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Evaluation of Die-Attach Bonding Using High-Frequency Ultrasonic Energy for High-Temperature Application

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Room-temperature die-attach bonding using ultrasonic energy was evaluated on Cu/In and Cu/Sn-3Ag metal stacks. The In and Sn-3Ag layers have much lower melting temperatures than the base material (Cu) and can be melted through the heat generated during ultrasonic bonding, forming intermetallic compounds (IMCs). Samples were bonded using different ultrasonic powers, bonding times, and forces and subsequently aged at 300°C for 500 h. After aging, die shear testing was performed and the fracture surfaces were inspected by scanning electron microscopy. Results showed that the shear strength of Cu/In joints reached an upper plateau after 100 h of thermal aging and remained stable with aging time, whereas that of the Cu/Sn-3Ag joints decreased with increasing aging time. η-Cu_7In_4 and $(Cu,Au)_{11}In_9$ IMCs were observed at the Cu/In joint, while Cu_3Sn and $(Ag,Cu)_3Sn$ IMCs were found at the Cu/Sn-3Ag joint after reliability testing. As Cu-based IMCs have high melting temperatures, they are highly suitable for use in high-temperature electronics, but can be formed at room temperature using an ultrasonic approach.

Key words: Transverse ultrasonic bonding, rugged electronics, die-attach bonding, high-temperature storage test, interfacial microstructure

INTRODUCTION

Nowadays, highly reliable packaging technologies for semiconductor devices that can endure extremely high environmental temperatures are becoming increasingly important in electronic systems for use in oil and gas well logging, automotive, and aerospace industries. In addition, emerging wide-bandgap devices such as those based on silicon carbide (SiC) and gallium nitride (GaN) frequently need to be operated at higher junction temperatures above 225°C. This requirement is far beyond the operating limit of conventional silicon (Si)-based devices and the corresponding packaging technologies, which is normally considered to be below 150°C. Such stringent and demanding requests have led to wide-scale efforts to identify new materials, at both the device and packaging levels.[1] To overcome the huge technology gap between conventional packaging and high-temperature-tolerant packaging, it is essential to have full understanding of the thermomechanical, chemical, and metallurgical behaviors of interconnection and packaging materials under target harsh environmental conditions through extensive case studies and in-depth characterization. Electronic packages for use in high-temperature applications should be continuously operated without degradation of performance or reliability. Material degradation, plastic deformation, creep, oxidation, and electromigration are the major failure mechanisms in electronics, and all of these degradation behaviors are normally accelerated by an increase of temperature. Similarly, in metallic bonding parts such as die-attach or flip-chip interconnects, the formation and diffusion of intermetallic compounds (IMCs) are also accelerated as the temperature is increased, and these

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