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Copper Wire Bonding Concerns and Best Practices

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Copper wire bonding of microelectronic parts has developed as a means to cut the costs of using the more mature technology of gold wire bonding. However, with this new technology, changes in the bonding processes as well as bonding metallurgy can affect product reliability. This paper discusses the challenges associated with copper wire bonding and the solutions that the industry has been implementing. The paper also provides information to enable customers to conduct qualification and reliability tests on microelectronic packages to facilitate adoption in their target applications.

Key words: Wire bonding, copper, gold, oxidation, corrosion, humidity

INTRODUCTION

Wire bonds form the primary interconnects between an integrated circuit chip and the metal lead frame in semiconductor packaging. They are generally considered a more cost-effective and flexible interconnect technology than flip-chip interconnects. Gold (Au) wire has been used for wire bonding in the electronics industry for more than 55 years because of its mechanical and electrical properties, high reliability, and ease of assembly. However, due to the increasingly high cost of Au, alternative wire bonding materials have been considered. Copper (Cu) is the most preferred alternative material for wire bonding because of its lower cost, higher mechanical strength, lower electrical resistance, slower intermetallic growth on aluminum (Al) pads, and higher thermal conductivity compared with Au.

Cu wire bonding has been investigated for more than 25 years.[1–4] Replacing Au wire with Cu wire in the wire bonding process presents many challenges. Cu wire bonds have the limitations of high oxidation rate, high hardness, and susceptibility to corrosion. Process and equipment changes are needed for conversion to Cu wire bonding, requiring new process optimizations and parameter adjustments for ball bond and stitch bond formation, and to achieve the looping profiles. To address Cu oxidation, bonding is carried out in an inert environment, e.g., in forming gas (95% N_2/5% H_2). In most cases, wire manufacturers adopt palladium-coated Cu (PdCu) wire, which is more resistant to oxidation than bare Cu, does not require forming gas, and has better second bond reliability. However, PdCu wires have the known challenges of higher hardness than bare Cu wires average hardness of (90 HV versus 85 HV),[5] higher melting point, as well as higher cost than bare Cu wires.[6]

Due to the high hardness of Cu, a relatively high bonding force (20% to 25% higher than for Au for the same ball height) is required to bond the Cu wire to bare Al pads, as compared with Au on Al pads.[7,12] The high bonding force makes Cu wire bonding unsuitable for fragile structures, and causes Al splash and possible damage to underlying circuitry. Since Al splash is considered unavoidable, the industry is currently using thinner Cu wires than Au to account for the splash. The industry is also exploring harder surface finishes, including Ni-based finishes (NiAu and NiPdAu). These finishes can address the high hardness, high yield strength, and required high bonding force in Cu wire bonding, since Ni is several times harder than both Al and Cu. However, Ni-based pad finishes are difficult to implement and significantly reduce the capillary lifetime (from 1 to 2 million bonds per capillary on Al pads, to 100 k to 200 k bonds per

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