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Design of Cu nanoaggregates composed of ultra-small Cu nanoparticles for Cu-Cu thermocompression bonding

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Abstract:

In this paper, new type Cu nanoaggregates (Cu NAs) were designed, and the Cu-Cu bonding by Cu NAs was investigated. The Cu NAs were obtained by agglomeration of the synthesized 5 nm Cu nanoparticles (Cu NPs). Compared to ultra-small Cu NPs, the collection difficulties were effectively solved and the antioxidation properties were also enhanced by the formation of Cu NAs. After sintering at 250 °C for 60 min, the Cu NAs film achieved a low electrical resistivity of 4.1 μΩ cm, which is only 2.5 times larger than that of bulk Cu. A high strength Cu-Cu bonding joint of 25.36 MPa can also be achieved via sintering of Cu NAs at 250 °C under a low bonding pressure of 1.08 MPa. After characterizations of Cu-Cu bonding interfaces and fracture structures of bonded joints, the Cu-Cu interconnection was demonstrated to be tightly contacted, sufficiently diffused and with high purity. In addition, a sintering and bonding mechanism by Cu NAs were proposed, explaining the key role played by ultra-small Cu NPs on the shell layer of Cu NAs. According to the advantages, Cu NAs are expected to be ideal substitutes to traditional solders, which have a huge application prospect in electronics packaging.

Keywords: Cu nanoaggregates; ultra-small nanoparticles; Cu-Cu bonding; sintering; thermocompression

1. Introduction

In recent years, with the decreasing size of integrated circuits (ICs), the packaging density has shown a significant increasing trend, the traditional Cu-Sn-Cu interconnection technology has presented a series of reliability problems, such as the short circuit of fine-pitch micro bumps caused by the overflow of melted Sn in the packaging process, the bridge failure caused by Sn whisker growth, and kirkendall voids formation caused by thermal load or electromigration enhanced diffusion at the Cu/Sn interface [1–3]. Therefore, the development of more advanced Cu-Cu bonding process by using higher performance interconnection materials is an urgent need to cater the high standard requirement of high reliability for high-density packaging.

Because of its high electrical and thermal conductivity, high thermal and mechanical stability, environmental friendliness and low cost, Cu has always been considered as an ideal interconnection material [4,5]. However, the process temperature of conventional reflow soldering is within 250 °C, and the high Cu-Cu bonding temperature caused by the high melting point of Cu (1083 °C) cannot meet the requirements of packaging [6–9]. These years,