Effect of Sn-*x*Cu Solder Alloy onto Intermetallic Formation After Laser Soldering

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Abstract: The awareness of lead-free solders can be attributed to their environmental and human-health related benefits. Due to this consciousness, research toward lead-free solder alloy became a concern. Tin-copper (SnCu) solder alloy is one of the candidates that can meet the characteristic of tin-lead (SnPb). The objective of this study is to analyse the wetting behaviour, intermetallic compound (IMC) thickness and also the spread ratio by varies the copper weight percentage (Cu wt%) in SnCu solder alloy. Solder alloy used was Sn-*x*Cu, where x = 0.0, 0.3, 0.5, 0.7, 1.0 which was soldered onto electroless nickel immersion gold (ENIG) substrate using carbon dioxide (CO_2) laser. Parameters used for laser soldering was 35 watts for the laser power, focal length was kept constant, scanning time was 0.04s, and scanning speed was 100mm /s. Then these sample were subjected to isothermal aging with the duration of 0, 200, 500, 1000 and 2000 hours. In the final analysis, the IMC thickness and wetting behaviour characteristics were characterized by metallographic microscopy. The results showed that the higher the Cu percentage in the solder alloy, the higher the thickness formed at the solder joint interface. Besides that, the morphology of IMCs additionally changed with aging time whereby it changed into much uniform and continuous shape, Nonetheless, its thickness was found to be increasing upon aging duration. Furthermore, the spread factor and spread ratio increase, but the equilibrium contact angle decreases with increasing Cu content. These results were the proof that Sn-0.7Cu/ENIG offers a good solder joint performance as compared to other copper percentage.

Keywords: Solder alloy, laser soldering, intermetallic compound, wetting behaviour

1 Introduction

In the last several years, tin-lead (SnPb) solder is used in electronics manufacturing because it has higher thermal resistance, improved mechanical characteristics, and smaller melting point, consequent in higher bond strength in solder connection [1]–[3]. Nevertheless, the European Union (EU) Waste Electrical and Electronic Equipment (WEEE) regulation prohibits usage of lead in electronic products on 2006. [4].

of the solder during solidification. The higher Cu amount interrupted the solder wettability, because the melt viscosity is increased and the solders spread over the substrate is reduced.

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6 Reference

[1] L. Zhang and L. Gao, "Interfacial compounds growth of SnAgCu(nano La2O3)/Cu solder joints based on experiments and FEM," *J. Alloys Compd.*, vol. 635, pp. 55–60, 2015, doi: https://doi.org/10.1016/j.jallcom.2015.02.110.

[2] M. K. Pal, G. Gergely, D. Koncz-Horváth, and Z. Gácsi, "Investigation of the Electroless Nickel Plated Sic Particles in Sac305 Solder Matrix," *Powder Metall. Met. Ceram.*, vol. 58, no. 9, pp. 529–537, 2020, doi: 10.1007/s11106-020-00107-y.

[3] H. Ma and J. C. Suhling, "A review of mechanical properties of lead-free solders for electronic packaging," *J. Mater. Sci.*, vol. 44, no. 5, pp. 1141–1158, 2009, doi: 10.1007/s10853-008-3125-9.

[4] J.-W. Yoon and S.-B. Jung, "Interfacial reactions between Sn–0.4Cu solder and Cu substrate with or without ENIG plating layer during reflow reaction," *J. Alloys Compd.*, vol. 396, no. 1, pp. 122–127, 2005, doi: https://doi.org/10.1016/j.jallcom.2004.12.009.

[5] I. Shohji, T. Yoshida, T. Takahashi, and S. Hioki, "Tensile properties of Sn–Ag based lead-free solders and strain rate sensitivity," *Mater. Sci. Eng. A*, vol. 366, pp. 50–55, Feb. 2004, doi: 10.1016/j.msea.2003.09.057.

[6] T. Takemoto and T. Funaki, "Role of Electrode Potential Difference between Lead-Free Solder and Copper Base Metal in Wetting," *Mater. Trans.*, vol. 43, no. 8, pp. 1784–1790, 2002, doi: 10.2320/matertrans.43.1784.

[7] K. Zeng and K. N. Tu, "Six cases of reliability study of Pb-free solder joints in electronic packaging technology," *Mater. Sci. Eng. R Reports*, vol. 38, no. 2, pp. 55–105, 2002, doi: https://doi.org/10.1016/S0927-796X(02)00007-4.

[8] J. Glazer, "Metallurgy of low temperature Pb-free solders for electronic assembly," *Int. Mater. Rev.*, vol. 40, no. 2, pp. 65–93, Jan. 1995, doi: 10.1179/imr.1995.40.2.65.

[9] Z. Zhao, C. Wang, M. Li, and L. Wang, "Nd:YAG laser surface treatment of copper to improve the wettability of Sn3.5Ag solder on copper," *Surf. Coatings Technol.*, vol. 200, no. 7, pp. 2181–2186, 2005, doi: 10.1016/j.surfcoat.2005.01.006.

[10] W. Luo, C. Ho, J. Tsai, Y. Lin, and C. Kao, "Solid-state reactions between Ni and Sn–Ag–Cu solders with different Cu concentrations," *Mater. Sci. Eng. A-*

structural Mater. Prop. Microstruct. Process. - MATER SCI ENG A-STRUCT MATER, vol. 396, pp. 385–391, Apr. 2005, doi: 10.1016/j.msea.2005.02.008.

[11] M. Abtew and G. Selvaduray, "Lead-free Solders in Microelectronics," *Mater. Sci. Eng. R Reports*, vol. 27, no. 5, pp. 95–141, 2000, doi: https://doi.org/10.1016/S0927-796X(00)00010-3.

[12] M. Zhao, L. Zhang, Z.-Q. Liu, M.-Y. Xiong, and L. Sun, "Structure and properties of Sn-Cu lead-free solders in electronics packaging," *Sci. Technol. Adv. Mater.*, vol. 20, no. 1, pp. 421–444, Mar. 2019, doi: 10.1080/14686996.2019.1591168.

[13] D. Q. Yu, C. M. L. Wu, D. P. He, N. Zhao, L. Wang, and J. K. L. Lai, "Effects of Cu Contents in Sn–Cu Solder on the Composition and Morphology of Intermetallic Compounds at a Solder/Ni Interface," *J. Mater. Res.*, vol. 20, no. 8, pp. 2205–2212, 2005, doi: DOI: 10.1557/JMR.2005.0275.

[14] C. B. Lee, S. B. Jung, Y. E. Shin, and C. C. Shur, "Effect of isothermal aging on ball shear strength in BGA joints with Sn-3.5Ag-0.75Cu solder," *Mater. Trans.*, vol. 43, no. 8, pp. 1858–1863, 2002, doi: 10.2320/matertrans.43.1858.

[15] J. Kim, W.-R. Myung, and S.-B. Jung, "Effects of Aging Treatment on Mechanical Properties of Sn-58Bi Epoxy Solder on ENEPIG-Surface-Finished PCB," *J. Electron. Mater.*, vol. 45, no. 11, pp. 5895–5903, 2016, doi: 10.1007/s11664-016-4803-z.

[16] C.-W. Hwang, K. Suganuma, M. Kiso, and S. Hashimoto, "Interface microstructures between Ni-P alloy plating and Sn–Ag–(Cu) lead-free solders," *J. Mater. Res.*, vol. 18, no. 11, pp. 2540–2543, 2003, doi: 10.1557/JMR.2003.0354.

[17] G. Zou, J. Yan, F. Mu, A. Wu, and Y. N. Zhou, "Recent progress in microjoining and nanojoining," *Hanjie Xuebao/Transactions China Weld. Inst.*, vol. 32, no. 4, pp. 107–112, 2011, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-79957667746&partnerID=40&md5=bd73953b19e5993693e1583565df1a10.

[18] C. Chaminade, E. Fogarassy, and D. Boisselier, "Diode laser soldering using a lead-free filler material for electronic packaging structures," *Appl. Surf. Sci.*, vol. 252, no. 13, pp. 4406–4410, 2006, doi: https://doi.org/10.1016/j.apsusc.2005.07.095.

[19] P. Xue-min, "The Growth Behavior of Interfacial IMC of Sn-0.7Cu/Cu by Laser Braze Welding," *J. Mater. Eng.*, 2009.

[20] L. D. Chen, M. L. Huang, and S. M. Zhou, "Effect of electromigration on intermetallic compound formation in line-type Cu/Sn/Cu interconnect," *J. Alloys Compd.*, vol. 504, no. 2, pp. 535–541, 2010, doi: https://doi.org/10.1016/j.jallcom.2010.05.158.

[21] C. K. Chung, J.-G. Duh, and C. R. Kao, "Direct evidence for a Cu-enriched region at the boundary between Cu6Sn5 and Cu3Sn during Cu/Sn reaction," *Scr. Mater.*, vol. 63, no. 2, pp. 258–260, 2010, doi: https://doi.org/10.1016/j.scriptamat.2010.04.011.

[22] M. K. Pal, G. Gergely, D. Koncz-Horváth, and Z. Gácsi, "Investigation of microstructure and wetting behavior of Sn–3.0Ag–0.5Cu (SAC305) lead-free solder with additions of 1.0 wt % SiC on copper substrate," *Intermetallics*, vol. 128, no. August 2020, 2021, doi: 10.1016/j.intermet.2020.106991.

[23] C. Yu, Y. Yang, P. Li, J. Chen, and H. Lu, “Suppression of Cu3Sn and Kirkendall voids at Cu/Sn-3.5Ag solder joints by adding a small amount of Ge,” *J. Mater. Sci. Mater. Electron.*, vol. 23, May 2012, doi: 10.1007/s10854-011-0412-z.

[24] J. O. Suh, K. N. Tu, G. V Lutsenko, and A. M. Gusak, “Size distribution and morphology of Cu6Sn5 scallops in wetting reaction between molten solder and copper,” *Acta Mater.*, vol. 56, no. 5, pp. 1075–1083, 2008, doi: https://doi.org/10.1016/j.actamat.2007.11.009.

[25] M. K. Pal and Z. Gácsi, “ANTAL KERPELY DOCTORAL SCHOOL OF MATERIALS SCIENCE & TECHNOLOGY Development of ceramic particle reinforced SAC305 lead-free solder composite material,” no. November, pp. 1–100, 2020, [Online]. Available: https://www.kerpely.uni-miskolc.hu/files/13101/Manoj Pal disszertáció.pdf.

[26] Y. Yan, G. Wang, K. Song, and K. Zhao, “Effect of Ag particles on wettability and creep rupture life of SnCu based composite solders,” *Mater. Sci. Forum*, vol. 650, pp. 78–84, 2010, doi: 10.4028/www.scientific.net/MSF.650.78.

[27] L. F. Li, Y. K. Cheng, G. L. Xu, E. Z. Wang, Z. H. Zhang, and H. Wang, “Effects of indium addition on properties and wettability of Sn–0.7Cu–0.2Ni lead-free solders,” *Mater. Des.*, vol. 64, pp. 15–20, 2014, doi: https://doi.org/10.1016/j.matdes.2014.07.035.

[28] D. M. Jacobson, *Principles of soldering*, vol. 42, no. 03. 2004.