. However, intermetallic compounds grow rapidly in a Au wire/Al pad bonded interfaces. In addition, the expensive cost of gold further restricts the application of Au wire as the bonding material in electronic industry. In recent years, copper wire receives some attentions as a substitute for gold wire. Although Cu wire has the advantages of low cost, high tensile strength, and good electrical and thermal conductivity, the inherent oxidation problems of Cu lead to great reliability concerns for electronic products. Furthermore, in contrast to the rapid growth of intermetallic compounds at the Au/Al interface, intermetallics do not easily form in a Cu wire bonded package, raising the risk of insufficient bonding (Chuang et al., 2013). During the Cu wire bonding process, an annoying problem occurs that a large bonding force is required due to the hardness of copper, which can cause a catastrophe of under-pad chip cratering.

Although silver possesses the highest electrical and thermal conductivity among all elements, certain drawbacks such as low tensile strength, unsatisfactory oxidation resistance, and sensitivity to electrolyte ion migration have been encountered by pure Ag wire used in electronic packages. In order to solve these problems of pure Ag wire, an innovative Ag alloy wire added with Au and Pd elements has been developed (Chuang et al., 2012; Lee et al., 2013). The addition of Au can improve the oxidation resistance of this Ag-alloy wire. Further alloying with Pd can not only increase the oxidation resistance but also to prevent the electrolyte ion migration of pure Ag wire. The low diffusivity of Pd can also slow the growth of intermetallic compounds at the interface between the Ag-alloy wire and Al pad.

This innovative Ag-alloy wire has been applied for the advanced flip-chip interconnection in IC and LED packages. The Ag alloy stud bumping packages revealed high performance during reliability tests. Recently, packages of 3-D IC and 2.5-D IC utilize Cu pillars as flip chip conductive bumps. However, the Cu pillars are hard and rigid, and therefore it is difficult to plastically deform for the solid contact between the Cu pillars and bonding pads during the assembly process utilizing hot pressing bonding, resulting in a problem of coplanar failure and a lot of voids or even failure to bond. The problem is getting worse according to the trend of decreasing the size of the package contacts. The Ag alloy stud bump is softer, and therefore is able to plastically deform during hot pressing to be in solid contact with the on-substrate bonding pad, completing a perfect bonding without the coplanarity problem that can occur with the utilization of Cu pillars in 3D-IC and/or 2.5D-IC packages. In addition, the failure of under-pad cratering occurred in Cu stud bumping can be prevented. Moreover, copper tends to be oxidized at high temperatures, especially for those stud bumps formed at the beginning of the process and have been heated with the wafer for a long time during the wafer level packaging.

During bumping process, an intermetallic compound of 0.5μm formed at the Ag-alloy stud bump/Al pad interface. In contrast, a much thicker intermetallics of 1.7 μm and an insufficient intermetallics of 0.1μm appeared at the bump/pad interfaces of Au and Cu stud bumping cases, respectively. The average bonding strength of Ag-alloy stud bumps with a diameter of of 50μm is 29.4 g, higher than those of Au stud bumps (24.3 g) and Cu stud bump (23.0 g), For the assembly of Ag stud bumping chip with PCB

using a Sn-3Ag-0.5Cu solder, 8.5μm thickness of intermetallics formed at the interface, while the Au stud bumps have completely dissolved into the solder to form brittle $AuSn_4$ intermetallic compounds. Therefore, the Au stud bump is generally assembled by a polymer conductive adhesive. However, the electrical and thermal conductivities of polymer conductive adhesive is much worse than metallic solder bonding, and the polymer conductive adhesive also lacks the advantages of self alignment and reworkability provided by soldering. The interfacial intermetallics at the Ag stud bumps grow to 18.5μm after 1000 hr aging at 150℃, which does not degrade the bonding effect of package.

During current stressing, the ternary Ag-Au-Pd alloy stud bumps have similar mean time to failure as that of Au stud bump and the binary Ag-Pd alloy stud bumps show much higher durability to electromigration than Au-stud bump due to the lower electrical resistivity. In contrast, Cu stud bumps were severely oxidized after current stressing at $1.23 \times 10^5$ $A/cm^2$ for only 1 hr. Furthermore, for the application in LED package, the Ag-alloy stud bumps provide an extra benefit of increasing the light output power (LOP) by about 3.2% due to the high reflectivity of silver.

## References


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