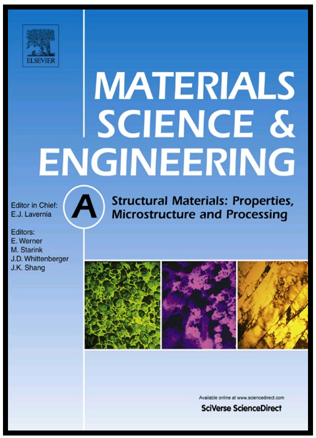

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Novel transient liquid phase bonding through capillary action for high-temperature power devices packaging

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Abstract

A novel transient liquid phase (TLP) bonding was achieved by using a hybrid solder preform containing porous Cu interlayer, which was prepared by compacting a thin layer of Cu powder with Sn foils. This method combines the advantages of the conventional TLP bonding and sintering, and it can accelerate the reaction rate, suppress the voids formation, and be performed with lower pressure. During bonding, liquid Sn on the two interfaces flows rapidly into the gaps between neighbored Cu particles through a strong capillary action, resulting in the densification of the microstructure. The TLP process can be accomplished at a temperature of 250 ºC within 20 min, sequentially producing a high heat-resistant joint, which is comprised primarily of Cu-Sn intermetallic compounds (IMCs) matrix and dispersive Cu particles. In this study, the microstructure evolution, mechanical property, thermal reliability, and the effects of Cu particle size and morphology on the bonding process were investigated systematically.

Keywords: TLP bonding; Capillary action; Intermetallic compounds; Mechanical property; Thermal reliability

1. Introduction

Nowadays, advanced development in the automotive, aerospace, deep oil and gas drilling, and energy production industry requires electronic devices to operate at high temperatures. For example, the deep oil and gas explorations will be conducted under harsher environments in the near future, thereby the control and sensing devices need to survive pressure reaching to 30000 psi and temperature up to 300 ºC [1]. Meanwhile, wide band gap semiconductors have been confirmed as alternative chip materials for the next generation of power nodules due to their superb electronic, physical, chemical and mechanical properties, where the silicon carbide (SiC) and gallium nitride (GaN) are capable of operating at temperatures even up to 600 °C theoretically, far more than the general junction temperatures of Si-based devices [2, 3]. The high-temperature application trend brings many challenges for the packaging technology, which requires the interconnection that exhibit high-temperature stability and reliability. However, traditional packaging materials (e.g. Sn-based solders) and micro joining techniques (e.g. soldering) cannot fulfill the demands of advanced electronic systems.

In recent years, transient liquid phase (TLP) bonding has been identified as a promising candidate to address this challenge, because it can be performed at relatively low temperature but produces high heat-resistant joint that is composed fully of intermetallic compounds (IMCs). However, a deadly drawback still remains in this method. It costs very long time (> 60 min) to accomplish the TLP process, which will reduce the bonding efficiency and increase the production cost. For example, the time duration making liquid Sn be exhausted was about 90 min in the interfacial reaction of Cu/Sn/Cu system at a temperature of 340 ºC [4]. Under this background, TLP sintering with mixed powders has been receiving considerable attention [5-7]. This method is actually a modified TLP bonding process, where the reaction rate has been accelerated by means of shortening diffusion distance and increasing effective reaction area. Nevertheless, a great amount of voids are simultaneously distributed along the intermetallic grain boundaries even though increasing the bonding pressure