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Wetting Behavior of Ternary Au-Ge-X (X = Sb, Sn) Alloys on Cu and Ni

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Au-Ge-based alloys are potential substitutes for Pb-rich solders currently used for high-temperature applications. In the present work, the wetting behavior of two Au-Ge-X (X = Sb, Sn) ternary alloys, i.e., Au-15Ge-17Sb and Au-13.7 Ge-15.3Sn (at.%), in contact with Cu and Ni substrates has been investigated. Au-13.7Ge-15.3Sn alloy showed complete wetting on both Cu and Ni substrates. Total spreading of Au-15Ge-17Sb alloy on Cu was also observed, while the final contact angle of this alloy on Ni was about 29°. Pronounced dissolution of Cu substrates into the solder alloys investigated was detected, while the formation of Ni-Ge intermetallic compounds at the interface of both solder/Ni systems suppressed the dissolution of Ni into the solder.

Key words: High-temperature solder, Au-Ge-based solder, wetting

INTRODUCTION

Au-Ge-based alloys have recently become of interest as potential lead-free solders for high-temperature applications.[1–4] The Au-Ge phase diagram shows the existence of a simple eutectic at 634 K.[5] Besides, Au-Ge-based alloys also possess many interesting properties which are required for high-temperature solders: better thermal conductivity than currently used high-lead-content solders,[6] good corrosion and oxidation resistance in the presence of high humidity at elevated temperatures, tendency for glass forming[7] which eases production of thin foils that are much more convenient to be applied than paste in many applications, low natural radius of curvature for use in miniaturization industry, and excellent biocompatibility and workability for environmental and health considerations.

On the other hand, addition of elements with low melting points, such as Sb, Sn or In, to the Au-Ge eutectic alloy leads to a further decrease of the melting point.[1,8,9] In particular, addition of Sb to the Au-Ge eutectic substantially improves its ductility.[1]

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The wetting performance of solder alloys is very important, since it directly affects the integrity of solder interconnections. Study of wetting behavior is not only an important step in the characterization of solder alloys but also provides basic physicochemical data for design and development of novel lead-free solder alloys. However, rather limited information on the wetting behavior of Au-Ge-based alloys on relevant substrates is available. The wettability of Au-Ge alloy on SiC and Be substrates has been studied by Wang et al. and Gilliland, respectively.[10,11] Strong wetting of Au-Ge eutectic alloy on Cu and Ni has been recently reported by Leinenbach et al.[12] Wetting tests performed using Ag-Au-Ge solder alloys in contact with Ni substrate[13,14] revealed good wettability and interfacial bonding. However, no information is available on the wettability of other Au-Ge-based ternary solders so far.

The development of computational thermodynamics has accelerated the materials design process. In our previous work,[8,9] the Au-Ge-Sb and Au-Ge-Sn ternary systems were thermodynamically assessed using the CALculation of PHAse Diagram (CALPHAD) method.[15] Figures 1 and 2 show the calculated Au-Ge-Sb and Au-Ge-Sn liquidus projections from Refs. 8 and 9, respectively. Some alloy compositions