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# Corrosion Behavior of Pb-Free Sn-1Ag-0.5Cu-*X*Ni Solder Alloys in 3.5% NaCl Solution

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Potentiodynamic polarization techniques were employed in the present study to investigate the corrosion behavior of Pb-free Sn-1Ag-0.5Cu-*X*Ni solder alloys in 3.5% NaCl solution. Polarization studies indicated that an increase in Ni content from 0.05 wt.% to 1 wt.% in the solder alloy shifted the corrosion potential ($E_{corr}$) towards more negative values and increased the linear polarization resistance. Increased addition of Ni to 1 wt.% resulted in significant increase in the concentration of both Sn and Ni oxides on the outer surface. Secondary-ion mass spectrometry and Auger depth profile analysis revealed that oxides of tin contributed primarily towards the formation of the passive film on the surface of the solder alloys containing 0.05 wt.% and 1 wt.% Ni. Scanning electron microscopy (SEM) and energy-dispersive x-ray spectroscopy (EDX) established the formation of a Sn whisker near the passive region of the solder alloy obtained from the polarization curves. The formation of Sn whiskers was due to the buildup of compressive stress generated by the increase in the volume of the oxides of Sn and Ni formed on the outer surface. The presence of $Cl^-$ was responsible for the breakdown of the passive film, and significant pitting corrosion in the form of distinct pits was noticed in Sn-1Ag-0.5Cu-0.5Ni solder alloy after the polarization experiment.

**Key words:** Corrosion, Pb-free solder alloy, polarization, passivity, pitting, SIMS

## INTRODUCTION

Due to the inherent toxicity of Pb-containing compounds, there has been a worldwide effort to eliminate Pb-containing solders from the electronics industry. Also, increased health concerns over the use of lead present in eutectic Sn-Pb solders have promoted the development of new lead-free solders for microelectronic packaging.[1–3] Among the new lead-free solders, the new eutectic Sn-Ag-Cu (SAC) solder alloys have been the most promising candidates for replacement of Pb-containing solders in packaging and interconnect applications.[4–6] The advantages of this alloy system over the Sn-Ag binary eutectic alloy are its superior mechanical properties, relatively low melting temperature, and good solderability.[7] Addition of copper also enhances the corrosion resistance of Sn-Ag solder alloys, which exhibit improved passivity behavior compared with $Sn_{73.9}Pb_{26.1}$ solder.[8] With the development of surface-mount technology and the popular trend towards ultrafine-pitch designs, it has become imperative to develop new lead-free solders with improved mechanical properties.[9] To further enhance the properties of SAC solder alloys, alloying elements such as Bi, Sb, Sn, and Ni have been added to these alloys.[10,11] Wang et al.[12] observed that addition of Ni to SAC solders retarded $Cu_3Sn$ growth and also changed the microstructure of the $Cu_6Sn_5$ compound formed near the interface. Dudek et al.[13] observed that addition of a small amount of rare-earth (RE) elements improved the reliability of SAC solder joints. Wang[14] found that addition of a trace amount of the RE cerium (Ce) also had a significant effect on the properties of SAC solder, such as the wetting, microstructure, creep behavior, and tensile properties of solder joints. Kim et al.[15] reported that

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