Journal of Materials Science and Engineering A 8 (9-10) (2018) 185-189
doi: 10.17265/2161-6213/2018.9-10.002

The Effect of Electrochemical Migration of Pb-free Sn-3.0Ag-0.5Cu Solder Reinforced by NiO Nanoparticles

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Abstract: As electronic devices continue to become lighter and thinner, they require much smaller solder joints and fine-pitch interconnections for microelectronic packaging. Pb-free solders incorporated with nano-sized particles have been identified as potential Pb-free nanocomposite solders that could provide higher microstructure stability and better mechanical properties than the conventional solders. The present study investigates the effects of NiO addition on the mechanical properties and microstructure of the Sn-3.0Ag-0.5Cu (SAC305) solder alloy. In this study, three different solder alloys were prepared by reflow soldering. Sn-3.0Ag-0.5Cu (SAC 305) solder alloys were doped with different percentage of NiO (nickel oxide) nanoparticles content; i.e. 0.01 wt%, 0.05 wt%, and 0.15 wt% in producing nanocomposite solder paste. Morphology refinement of SAC305-NiO nanocomposite solder contributed to the enhancement of mechanical properties in the field of microelectronic industries. ECM (electrochemical migration) of SAC-NiO nanocomposites solder pastes was measured using a WDT (water drop test). Effects of electrochemical migration of its surface morphology were investigated using OM (optical microscopy).

Key words : SAC305, NiO nanoparticle, microstructure, corrosion, dendrite.

1. Introduction

Soldering offers important technology on microelectronic packaging industries. It allows electrical current to flow from one point to another and become a supporter of the electrical components. Recently, lead free, tin, silver and copper (Sn-Ag-Cu) solder alloy has been commercially used as an alternative to tin and lead (Sn-Pb) solder due to the vital issue on hazardous effect [1–4]. This is due to poisonous qualities of lead which are harmful to human health and also to the environment [5].

Tin based solder alloy becomes the replacement for lead solder alloy. Tin has been described as the most attractive element for the replacement of the typical Sn-Pb solder as it can overcome the environmental problem and fulfil economic growth and metallurgical development [4]. Tin containing binary and ternary alloying elements has been most directed towards it [6].

Basically, not all lead free solders are suitable to be used in microelectronic packaging aspects since reflow soldering poses risk of damaging electronic components [7–9]. Other researchers had focused on some lead-free content solders which may cause high risk in electronic devices due to ECM (electrochemical migration) failure phenomenon [9]. ECM commonly occurs in all electronic devices in the electronic industry. This phenomenon involves the dendritic growth [10, 11] . It will led to short circuit to occur in the electronic device issue which is related to the susceptibility of Sn-Ag-Cu to corrosion [12].

The overall properties include the mechanical properties and reliability of lead free solders as Sn-Pb solder replacements is very promising [13]. Moreover, the properties of the lead-free solder alloys containing NiO nanoparticles have not been widely reported even though it is an important issue in many work fields.

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According to the previous work, researchers tend to investigate of lead free solder alloys using alkaline solution, acidic solution and saline solution [13]. ECM investigation of the lead-free SAC305 contains NiO nanoparticles solder alloy when it is exposed to NaCl (sodium chloride) solution that simulates the seawater [14].

Therefore in this paper, the ECM behaviour of lead-free SAC305 is investigated by using the WDT with NaCl solution as a medium. It was carried out to record the time-to-failure of each sample. The results are then taken to compare its susceptibility to ECM despite using OM (optical microscopy).

2. Experimental Setup

Water Drop Test (WDT) is carried out by using a standard comb pattern. It was designed according to the IPC-B-24 test board as shown in Fig. 1. The test board was well-printed with SAC305 containing different wt.% of NiO content solder alloy by using DEK NeoHorizon 01 iX, then the test board passed into reflow soldering by using Vitronics XPM2 Reflow Oven. Fig. 2 shows the schematic diagram of the applied test platform of WDT. The time-to-failure which indicates the short circuit formation was detected by voltage step measurements on a resistor (R =1 kΩ) connected in series to the interdigital structure.

During WDT, a droplet of 15 µmL NaCl solution was placed by micropipette onto comb patterns and 10 V DC was applied. To simulate the seawater or other salty contaminations, a WDT has to be carried out by using deionized water. Based on investigation by other researcher , the MTTF (mean-time-to-failure)

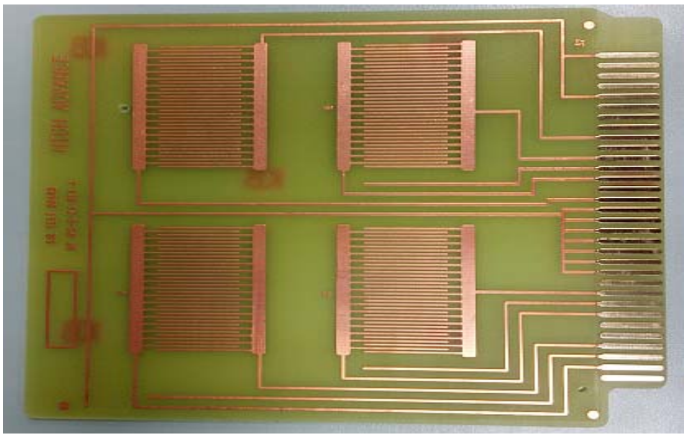


Fig. 1 IPC-B-24 standard comb pattern test board.

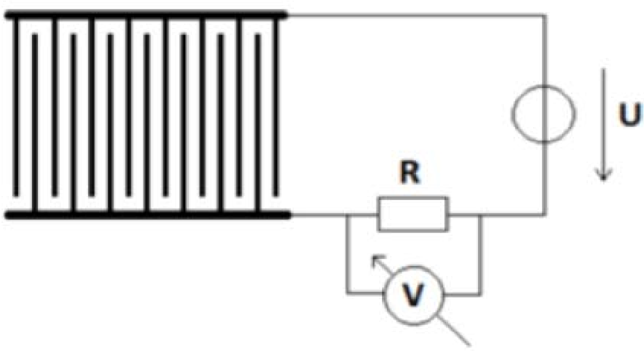


Fig. 2 Schematic diagram of the test platform of WDT.

shall not be less than 180 s. If the dendrites grow within 180 s, it shows that the tests board us unclean and it cannot further continue with WDT using the NaCl solution [15]. The formation of dendrites was monitored visually by an optical microscope AXIOLAB A1 [16].

3. Experimental Results

3.1 MTTF Analysis

WDT has been carried out by using electric current and NaCl solution with the power voltage, resistance and volume of solution droplets set constant. While carrying out the WDT, the time taken for the short circuit to occur, that is the time-to-failure when the voltage value drops to 0 V, is recorded. The average values of measured failure times are then calculated as MTTF. Results are shown in Fig. 3.

Referring to Fig. 3, SAC 305 added with 0.15wt% of NiO nanoparticles has shown the longest MTTF in 1 M of NaCl. Then, it is followed by SAC305-0.05wt%, SAC305-0.01wt% and SAC305 only. According to Tanaka (2002), the phenomenon related to chemical solutions and electric potential is known as ionic migration or the ECM [17]. In this case, SAC305-NiO wt% is believed to have undergone ECM where the metal ion has migrated themselves from the anode to cathode causing the depreciation of voltage to 0 V and the failure of whole devices. Based on the previous literatures, this ECM phenomenon is related to the susceptibility of SAC305 towards corrosion. Therefore, it can be said that SAC305 corrodes at the fastest rate when it does not contain NiO nanoparticles. Whilst, when the solder alloy SAC305 is added with NiO nanoparticles, the rate of corrosion decreases.

3.2 Optical Microscope Observation

OM had been used to observe the IPC-24 test board after the WDT. The changes occur observed under OM. Fig. 4 exhibits that all the test board samples had undergone the electrochemical migration. The formation of dendrites leads to the short circuit of the microelectronic board.

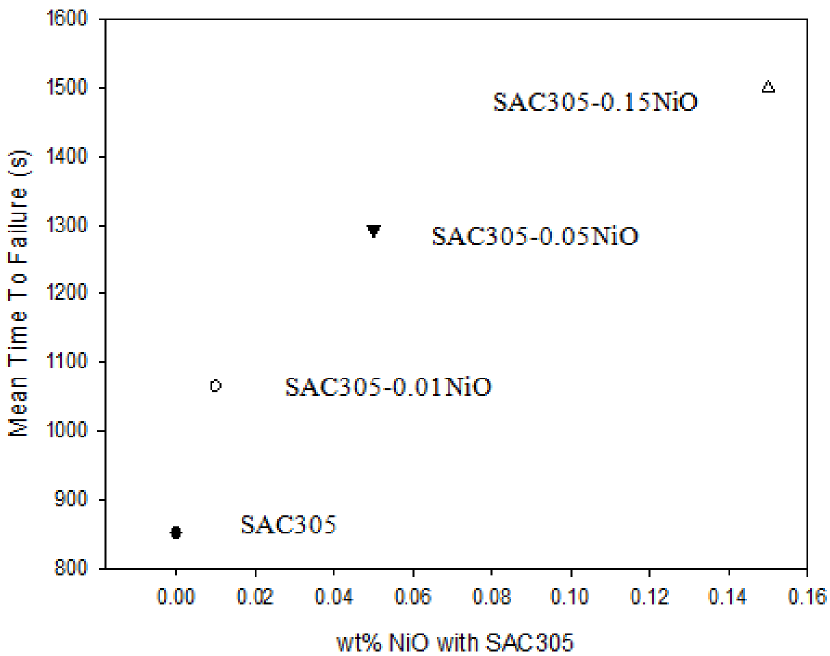
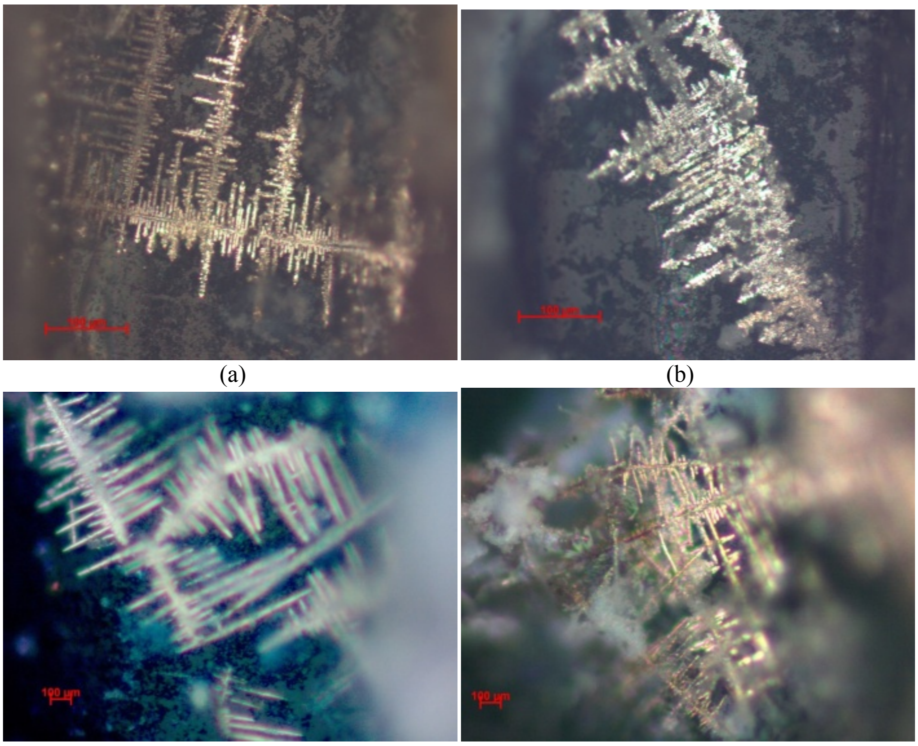


Fig. 3 MTTF of SAC 305 added with 0.01, 0.05, 0.15wt% NiO with NaCl solution.



(a) (b) (c) (d)

Fig. 4 Optical microscopy image of SAC305 at magnification of 100X. (a) SAC305; (b) SAC305-0.01NiO; (c) SAC305-0.05NiO; (d) SAC305-0.15NiO after WDT using NaCl solution.

4. Conclusions

Based on the findings, it can be concluded that:

The corrosion susceptibility of SAC 305 is affected by the addition of NiO used. The greater the wt% of NiO nanoparticles used, the greater or slower the MTTF, the weaker the susceptibility to corrosion.

Acknowledgments

The authors would like to acknowledge the financial support provided by the UKM research grant FRGS/1/2016/STG07/UKM/02/1 and JABIL circuit for the cooperation in this research.

References

[1] Elektroniikan, E. H. 2015"Comparing SAC and SnCuNi Solders in Lead-Free Wave Soldering Process." Presented at NEXT Symposium, Finland.

[2] Biocca, P., and Rivas, C. 2008 "Case Study on the Validation of SAC305 and SnCu-based Solders in SMT, Wave and Hand-Soldering at the Contract Assembler Level." *Proc. Int. Symp. Exhib. Adv. Packag. Mater. Process. Prop. Interfaces*, pp. 152–7.

[3] Loss, W. 2004. "A Study of Lead-Free Wave Soldering." *Am.*, pp. 7–8.

[4] Efzan Mhd Noor, E., and Singh, A. 2014. "Review on the Effect of Alloying Element and Nanoparticle Additions on the Properties of Sn-Ag-Cu Solder Alloys." *Solder. Surf. Mt. Technol.* 26 (3): 147–61.

[5] Jung, J. Y., Lee, S. B., Lee, H. Y., Joo, Y. C., and Park, Y. B. 2008. "Effect of Ionization Characteristics on Electrochemical Migration Lifetimes of Sn-3.0Ag-0.5Cu Solder in NaCl and Na_2SO_4 Solutions." *J. Electron. Mater.* 37 (8): 1111–8.

[6] Ahmad, I., Jalar, A., Majlis, B. Y., and Wagiran, R. 2007. "Reliability of SAC405 and SAC387 as Lead-Free Solder Ball Material for Ball Grid Array Package." *International Journal of Engineering and Technology* 4 (1): 123–33.

[7] Yamamoto, T., and Tsubone, K. I. 2007 "Assembly Technology Using Lead-Free Solder." *Fujitsu Sci. Tech. J.* 43 (1): 50–8.

[8] Kang, S. K., and Sarkhel, A. K. 1994. "Lead (Pb)-Free Solders for Electronic Packaging." *J. Electron. Mater.* 23 (8): 701–7.

[9] Medgyes, B., Illes, B., and Harsanyi, G. 2013 "Electrochemical Migration of Micro-alloyed Low Ag Solders in NaCl Solution." *Period. Polytech. Electr. Eng.* 57 (2): 49–55.

[10] Mendes, L. T. F., Cardoso, V. F., and da Silva, A. N. R.

2011. "Electrochemical Migration on Lead-Free Soldering of PCBs." *J. Integr. Circuits Syst.* 6 (2): 127–30.

[11] Wayman, G. A., et al. 2012. "PCB-95 Promotes Dendritic Growth via Ryanodine Receptor-Dependent Mechanisms." *Environ. Health Perspect.* 120 (7): 997–1002.

[12] See, C. W., Yahaya, M. Z., Haliman, H., and Mohamad, A. A. 2012. "Corrosion Behavior of Corroded Sn–3.0Ag–0.5Cu Solder Alloy." *Procedia Chem.* 19 (5): 847–54.

[13] Li, D., Conway, P. P., and Liu, C. 2014. "Corrosion Characterization of Tin-Lead and Lead Free Solders in 3.5 wt.% NaCl Solution." *Corros. Sci.* 50 (4): 995–1004.

[14] Zou, C. D., et al. 2009. "Nanoparticles of the Lead-Free Solder Alloy Sn-3.0Ag-0.5Cu with Large Melting Temperature Depression." *J. Electron. Mater.* 38 (2): 351–5.

[15] Nguyen, M. T. T. 2013. "Reliability Assessment of Ion Contamination Residues on Printed Circuit Board." M.Sc. thesis, University of South Florida.

[16] Othman, N. K., Teng, K. Y., Jalar, A., Che Ani, F., and Samsudin, Z. 2016. "Electrochemical Migration Behaviours of Low Silver Content Solder Alloy SAC 0307 on Printed Circuit Boards (PCBs) in NaCl Solution." *Mater. Sci. Forum* 846: 3–12.

[17] Tanaka, H. 2002. "Chemical Solutions and Electric Potential is Known as Ionic Migration or the ECM." *Espec Technology report* 14: 1-9.