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Behavior of palladium and its impact on intermetallic growth in palladium-coated Cu wire bonding

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Abstract

This paper describes the behavior of palladium in palladium-coated Cu (PdCu) wire bonding and its impact on bond reliability by utilizing transmission electron microscopy (TEM). A Pd layer approximately 80 nm thick, which is coated on the surface of Cu wire, dissolves into the Cu matrix during ball formation (under N_2 gas protection) when the wire tip is melted to form a ball. As a result of dissolving the very thin Pd layer into the ball, Pd is almost undetectable along the entire bond interface between the ball and the Al pad. The behavior of Pd during thermal aging in air, however, is different for central and peripheral interfaces. At the central interface, less than 5 at.% Pd is present after 168 h aging at 175 °C. At the periphery, however, Pd diffuses back and congregates, reaching a level of ∼12 at.% after 24 h, and a Pd-rich $(Cu,Pd)_9Al_4$ layer (>40 at.% Pd) forms after 168 h. Pd acts substitutionally in Cu_9Al_4 but cannot penetrate into the $CuAl_2$ or CuAl. By comparison of intermetallic thickness and interfacial morphology between PdCu and bare Cu wire bonds, it is concluded that the presence of Pd reduces intermetallic growth rate, and is associated with numerous nanovoids in PdCu bonds.

Keywords: Palladium-coated copper wire; Wire bonding; Interfacial structure; Intermetallic compounds; Void

1. Introduction

Copper wire is increasingly becoming the material of choice for interconnection in wire bonding packages. While gold wire has been used in wire bonding for many years, continuous increases in the price of gold in recent years have driven a rapid shift to copper wire as an attractive alternative to achieve significant package cost savings [1]. Copper wire provides better thermal and electrical characteristics and performance, and much slower intermetallic compound (IMC) growth with Al bond pad compared to gold wire [2,3]. However, bare Cu wire has several drawbacks, most importantly oxidation and high hardness. As copper is readily oxidized in air, its storage lifetime before bonding is much shorter than that of gold wire. The second bond process with bare Cu wire is less robust. Recently, a palladium-coated copper (PdCu) wire has been developed as an alternative to bare copper wire. The Pd coating is typically about 100 nm thick, which is expected to limit copper oxidation. Bare Cu wire bonding has to be performed under a forming gas of typically 95% N_2 + 5% H_2 or the Cu free air balls (FABs) are badly oxidized. In contrast, PdCu wire bonding was successfully performed in a pure nitrogen atmosphere without any oxidation of the PdCu FABs [4]. This not only reduces the shielding gas cost, but also lowers the infrastructure costs as it is then only necessary to deliver pure nitrogen gas rather than a forming gas to the production floor.

Tomohiro [5] reported, based on a pressure cooker test and a highly accelerated temperature and humidity stress test, that PdCu wire bonds have longer lifetimes than bare copper wire bonds due to the better corrosion resistance of

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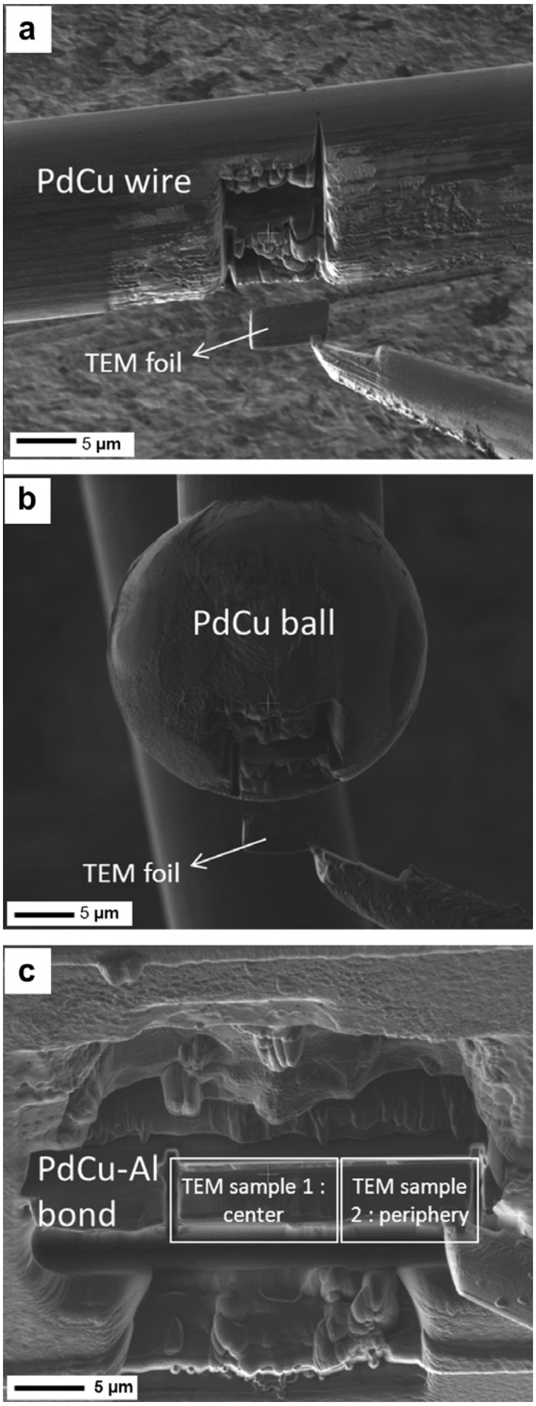

Fig. 1. TEM specimen preparation using FIB: (a) TEM specimen from a PdCu wire; (b) TEM specimen from the bottom of a PdCu ball; (c) cross-sectional TEM specimens from central interfacial area and peripheral interfacial area of bonds, respectively.

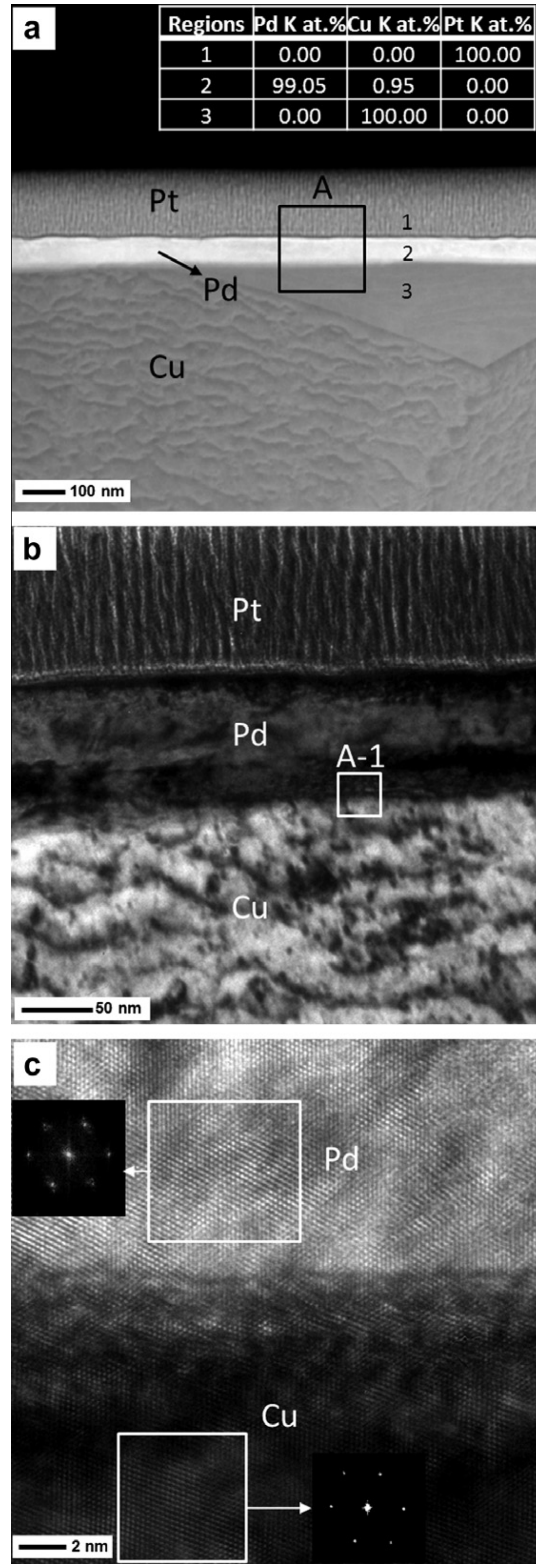

Fig. 2. TEM showing ~80 nm Pd coating abutting Cu: (a) HAADF-STEM image; (b) bright-field TEM image; (c) lattice image and Fourier reconstructed patterns of region A-1 in (b) showing the Pd–Cu interface. A Pt layer was deposited during TEM specimen preparation process so as to prevent the damage to the Pd layer.

the former. However, our previous study [6] showed that PdCu wire bonds have a much higher pad peeling failure rate than Cu wire bonds after 24 h isothermal aging at 175 °C in air, and the longer the aging time, the higher peeling rate in PdCu bonds. The development and optimization of PdCu wire bonding requires a fundamental understanding of interfacial characteristics of bonds during both bonding and reliability tests, especially the behavior of Pd and its impact on bondability and reliability. While knowledge of the interfacial characteristics of bare copper