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Evaluation of Operation Lifetime of SN-35BI-0.5CU-0.03NI BGA Joints Based on Arrhenius Mode with Humidity and Microstructure Evolution

Authors : Vichea Duk, Gong Zhang, Qingyu Shi

Abstract : The Sn-35Bi alloy, which is near eutectic, has garnered attention for its potential use as a low-temperature, lead-free solder due to its advantageous properties, including low density, a melting point ranging from 141℃ to 182℃, and cost-effectiveness. Despite these benefits, the practical application of Sn-Bi alloys necessitates significant enhancements in their properties and those of their joints. Two critical challenges must be addressed: the inherent brittleness of bismuth (Bi) and the tendency for microstructure coarsening in these alloys after thermal aging, particularly in PC laptops. In this study, the Arrhenius model was employed to analyze and modify the functional requirements of Sn-35Bi-0.5Cu-0.03Ni solder joints. Mechanical performance was assessed using vibration and shock tests, while microstructure evolution was examined to understand the electrical performance requirements. Results showed that after operating under conditions of 46°C and 90% relative humidity for 1000 hours, the Bi element in the SnBi-based solder joints aggregated significantly, forming coarse, block-like Bi phase structures. The thickness of the intermetallic compound (IMC) layer also increased markedly. Prolonged exposure to the same conditions for 1500 hours further highlighted this microstructure evolution. After 2607 hours of operation, although no cracks were observed in the resin substrate on the package side, the Bi-phase coarsened further, and the IMC layer's thickness nearly doubled compared to the initial state. Notably, the GPU microstructures showed more pronounced changes due to higher electrochemical migration (ECM) compared to the CPU. Overall, the study demonstrated a decline in the reliability of the PC laptop after 2607 hours of operation at 46°C and 90% relative humidity, equivalent to over three years under normal room temperature conditions. Despite this, the Sn-35Bi alloy met both the functional and mechanical-electrical performance requirements, underscoring its potential as a viable lead-free solder for low-temperature applications.

Keywords : Sn-35Bi-0.5Cu-0.03Ni BGA joints, lead-free solder, Arrhenius mode with humidity, microstructure evolution, reliability
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