Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals of DAAAM International

STUDY THE GROWTH OF INTERMETALLIC PHASES IN SN 3.5AG XCU (X = 0.3, 0.7, 1.0) / CU SOLDER JOINTS

SZEWCZYKOVA, B[eata]; LECHOVIC, E[mil]; HODULOVA, E[rika] & ULRICH, K[oloman]

Abstract: *The contribution deals with the study the growth of interfacial IMC compounds between SnAg3.5CuX lead-free solders and copper substrate. Aging of joints made with tin-silver solder containing 0.3%, 0.7% and 1.0% copper was carried out at various temperatures ranging to 160°C, at various times ranging to 360 h. The quality of soldered joints was assessed by optical microscopy and by X-ray microanalysis.*
Key words: *Lead-free solder, Intermetallic compound, Aging, Interfacial reaction, Activation energy*

1. INTRODUCTION

All known base materials, coatings in electronic products formed during brazing with an active element (usually Sn) in the molten solder intermetallic phase (IMF) at the interface solder - substrate. Their existence in contact area indicates the creation of a metallurgical quality service. As the trend in microelectronic devices is still progressing towards minimizing the dimensions of devices, chips, circuits, and single connections are exposed to unfavourable conditions. There is a higher evolution of more heat (heat vented from the encapsulated device) which resulted in a growing layer is IMF strong in thickness and solder interface - the IMF has become a source of light formation and spread of cracks (Vuorinen, V., 2006, Suganuma, Katsuaki, 2004, Šebo, et al., 2009).

Currently, lead-free solders from getting the attention of eutectic SnAg alloy. It has a higher melting point than SnPb alloy and no risk to the environment. Systems of lead-free solders are mainly based on the addition of a small amount of third-or fourth impurities in binary alloys to improve their properties. Copper is added to reduce the melting temperature, improved resistance to thermo-mechanical fatigue and improve solder wettability. It also slows the dissolution of Cu substrate in molten solder during soldering (Vuorinen, V., 2006; Madeni & Liu, 2006; Viňáš, et al., 2008).

2. EXPERIMENT

The experiment was selected ternary alloys SnAg3.5CuX with different percentage presence of copper (X = 0.3, 0.7, 1.0% Cu) (Fig. 1). Selected compositions of solders were prepared with cast, gradually melted pure metals and solder alloys in Al_2O_3 crucible. As a basic material used most frequently used material in electrical engineering, technical copper (with purity of 99.995). Before brazing copper substrate surface was ground, polished (until a mirror surface) and fat-free and free of impurities in ultrasonic cleaners. Solder itself was implemented using the method of hot plates. Soldering was carried at 250 ° C for 5 s. Done samples Cu solder joints - SnAg3.5Cu0.3, Cu - and Cu SnAg3.5Cu0.7 - SnAg3.5Cu1.0 subsequently was aging at 140, 150, 160 ° C for 15 days. Individual samples collected sequentially from the vacuum furnace at intervals of 1, 3, 5, 9 and 15 days. The investigation of intermetallic phases (shape and size) present in the structure at the interface of solders and solder joints used light optical microscopy. To assess the chemical composition and representation of the phases present was made bar EDX microanalysis. To determine the diameters of the IMF, the interface microstructure images using solder joints made light microscopy. Using the software "Image tool" was measure thickness of IMF and averaged intermetallic phases. From the measured thickness was calculated activation energy.

3. RESULTS AND DISCUSSION

3.1 D evelopment of intermetallic phases at the interface

Microstructure of solder joints Cu-SnAg3.5CuX (X = 0.3, 0.7, 1.0% Cu) after subsequent heat affected at 160 ° C is shown in Fig. 1.

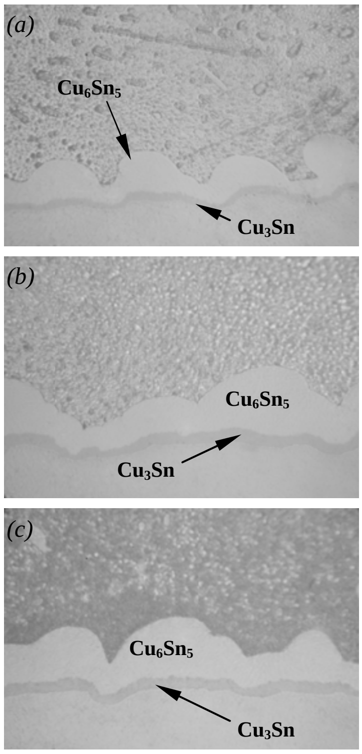

Fig. 1. Microstructural evolution of Cu–SnAg3.5CuX solder joints aged at 160°C for 360 h; (a) Cu–SnAg3.5Cu0.3, (b) Cu–SnAg3.5Cu0.7, (c) Cu–SnAg3.5Cu1.0

The volume of solders is documented occurrence of a long thin needles shape Cu_6Sn_5 phase and sometimes the creation phase Ag_3Sn, which with the influence of thermal effect on changing shape and size. These phases are formed from Ag and Cu elements contained in the solder composition used. As a result of dissolution of the basic material of Cu in molten solder for brazing alloys based on Sn, the interface is characterized by the occurrence of intermetallic phases Cu_6Sn_5. After annealing there is another type of laminated IMF interface Cu-substrate/phase Cu_6Sn_5 documented as Cu_3Sn. Cu_6Sn_5 phase is characterized by an asymmetric morphology is formed rolling surface and occasionally occurring growths different orientation to the solders. Growths are narrow and elongated shape. Height of both phases (Cu_6Sn_5 and Cu_3Sn) on the dividing line was confirmed dot EDX microanalysis.

The metallographic analysis it is clear that with increasing annealing time increases the thickness of the IMF at the interface and also causes significant thickening of the structure of the solder. During annealing, the asymmetric surface Cu_6Sn_5 intermetallic phase offset at the interface. "Smoothing" is largest in the solder SnAg3.5Cu0.7. Solders also differ in the thickness of the phases (and Ag_3Sn Cu_6Sn_5) located in the volume of solder.

3.2 Growth kinetics of intermetallic phases

Relationship between the average thickness of intermetallic phases (Cu_3Sn and Cu_6Sn_5) and annealing time at 150 °C shows Fig.2. The results show that the thickness of intermetallic phases decreases with increasing Cu content in the alloy SnAgCuX. Declining persists until the amount of Cu in the alloy close to the value of 0.7%. Above this amount of Cu layer thickness of intermetallic phases is a growing trend. The growth of thick layers of intermetallic phases was used at annealing temperatures similar trend.

The relationship between the thickness of IMF and the annealing time generally reflects the following equation [2, 6]:

$$h = \sqrt{2Dt} \qquad (1)$$

Where h is thickness of IMF (μm), D – diffusion coefficient ($m^2 . s^{-1}$), t - annealing time (days). Diffusion coefficient can be expressed depending on the temperature [2, 6]:

$$D = D_0 . e^{\left(\frac{-E}{k_B . T}\right)} \qquad (2)$$

Where D is diffusion coefficient ($m^2 . s^{-1}$), D_0 – coefficient of diffusion ($m^2 . s^{-1}$), E – activation energy (eV), k_B – Boltzmann constant ($8{,}617.10^{-5}$ $eV.K^{-1}$), T – temperature (K).

Diffusion coefficient obtained from the measured values of thickness IMF used to calculate the activation energy.

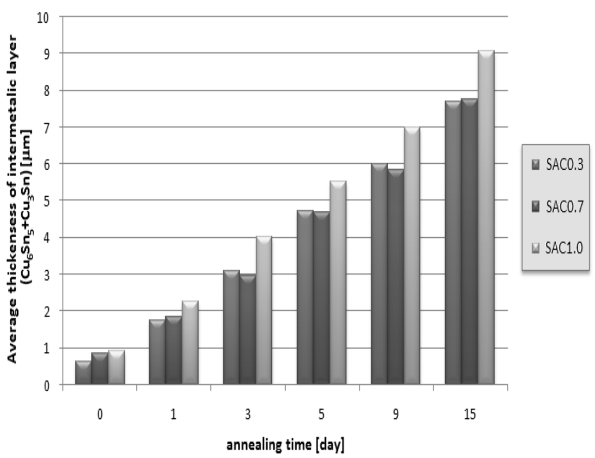

Fig. 2. Dependence graph of the thickness of the IMF from time annealing at 150 ° C

Activation energy dependence on the percentage quantity of Cu has activation energy 1273 eV (the third day). Gradual increase in Cu content in solders SnAg3.5CuX to a value of 0.7% will increase the activation energy value of 1568 eV (the fifth day). Another addition to the Cu value of 1.0%, the activation energy decreases to values even lower than connect with the content of 0.3 Cu (Fig. 3).

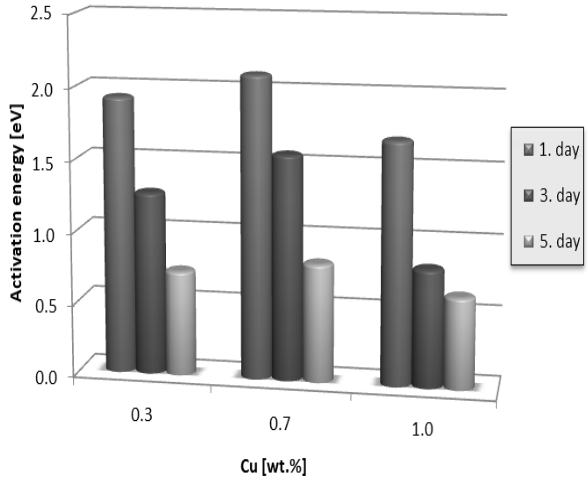

Fig. 3. Dependence of activation energy from the percentages of Cu in solder SnAg3.5

4. CONCLUSION

The results of the study interface solder joints, it is clear that during the annealing of services there are significant structural changes. The results show that the thickness of intermetallic phases decreases with increasing Cu content in solder SnAg3.5CuX. The growth of thick layers of intermetallic phases was used at annealing temperatures similar trend. From the relationship and the thickness of intermetallic phases of activation energy, it is noted that the addition of approximately 0.7% Cu into the alloy SnAg3.5 the activation energy reaches the highest value, what is leading to slower diffusion of atoms, as well as curb the excessive growth of the IMF at the interface.

5. ACKNOWLEDGEMENTS

This paper was supported under projects VEGA 1/0381/08 and VEGA 1/0111/10.

6. REFERENCES

Vuorinen, V. (2006). Interface reactions between Sn-based solders and common metallisations used in electronics, Helsinki University of Technology, Espoo, 2006.

Suganuma, Katsuaki (2004). Lead-Free Soldering in Electronics: Science, Technology, and Environmental Impact. New York: Marcell Dekker, 2004. ISBN 0-8247-4102-1

Madeni, J. & Liu. S. (2006). Intermetallics formation and growth at the interface of Tin-based solder alloys and copper substrates, Second Int. Brazing and Soldering Conference, San Diego, CA, February 2006

Šebo, P. et al. (2009). Effect of indium on the microstructure of the interface between Sn3.13Ag0.74CuIn solder and Cu substrate. *Journal of Alloys and Compounds,* Vol. 480, No. 2, (07-2009), page numbers (409-415) ISSN 0925-8388

Viňáš, J. et al. (2008). Faktory vplývajúce na kvalitu MIG spájkovaných spojov pozinkovaných oceľových plechov *Acta Mechanica Slovaca*, Vol. 12, No. 3-a, (2008), page numbers (501-506). ISSN 1335-2393

Viňáš, J. et al. (2009). Evaluation of corrosion resistance of MIG soldered hot-dip galvanized sheets with various brazing parameters. *Proceedings of Progressive technologies and materials*, pp. 29-39, ISBN 978-83-7199-550-7, Oficyna Wydawnicza Politechniki Rzeszowskiej, 2009, Rzeszów