Effect of In, Al, and Cu Addition on Corrosion behavior of Sn-based Ternary Lead-free Solder Alloys

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by

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Chapter-7

Summary and Suggestions for Future Work

7.1 Introduction

This chapter summarizes the essential observations presented in the thesis and gives brief incitement of the scope of future research to be carried out.

7.2 Overall Conclusion

Solder alloys are widely used in the electronic industry for electronic component joining and assembly because they provide mechanical and electrical properties. Sn-Pb-based solder alloys predominate the choice of the electronic industry, but the use of lead-based solder alloys was limited due to the toxicity nature of lead on humans and the environment. The most famous alloys, such as SAC305 and SAC405 silver-based alloys, replace Sn-Pb solder. But the cost of silver-based alloys is very high due to the patent of these alloys and silver cost. In this investigation, three lead-free solder alloys were successfully developed.

The following results were obtained from the electrochemical corrosion behaviour of Sn-0.7Cu-xIn solder alloys in 3.5wt. % NaCl.

- An increase of indium content from 1 to 3 weight percentage leads to a significant improvement in corrosion resistance of Sn-0.7Cu solder alloys, resulting in a higher range of pseudo passivation and lower current density pseudo passivation.
- By the addition of Indium to Sn-Cu binary solder alloys, β-Sn grains have been significantly refined. The resulting microstructure of fine solder alloys now has a more uniform distribution of various phases, which is responsible for improving corrosion resistance.

- The addition of Indium in Sn-0.7Cu solder alloys modifies the morphology of corrosion products on alloys' surfaces and changes the corrosion kinetics from the charge transfer to the diffusion control process.
- The corrosion products on the surface of all solder alloys studied after potentiodynamic polarisation consists of tin oxide chloride hydroxide $Sn_3O(OH)_2Cl_2$ and $Sn_4(OH)_6Cl_2$.

The following results were obtained from the electrochemical corrosion behaviour of Sn-0.7Cu-xAl solder alloys in 3.5wt. % NaCl.

- As a result of adding Al to the Sn-0.7Cu alloy, the microstructure of corrosion products on the surface of solder alloys would alter. The kinetic characteristics of the corrosion product layer would shift from the charge transfer control process to the diffusion control process.
- The inclusion of Al refines the coarse primary Sn phase and generates a homogeneous eutectic microstructure, which increases corrosion resistance. Sn-0.7Cu-1Al has a superior corrosion resistance than Sn-0.7Cu-2Al and Sn-0.7Cu-3Al.
- When Al addition to Sn-0.7Cu alloys is more than 1wt.%, Al_2Cu IMCs are formed. Those IMCs would break the corrosion product layer's continuity, causing pitting and reducing the corrosion resistance of Sn-0.7Cu alloys due to their presence.
- The corrosion products on the surface of all solder alloys studied after potentiodynamic polarization consists of tin oxide hydroxide chloride $Sn_{21}Cl_{14}(OH)_{14}O_6$.

The following results were obtained from the electrochemical corrosion behaviour of Sn-9Zn-xCu solder alloys in 3.5wt. % NaCl.

- The Corrosion rate observed from the potentiodynamic polarization test reveals that the highest corrosion rate (0.15056×10^{-2} mm/y) was observed for the Sn-9Zn alloy and the lowest (0.0693×10^{-2} mm/y) for that of Sn-9Zn-3Cu. The immersion test and EIS measurements revealed a similar trend in the corrosion performance of the Sn-9Zn-xCu alloy in 0.5M NaCl solution.
- When copper is added to the Sn-9Zn solder alloy, the corrosion kinetics shift from charge transfer to diffusion control.
- The inclusion of copper in Sn-9Zn solder binary solder alloy resulted in a more uniform distribution of intermetallic phase and refined microstructure, which is responsible for improving corrosion resistance.
- Corrosion product formation on the surface of alloys was primarily zinc hydroxide chloride ($Zn_5(OH)_8Cl_2.H_2O$), tin oxide chloride hydroxide ($Sn_3O(OH)_2Cl_2$), tin oxide (SnO), and zinc oxide (ZnO) have plate-like forms.

7.3 Suggestions for Future Work

The following are the suggestions for future work on lead-free solder alloys in the present investigations

1. It is suggested to evaluate the Mechanical properties like elongation to failure and hardness as these alloys are not very brittle. Brittle solder alloy will very quickly break at the contact due to the formation of intermetallic.

2. The melting temperature of all solder alloys should be measured to find an accurate operation temperature.
3. The wetting behaviour of all solder alloys is needed to be studied.
4. The corrosion behaviour of the lead-free solder alloys may be studied by adding greater than 3wt.% of Cu, In, Al in Sn-9Zn-xCu, Sn-0.7Cu-xIn, and Sn-0.7Cu-xAl, respectively.