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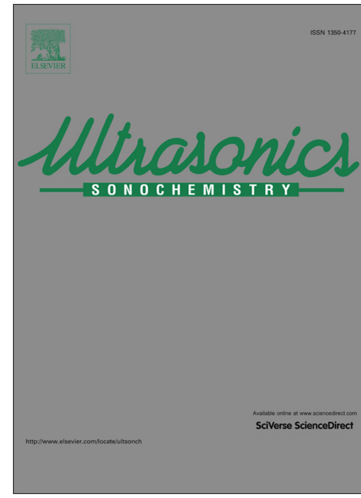

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Rapid Ag/Sn/Ag transient liquid phase bonding for high-temperature power devices packaging by the assistance of ultrasound

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Abstract: Rapid transient liquid phase (TLP) bonding process on Ag/Sn/Ag system is achieved in air by the assistance of ultrasonic, which has great potential to be applied to high-temperature power devices packaging. In this study, the influence of ultrasonic effect on the morphology and growth kinetics of Ag_3Sn grains, and the joint microstructure, mechanical property and thermal reliability were systematically investigated. Experimental results indicated that the rapid consumption of the "dynamic" transient liquid phase was attributed to the accelerated dissolution of Ag substrate and the extrusion of liquid Sn, which were entirely induced by the complex sonochemical effects on the liquid/solid intermetallic compounds (IMCs) interface. An elongated scallop-like morphology of Ag_3Sn grains was developed during Ag/Sn interfacial reaction with ultrasonic, accompanied by widening of grooves between neighbored grains. This phenomenon is called as a strengthening thermal grooving, in which the grooves at grain boundaries provide stable molten channels for Ag atoms diffusion from the substrate. Consequently, the improved elemental diffusion was evaluated through the growth kinetics of Ag_3Sn IMCs, with conservative estimation of 6-16.5 times faster than the traditional TLP process. In addition, both excellent mechanical property and thermal reliability of the Ag-Sn intermetallic joint were experimentally verified by shear test and high-temperature storage test, respectively.

Key words: TLP bonding; ultrasonic; intermetallic compounds; growth kinetics; thermal grooving; reliability

1. Introduction

The demand for high-temperature electronic devices, with much higher thermal functionality and reliability, is continuously increasing in a wide variety of industries in recent years [1]. It has been reported that two important factors result in this trend. (1) The development of electronic component is tending towards miniaturization, high integration, multi-functionalization, and high power density. For example, as a result of the efforts to reduce the size of power control unit (PCU) in Toyota and increase its power output, the power density has increased by approximately 2.5 times from the first generation to the third generation [2]. (2) More and more electronic systems are required to be operated in harsh environments, such as high temperature, large current, and humid ambient. For instance, the control and sensing electronics in deep oil and gas drilling will be need to survive pressure reaching to 30000 psi and temperature up to 300 ºC for deeper exploration [3]. The high-temperature applications bring great challenges to the electronic material and packaging technology. Nowadays, a wide band gap semiconductor technology has solved the problems of chip material in power devices, such as silicon carbide (SiC) and gallium nitride (GaN), which enable undergoing long-term operation at high temperatures of more than 300 ºC. Therefore, the study of packaging methods is extremely crucial to promote the development of wide band gap semiconductors in power devices [4].