

## Influence of Al addition on thermal parameters, microstructure and hardness of a Sn-Cu eutectic alloy

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### Abstract

The present work investigated the microstructure evolution as well as the mechanical property (Vickers microhardness) of Sn-0.7%Cu alloy samples (with and without the addition of 0.1%Al) obtained by unsteady-state solidification. The use of a water-cooled solidification device permitted to encompass the cooling conditions found in real welding situations. An experimental approach to determine quantitatively the thermal parameters such as growth and cooling rates was carried out. Metallographic investigations of solidification microstructures were performed and the microstructural spacing were correlated with the thermal parameters and, with the mechanical property of Vickers microhardness.

### Key words:

Solidification, Electronic solder alloy, Microstructure.

### Introduction

During the last years, the manufacturing processes of electronic devices have been fitting to the new directives that restrict the use of hazardous substances in electrical and electronic equipment. The classic solder alloy used by electronic industry is the eutectic alloy Sn-37%Pb. The European Union (EU) and the United States of America (USA), through their regulatory agencies, banned the lead (Pb) in electronic products, aiming to reduce the environmental impacts, and thus, demanding the research of alternative Pb-free solder alloys. In this sense, Pb-free solder alloys should be of great interest to electronic industry in order to replace the classic Sn-Pb alloy. Preliminary studies indicate that Sn-Zn, Sn-Bi, Sn-Ag and Sn-Cu alloys consist in promising alternatives. The Sn-Cu alloys have been receiving much attention not only due to its low cost when compared to alternative alloys containing silver (Ag), but also due to their excellent weldability in commercial scale.

This work aims to investigate the influence of Al addition in an eutectic Sn-Cu alloy, solidified by upward unidirectional unsteady-state condition. Correlations among thermal parameters of solidification, microstructural spacings and Vickers microhardness have been established.

### Results and Discussion

The cooling rate profile, from the ingot with addition of 0.1%Al, is lower than the one without addition whilst the growth rate was the same for both cases.

The microstructural analysis showed dendrites in the entire ingot of both alloys. The X-Ray Diffraction tests showed that, in the ingot with the Al addition, the presence of  $\delta$ -Al<sub>2</sub>Cu instead of Cu<sub>6</sub>Sn<sub>5</sub> which was suppressed according to the literature (Yang et al., 2014). In addition,  $\delta$ -Al<sub>2</sub>Cu is finer than Cu<sub>6</sub>Sn<sub>5</sub>.

It was observed that the hardness for the Sn-0.7%Cu varied from 11 to 13.2HV, while the Sn-0.7%Cu-0.1%Al varied from 8.2 to 10.5HV. These results were considered suitable for soldering application since they are both close to the hardness of 12.9HV of the Sn-Pb reported in the literature (Siewert et al., 2002).

The correlation established between microstructural spacing and cooling rate was (figure 1.a)  $\lambda_1=51(T)^{-0.55}$  ( $R^2=0.85$ ). Analogously for microhardness (figure 1.b), the expressions obtained were  $HV=10+16(\lambda_1)^{-1/2}$  ( $R^2=0.92$ ) for Sn-0.7%Cu and  $HV=7.5+16.6(\lambda_1)^{-1/2}$  ( $R^2=0.62$ ) for Sn-0.7%Cu-0.1%Al.

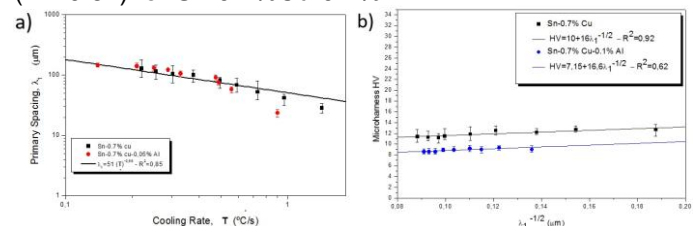


Figure 1. Correlation between primary dendritic spacing among (a) cooling rate and (b) microhardness.

### Conclusions

- The Sn-0.7%Cu-0.1%Al alloy showed intermetallics more refined than the ones from Sn-0.7%Cu;
- The Sn-0.7%Cu-0.1%Al alloy presented  $\delta$ -Al<sub>2</sub>Cu intermetallic while Sn-0.7%Cu, the Cu<sub>6</sub>Sn<sub>5</sub>;
- The Sn-0.7%Cu-0.1%Al revealed lower values of Vickers hardness if compared to Sn-0.7%Cu indicating that the Al addition enhances ductility.

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