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Kinetics of Dissolution and Isothermal Solidification for Gold-Enriched Solid–Liquid Interdiffusion (SLID) Bonding

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This paper presents the development and characterization of a fluxless die-attach soldering process based on gold-enriched solid–liquid interdiffusion (SLID). Eutectic Au-Sn and pure Au were deposited by jet vapor deposition (JVD) onto two substrates, assembled in a sandwiched structure, and processed in a vacuum furnace using different temperatures and times. Microstructural characterization, based on scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) analysis, revealed the formation of sound joints governed by the interdiffusion of the main constituents. Kinetic studies for the dissolution and the isothermal solidification stages were conducted. Differential scanning calorimetry (DSC) revealed a solder joint that is thermally stable up to 498°C, thus demonstrating the effectiveness of using the SLID process for the production of joints which require a lower processing temperature compared with their remelting point. Based on these findings, the recommended final bonding parameters are processing temperature and time of 340°C (310°C < T_P < 340°C) and 5 min, respectively.

Key words: SLID, isothermal solidification, lead-free solder, fluxless, high temperature, eutectic gold-tin

INTRODUCTION

Nowadays, there is an increasing demand for electronics capable of operating beyond the traditional 125°C limit. This kind of high-temperature environment can be found in a wide range of military and commercial applications such as avionics, deep well drilling, chemical processing systems, space/Earth exploration, and hybrid-electric vehicle electronics.[1–3] Currently, advances in wide-bandgap (WBG) technology have enabled operation in high-temperature (>500°C) environments, but packaging technologies, specifically the interconnections, are still the major hurdle to product development.[1,2,4] Typically, joints intended for extreme temperatures have been fabricated using high-melting-temperature metallic alloys. However, the mismatch of the coefficient of thermal expansion (CTE) between the WBG chip and the substrate generates high thermomechanical stresses resulting in potential damage to the device, particularly during the assembly process.

Besides the high-temperature and harsh-environment requirements, environmental regulations such as the Restriction of Hazardous Substances (RoHS) Directive (Pb-free)[5] have driven research for the development of new lead-free bonding techniques for assembly of electronic components. Due to its many advantages, such as high strength, no thermal fatigue due to a creep mechanism,[4] and low processing temperature, eutectic Au-Sn (80 wt.% Au and 20 wt.% Sn) presents a solution for these extreme environments. However, the melting temperature (280°C) of this hard solder is still below the operating potential of WBG devices. Consequently, a bonding technique that could offer a low processing temperature while resulting in a higher remelting point is much needed. Solid–liquid interdiffusion (SLID) bonding relying on the gold-enriched system (92 wt.%

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