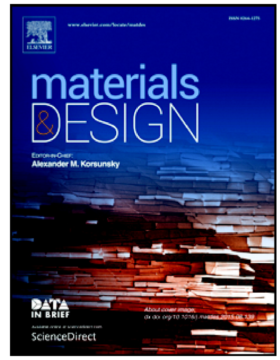
Accepted Manuscript



A novel multiscale silver paste for die bonding on bare copper by low-temperature pressure-free sintering in air

Jie Li, Xin Li, Lei Wang, Yun-Hui Mei, Guo-Quan Lu

PII: S0264-1275(17)31085-7
DOI: doi:10.1016/j.matdes.2017.11.054
Reference: JMADE 3531

To appear in: *Materials & Design*

Received date: 15 May 2017
Revised date: 9 November 2017
Accepted date: 24 November 2017

A novel multiscale silver paste for die bonding on bare copper by low-temperature pressure-free sintering in air

Jie Li [a], Xin Li [a, *], Lei Wang [b], Yun-Hui Mei [a], Guo-Quan Lu [a, c]

[a] School of Material Science and Engineering, and Tianjin Key Laboratory of Advanced Joining Technology, Tianjin University, Tianjin, People's Republic of China.

[b] School of Chemical Engineering and Technology, Tianjin University, Tianjin, People's Republic of China.

[c] Department of Material Science and Engineering, Virginia Tech, Blacksburg, VA, USA.

Abstract

Nanosilver sintering is expected to overcome the limitation of relatively high production cost and become widely available for the die bonding of power electronics. A potential application of nanosilver sintering is bare copper bonding, where replacing substrates with auxiliary silver or other plating that can damage bonding would be advantageous. Here, we introduce a novel multiscale silver paste containing both nanoparticles (20–100 nm) and microparticles (1–5 μm) for the bonding of high-power chips on a bare copper substrate by pressure-free sintering in air. The energy potential difference generated in the surface force field was critical in the formation of sintering necks between the nano and microparticles, which, together with other microparticles, formed the high-density sintered structure. Despite the development of a copper oxide film, the interfacial bonding was comparable to or higher than the sintering force due to the high surface energy of porous sintered structure and easy diffusion of nanoparticles occurred. A processing temperature of 265 °C was considered optimal for bare copper joint (shear strength: 53 MPa, transient thermal impedance: 0.132 °C/W) considering the trade-off between achieving excellent mechanical and thermal properties while minimizing oxidation.

Keywords: Silver nanoparticles, Silver microparticles, Bare copper, Air sintering, Pressure-free bonding

1. Introduction

With the emergence of wide-band-gap technologies, die attachment demands lower curing temperatures and higher operating temperatures, while also providing excellent thermal and electrical performance. Silver paste sintering, a newly developed bonding technique, is becoming popular because of the outstanding thermal and electrical conductivities of silver. Many studies have demonstrated the successful application of silver nanoparticle sintering for bonding with silver-plated substrates, which benefits from the nano-size effect [1-5]. Activated surfaces can result in significant melting-point suppression and improved toughness of nanoscale particles. At present, the solidification of nanosilver pastes can be realized at temperatures below 300 °C and the process can be undertaken with or without pressure, depending on the paste composition and particle size. After sintering, the particles form a porous structure that improves the fatigue resistance by stress release. This promising technique is expected to gain prominence in the development of future power electronics, including applications in communication, information technology, and emergent energy systems. However, the use of nanosilver paste is limited by both the high production cost of the constituent nanoparticles and the high sintering temperatures required to remove dispersants in the pastes [3-6]. These concerns led to