Properties of SnAgCu Solders Bearing Al Nanoparticles

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***Abstract*—In order to enhance the properties of SnAgCu lead-free solders, the Al nanoparticles was selected as the additives. The effects of Al nanoparticles on wettability and mechanical properties of solder and solder joints were studied. The results showed that a small amount of Al can enhance the wettability of SnAgCu solders. With the N_2 atmosphere, the wettability of SnAgCu-xAl can be increased obviously, which can be attributed to the N_2 can resist the oxidation of molten solder. Combing different fluxes, the wettability of lead-free solder can represent variation, the suitable flux can improve the wettability of SnAgCu-xAl solders. Moreover, the mechanical property of solders can be improved obviously with the addition of Al nanoparticles.**

Keywords-lead-free solder; wettability; N2 atmosphere; mechanical property

I. INTRODUCTION

SnPb alloys have been used extensively in chip attachment and surface-mount processes in electronic packaging[1], the excellent properties showed by Pb-contained solders were not doubted until it was realized that lead is a hazardous element because of its toxicity[2]. Therefore, considering the health and environmental safety, the investigation of lead-free solders play an important role in electronic industry. Among series of lead-free alloys, SnAgCu solders have been regarded as the most promising solders that can replace traditional SnPb solders in electronic packaging[3,4]. Moreover, due to the requirement of high-density and high reliability in electronic device, the properties of SnAgCu solder should be improved to meet the development trend.

The addition of nanoparticles into solders was proposed as an effective way to improve the properties. Liu[5] found that the addition of grapheme nanosheets can enhance the wettability of SnAgCu solder, and low the CTE values. ZnO nanoparticles can reduce the β-Sn grain size and spacing between Ag_3Sn and Cu_6Sn_5 particles, this obviously improve the yield stress and ultimate tensile strength of SnAgCu solder[6]. Addition of SiC nanoparticles to SnAgBiIn lead-free solder refined its microstructure and improved its electromigration reliability under high current stress[7]. Al nanoparticles can improve the fatigue life of SnAgCu solder joints in QFP device under thermal cycling[8].

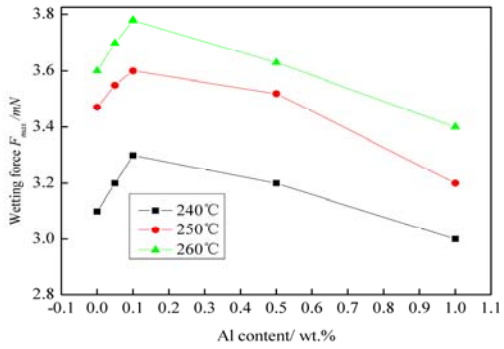
In this paper, the wetting balance method was used to analyze the wettability of SnAgCu solder bearing Al nanoparticles at different atmospheres and fluxes. In addition, the mechanical property and fatigue life of SnAgCu-Al solder joints were tested, the content of Al nanoparticles was optimized.

II. EXPERIMENTAL

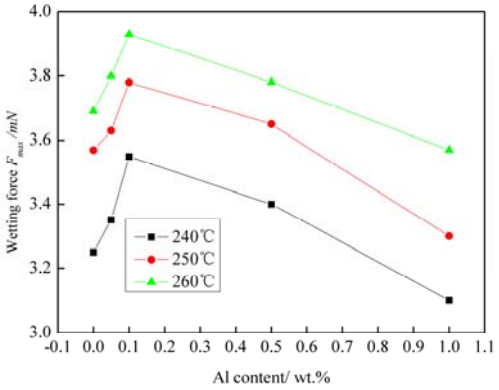
SnAgCu-based alloys were prepared via mechanically incorporating different contents of Al nanoparticles for about 15 minutes to promote uniform particles distribution. A Rhesca SAT-5100 wetting tester was used in the wetting experiments following IPC-J-STD-003B (solderability tests for printed boards) and Japanese Industry Standard JIS Z 3198-4 (Test methods for lead-free solders-Part 4: Methods for solderability test by a wetting balance method and a contact angle method)[9]. Moreover, different atmospheres (air and N_2) and different fluxes (R and RMA) were selected to be used in the solderability testing. And the SnAgCu-xAl solders were used for soldering of R0805 resister, and STR-1000 tester was used to testing the shear force of SnAgCu-xAl solder joints in R0805 resister.

III. WETTABILITY

Wetting is crucial for soldering because it plays an essential role to ensure the good bonding between the solder materials and the substrate, wettability between the solder and substrate is also an important issue in reliability of electronic products[10]. The wetting time and maximum wetting force in the wetting balance testing can be used to evaluate the effect of Al nanoparticles on the wettability of SnAgCu solders. Figure 1~Figure 4 show the data of wettability with different Al content, temperatures, atmospheres and fluxes. It is found that when the content of Al nanoparticles is less than 0.1%, the wetting force increases and wetting time decreases as Al increases. When the content of Al nanoparticles is 0.1%, the wetting force of solders gives a maximum increase, and wetting time shows a maximum decrease. When the content of Al is over 0.1%, there is an opposite tendency for the wetting data to happen obviously.

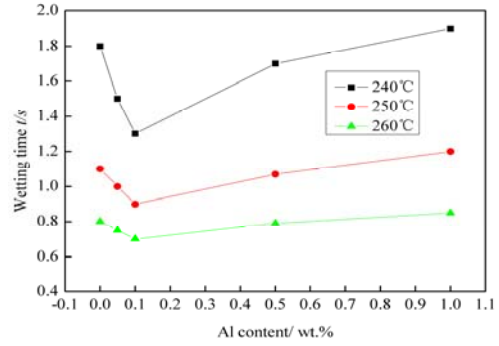


(a) Air



(b) N_2

FIGURE I. WETTING FORCE OF SnAgCu-xAl SOLDERS DURING DIFFERENT ATMOSPHERES WITH R FLUX.



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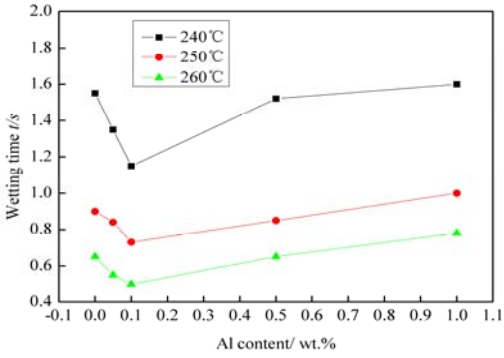
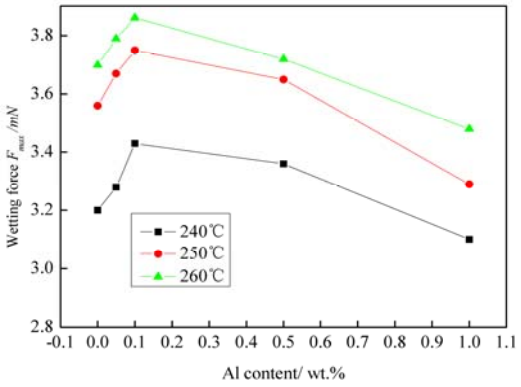


(b) N_2

FIGURE II. WETTING TIME OF SnAgCu-xAl SOLDERS DURING DIFFERENT ATMOSPHERES WITH R FLUX.

Moreover, comparing with the wettability of SnAgCu-xAl solders with air atmosphere, with N_2 atmosphere, the wetting force increases significantly, meanwhile the wetting time drops, which demonstrates that the N_2 atmosphere can improve the solderability of solders, which can be attributed to the N_2 can resist the oxidation of molten SnAgCu-xAl solders. And the fluxes transformation (R-RMA) can also improve the wettability of solders, however, the amplitude of enhancement is not higher than N_2 atmosphere. This is due to the minimal amount of oxygen in the N_2 atmosphere as compared to ambient, during heating of solder, although flux activation is present, some sort of oxides would still form. Prabhu[11] also demonstrated the advance effect of N_2 atmosphere in protecting the molten solders. Cheng[12] found the wettability was significantly improved by using the nitrogen protection, was more profound for the SnAgCu lead-free solders.



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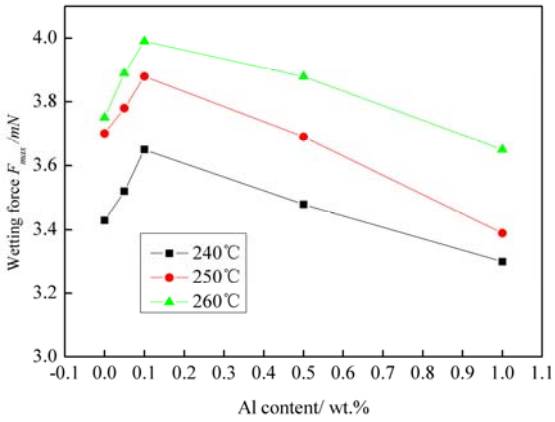
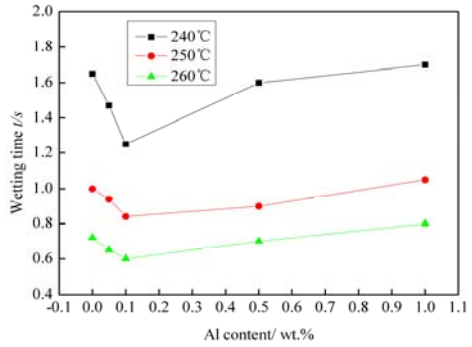
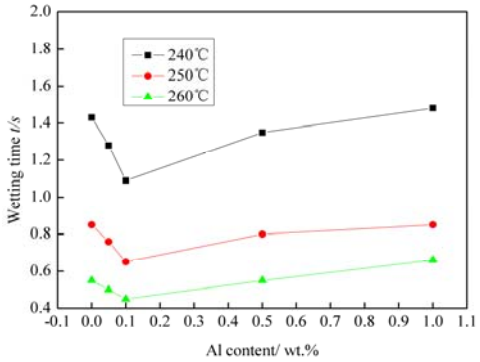


(b) N_2

FIGURE III. WETTING FORCE OF SnAgCu-xAl SOLDERS DURING DIFFERENT ATMOSPHERES WITH RMA FLUX.



(a) Air



(b) N_2

FIGURE IV. WETTING TIME OF SnAgCu-xAl SOLDERS DURING DIFFERENT ATMOSPHERES WITH RMA FLUX.

IV. MECHANICAL PROPERTY

Shear force of SnAgCu-xAl solder joints in R0805 resister was tested, which can be used to evaluate the effect of Al nanoparticles on the mechanical properties of SnAgCu solder joints. Figure 5 show the shear force of SnAgCu solder joints bearing different Al content, the results revealed that with the addition of Al nanoparticles as reinforcement, shear force can be improved significantly. When the Al content is more than 0.1%, the improvement effect is little, this can be attributed to the strength effect of nanoparticles, hindering the movement of dislocations and refinement of microstructure matrix of solder joints. Then it is can be concluded that the optimal content of Al nanoparticles is 0.1%.

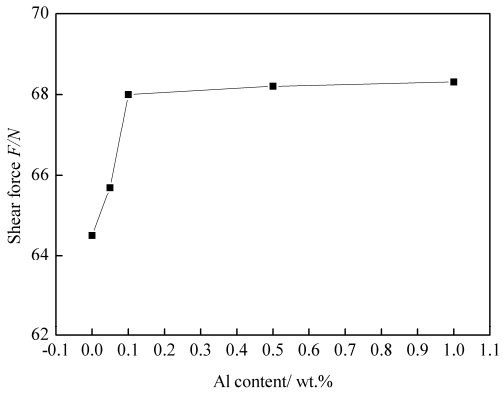


FIGURE V. SHEAR FORCE OF SnAgCu-xAl SOLDER JOINTS IN R0805 RESISTER.

V. CONCLUSIONS

With the addition of Al nanoparticles into SnAgCu alloys, the wettability of solders can be improved obviously, the optimum content of Al is 0.1 wt %, and with the N_2 atmosphere, the wettability of SnAgCu-xAl can be increased obviously, which can be attributed to the N_2 can resist the oxidation of molten solder. Combing different fluxes, the wettability of lead-free solder can represent variation, the suitable flux can improve the wettability of SnAgCu-xAl solders. And the shear force of SnAgCu-0.1Al is higher than that of SnAgCu solder.

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REFERENCES

[1] L Zhang, K N Tu. Structure and properties of lead-free solders bearing micro and nano particles[J]. Materials Science and Engineering: R: Reports, 2014, 82:1-32.

[2] S M A A Mohd, A M M A Bakri, H Kamarudin, M Bnhussain, H M H Zan, F Somidin. Solderability of Sn-0.7Cu/Si_3Ni_4 lead-free composite solder on Cu-substrate[J]. Physics Procedia, 2011, 22:299-304.

[3] A A EI-Daly, A E Hammad, G S AI-Ganainy, M Ragab. Properties enhancement of low Ag-content Sn-Ag-Cu lead-free solders containing small amount of Zn[J]. Journal of Alloys and Compounds, 2014, 614:20-28.

[4] L Zhang, J G Han, Y H Guo, L Sun. Properties and microstructures of SnAgCu-xEu alloys for concentrator silicon solar cells solder layer[J]. Solar Energy Materials and Solar Cells, 2014, 130:397-400.

[5] X D Liu, Y D Han, H Y Jing, J Wei, L Y Xu. Effect of graphene nanosheets reinforcement on the performance of Sn-Ag-Cu lead-free solder[J]. Materials Science & Engineering A, 2013, 562:25-32.

[6] A A EI-Daly, T A Elmosalami, W M Desoky, M G EI-Shaarawy, A M Abdraboh. Tensile deformation behavior and melting property of nano-sized ZnO particles reinforced Sn-3.0Ag-0.5Cu lead-free solder[J]. Materials Science & Engineering A, 2014, 618:389-397.

[7] Y Kim, S Nagao, T Sugahara, K Suganuma, M Ueshima, H J Albrecht, K Wilke, J Strogies. Refined of the microstructure of Sn-Ag-Bi-In solder, by addition of SiC nanoparticles, to reduce electromigration damage under high electric current[J]. Journal of Electronic Materials, 2014, Doi:10.1007/s11664-014-3377-x.

[8] L Zhang, X Y Fan, Y H Guo, C W He. Microstructures and fatigue life of SnAgCu solder joints bearing nano-Al particles in QFP devices[J]. Electronic Materials Letters, 2014, 10(3):645-647.

[9] H Wang, S B Xue, F Zhao, W X Chen. Effects of Ga, Al, Ag, and Ce multi-additions on the wetting characteristics of Sn-9Zn lead-free solder[J]. Rare Metals, 2009, 28(6):600-605.

[10] L Zhang, J H Cui, J G Han, Y H Guo, C W He. Microstructures and properties of SnZn-xEr lead-free solders[J]. Journal of Rare Earths, 2012,30(8):790-793.

[11] K N Prabhu, M Varun, Satyanarayan. Effect of purging gas on wetting behavior of Sn-3.5Ag lead-free solder on nickel-coated aluminum substrate[J]. Journal of Materials Engineering and Performance, 2013, 22:723-728.

[12] F J Cheng, F Gao, J Y Zhang, W S Jin, X Xiao. Tensile properties and wettability of SAC0307 and SAC105 low Ag lead-free solder alloys[J]. Journal of Materials Science, 2011, 46:3424-3429.