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Impact of Thermal Aging on the Microstructure Evolution and Mechanical Properties of Lanthanum-Doped Tin-Silver-Copper Lead-Free Solders

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An extensive study is made to analyze the impact of pure lanthanum on the microstructure and mechanical properties of Sn-Ag-Cu (SAC) alloys at high temperatures. Different compositions are tested; the temperature applied for the isothermal aging is 150°C, and aging times of 10 h, 25 h, 50 h, 100 h, and 200 h are studied. Optical microscopy with cross-polarized light is used to follow the grain size, which is refined from 8 mm to 1 mm for as-cast samples and is maintained during thermal aging. Intermetallic compounds (IMCs) present inside the bulk Sn matrix affect the mechanical properties of the SAC alloys. Due to high-temperature exposure, these IMCs grow and hence their impact on mechanical properties becomes more significant. This growth is followed by scanning electron microscopy, and energy-dispersive spectroscopy is used for elemental mapping of each phase. A significant refinement in the average size of IMCs of up to 40% is identified for the as-cast samples, and the coarsening rate of these IMCs is slowed by up to 70% with no change in the interparticle spacing. Yield stress and tensile strength are determined through tensile testing at 20°C for as-cast samples and after thermal aging at 150°C for 100 h and 200 h. Both yield stress and tensile strength are increased by up to 20% by minute lanthanum doping.

Key words: Lanthanum, SAC alloys, intermetallic compounds, aging temperature, aging time

INTRODUCTION

Sn-Pb solder has long been used in the electronics industry, but due to its toxic nature and environmental effects, certain restrictions are made on its use by the European RoHS directive, and therefore, many researchers are looking to replace it. This is because Pb and Pb-containing compounds, as cited by the US Environmental Protection Agency (EPA), is one of the top 17 chemicals posing the greatest threat to human beings and the environment.[1] The new lead-free solders are mostly Sn-containing binary and ternary alloys.[2] Due to their better thermomechanical properties, SAC alloys are considered as the best choice.[2,3] However, because of their coarse microstructure, iron (Fe), cobalt (Co), and nickel (Ni) have been used as refining elements, and their effects on the microstructure have been investigated.[4] Many combinations of, e.g., indium (In), antimony (Sb), bismuth (Bi), copper (Cu), and silver (Ag) are also used as alloying elements.[2] Extensive knowledge and understanding of the mechanical behavior of the emerging generation of lead-free solders is required to satisfy the demands of structural reliability.

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