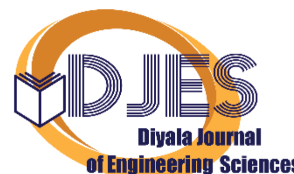
Diyala Journal of Engineering Sciences

Journal homepage: https://en.enginmag.uodiyala.edu.iq/

ISSN: 1999-8716 (Print); 2616-6909 (Online)



Development of Sn-9Zn Solder Alloy by Adding Bismuth

Abbas AL-ALbawee*

Department of Material Engineering, College of Engineering, University of Diyala, 32001 Diyala, Iraq

ARTICLE INFO

Article history:
Received 6 July 2020
Accepted 24 Sep 2020

Keywords: melting point; lead-free solder; electrical resistivity; wettability; specific heat; heat of fusion

ABSTRACT

Tin-Zinc based on solder is a probable changing of lead element solder as a result of its enhanced mechanical characteristics. This alloy needs to be studied and explored to get a usable solder alloy having better properties. In this work Our objective of the accompanying investigation for alteration the warm, physical and bind qualities of eutectic tin-9Zinc fastening alloy by expansion various ratios of bismuth content to give elective without lead solder alloy to utilize this compound for efferent electronic ventures. We found that the addition of bismuth element content improved the thermal, physical and electrical features and qualities. We got the mentioned results by using x-ray diffractometer, differential scanning calorimetry and LCR instrument to calculate electric resistivity and the contact edge (CA) is the most important factor used for assessing the solid surfaces wettability. Sn91Zn3Bi6 alloy has best solder properties as low melting temperature, pasty range and contact angle. And has the beast soldering properties for electronic application compared to commercial Pb- Sn alloy.

1. Introduction

Bind is depicted as fusible combination with liquidus temperature beneath 250°C. Tin, lead, silver, bismuth, indium, antimony and cadmium are utilized in bind composites. We separate Fastens into two sorts, Eutectic bind compounds have certain dissolving temperature and Non-eutectic patch amalgams commit a solidus and liquidus district.

Structure of Framework, warm, physical activities and contact edge of Tin-9Zinc composite adjusted after expansion bismuth component content [1]. So also expansion bismuth diminished the dissolving point temperature, contact edge of Tin-9Zinc compound [2].The contact edge, softening point Tin-9Zinc amalgam decreased however electrical resistivity expanded after expansion bismuth [3]. The structure, physical highpoints and wetting conduct of Tin-9Zinc amalgams have been concentrated by El-Bediwi et al [4]. The outcomes show that, liquefying point, of Tin-9Zinc compound diminished while electrical resistivity expanded after the expansion of bismuth content. In like manner wetting conduct of Tin-9Zinc amalgam differed after the expansion of the bismuth content. various components have been selected as alloying components, for example, Zn, Bi, Cu, Ag, Sb, etc [5, 6, 7]. A few analysts [8, 9, 10, 11] announced that, tin-zinc eutectic weld composite has little wettability; dependability, simple oxidation and miniaturized scale void deveolpment. To keep away from these hindrances or improve its properties, they included limited quantity of Bi element to change Tin- 9Zinc Pb free alloys. The aim of our work was to modification soldering

*Corresponding author.
E-mail address: abbash77@yahoo.com
DOI: 10.24237/djes.2020.13405

characteristics of Tin- 9Zinc alloy by changed their composition by adding different ratios of bismuth content [12]. As they combine several attractive properties such as high density and that lead to rigidity, respectable features, as well as enhanced properties if the alloy microstructure is refined or modified [13].

2. Exprimental work

The relax balck surface was used to prepare Tin-(9-x)Zinc-Bix (x = 0, 3, 6, and 9) wt.% alloys. Beginning, a muffle warmer was used to relax the alloys. Second, the alloys were re-mollified to improve the homogeneity of the formed ingots. Next, alone roller break up mass surface framework was used to prepare masses. A x-pillar diffractometer,for recognizing the pearl organizes and evaluating changes in the cross segment Tetragonal Sn parameters and particle shape. The contact edge (CA) has been the most significant issue that used to evaluate the wetting with solid surfaces[14]. Going to spread assessments are often used to start measuring the contact edge. In additament, differential calorimetric analysis (DSC) twists (SDT, Q600, V20.9 develop 20, USA) were obtained at a heating rate of 10 ° C / min at a temp from between 0 ° C and 400 ° C. Also used present the hot properties of the resulting solder matrix. The electric power interruption of the disassembly bulk surface matrix was measured to use the LCR meter as shown in the following:

$$\varepsilon` = \frac{Cd}{A\,\varepsilon} \quad (1)$$

$$\varepsilon`` = \varepsilon` D \quad (2)$$

$$\delta = \varepsilon` \varepsilon_{\circ} w = 2\pi f \varepsilon`` \varepsilon_{\circ} \quad (3)$$

$$D = \tan\delta \quad (4)$$

$$\tan\delta = \frac{\varepsilon``}{\varepsilon`} \quad (5)$$

where, d is the thickness of the sample (cm), c is the capacitance (F), A is the surface area of the holder (cm^2), (ε°) is The Permissibly of Electricity within Free Spaces (F m^{-1}), (ε`) is relative static permittivity (F m^{-1}), (ε``) is the imaginary relative static permittivity (F m^{-1} cm), D is the loss factor, (tanδ) is the loss angle (degrees), (δ) is the electrical conductivity ($(\Omega.m)^{-1}$), and w is the angular frequency (Hz).

3. Result and discussion

3.1 X-Ray Diffraction (XRD) investigations

Tin element from type (β-Sn) were the key constituents of the eutectic Sn-Zn. Sectors also included in the Sn-based alloy may form a substitute or extracellularly composite material as they take up a crystallographic representative sample of the base metal. Though, an alloy outside of what many would consider possible of the segment in the base alloy may result in the formation of Alloying with additional amount portion (Bi) occurred without any considerable credential in cell parameters, cross-area dimensions, or crystal size (β)-Sn partnership.. The statistics has been done utilizing Eqs. 6 and 7 [15].

$$\frac{1}{d^2} = \frac{h^2+k^2}{a^2} + \frac{l^2}{c^2} \quad (6)$$

Unit- cell volume (V) = a^2 c (7)

The average crystallite size relying on the broadening of the absorption spectra was evaluated by the formula given. [15,16]:

$$\tau = \frac{0.95\lambda}{\beta \cos\theta} \quad (8)$$

where λ is represents the lenth of the wave of diffraction of the x-rays (A˚ ancstrom), β is the lf width full maximum of the broadening (radians), (radians), and τ is the size of crystallite (A˚ ancsrom). The effects showed that the parameters of framework of the tetragonal system of tin element organize of late developing solders be there local to the of the base alloy considerations, not under any circumstance similar, for model, the obtained results on minor adding of (l.5 of wt.% Bismuth element to tin-0.7 wt.%Copper and 0.05 wt.%Nichel in [17], wherever the cross area parameters of tin element arrange remained obviously extended.

The diffractrometer of X-ray is an device which is used for investigating the fine construction of the materials. This techniqe and other techniqes is usefull for characterizing the construction of melting substance alloys, for

studying/confirming the diffrent phases that seemed throughout melted alloy preparing/rapidly make cold procedure. Credentials of used of bulk melted alloys was accomplished with a Shimadzu instrument for diffractometed x-ray (D_x-30)] technology university in Baghdad[.A Cu-Kαradiation with wavelength, λ=1.54056 Å at 45 Kv and 35 mA with Nichel-filter for using and applied to flat samples in the range angular 2θ ranging from 10^0 degrees to 90^0 degrees in uninterrupted manner, that includes the strongest spreading signals, by a speed of scan 5 deg/min.

4. Wetting properties

The implementation of a specific transaction of Bismuth element would have a huge impact on the point of contact and also the wettability of the able to prepare solders. Designed to spread checks have been used to evaluate the wetting of an institution by measuring the going to spread width and size of the combined knock, required to just have the ideal product from the round top (Figure 1). Equation 9 has been used to process the welded quantities

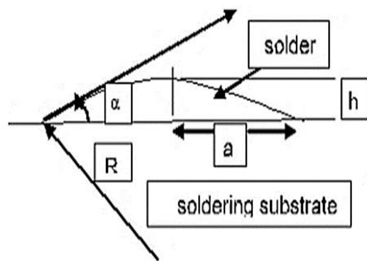


Fig 1. Wetting angle calculation with ZnO-forming oxygen restricts their wetting on the base

$$V = (3a^2 + h^2)\,\frac{\pi h}{6} \quad (9)$$

The wetting angle (a) was calculated using Eqs. 10 and 11. The angle does not depend on solder amount. [17]

$$R=\frac{V}{\pi h^2} + \frac{h}{3} \quad (10)$$

$$\alpha = \frac{\pi}{2} - \text{arctg}\,\frac{(R-h)}{a} \quad (11)$$

The wettability of surface area is usually shown by low 90 degrees (low contact angle), because fluid is spread over a large surface area [18]. The The contact angle results of the study also for solder paste have been seen in Table II. The incorporation of Bi might well raise the wetting of Sn-Zn-dependent solders on the Cu substrate. [11, 12, 22] noted that now the implementation of bismuth could decrease the surface tension of molten solders by increasing their expansion to a copper substrate given the fact that perhaps the surface tension of it's molten Sn-Bi eutectic alloy had already increased. is increasing and therefore, The Bi concentration of touch angle decreases by 9 wt. percent. The wettability of Sn-9Bi alloy with 0 percent Zn is higher as the easy reaction of zinc.

5. Thermal properties

The successful solder is predicted to get a low melting temperature and a limited pasty range. Figure 3 shows the differential calorimeter scanning (DSC) curvature with recently designed solders created at such a temperature of 100 K / min. Which can be seen in (Table III), a melting temperature of reference alloy Sn-9Zn has been decreased by increasing the addendum of bismuth. The Tm of the base alloy evaluated at the endothermal maximum seemed to be 203 ° C. The addendum of 3 wt. per cent, 6 wt. per cent Bi, lowered the Tm covering nearly 196 ° C, signifying the melting temperature nearby with that of the poisonous 63Sn37Pb. According to another binary phase transition of Sn – Bi[18] Bi-addition could leads to the formation of the solid solution to Sn. Also because solubility of Bismuth in tin would be less from over Three wt percent At temp of room , the raised Above saturation of Bismuth at low temp is Comfortable also by production of Bismuth precipitate and/or SnBi inter-metal compounds [11]. The eutectic temperature of Sn-Bi alloys is 139 ° C, which decreases the melting point of the basic alloy to it as reduced as 196 ° C. Throughout adding, Bi insert marginally expands the temp of the pasty scope among liquids(Tend) And solidus (T onset) temps marginally greater unlike 7 ° C for Sn-9Zn and close to 11.5 ° C for Sn-Pb eutectic alloy[11]. It has already been noted by [19, 20] that a wide range of pastes increases the tendency for porosity as well as fillet trying to

lift (full or partial segregation during alloy solidification of its soldering combined fillet from of the inter - metallic compounds). Consequently, most other formulated solders have already shown corresponding information. As shown in Table III, the melting temp of Sn-9Zn, Sn-6Zn-3Bi, Sn-3Zn-6Bi and Sn-9Bi is 0.0152, 0.0181, 0.0194 and 0.01168 j / g respectivelySn91Bi9 solder alloy. This is also demonstrated that perhaps the changing in the quantities of Sn greatly impacted the thermal energy by having to add the varying rates with Bismuth element.

6. Electrical properties

As seen in Figure 4, the electrical resistance of a formulated alloys at room temperature has been enhanced. The significant rise in resistance with the addition of Bi might well be linked to a supersaturation of bismuth at low temperatures that also produces Bi precipitate and/or SnBi intermetallic compound behaving as diffusion centers for conductive electrons, The bismuth phase that forms and dissolves in the Sn-Zn matrix is a p - type semiconductor with good resistance [14, 20]. A results demonstrate that perhaps the conductivity of a three percent Bi-addition weld had been the nearest with that of the Sn-9Zn base material. "in many other micro - electronic implementations, the resistance of an interlinked weld should be just as small as possible so not to actually effect the features of the interlinked weld [3].

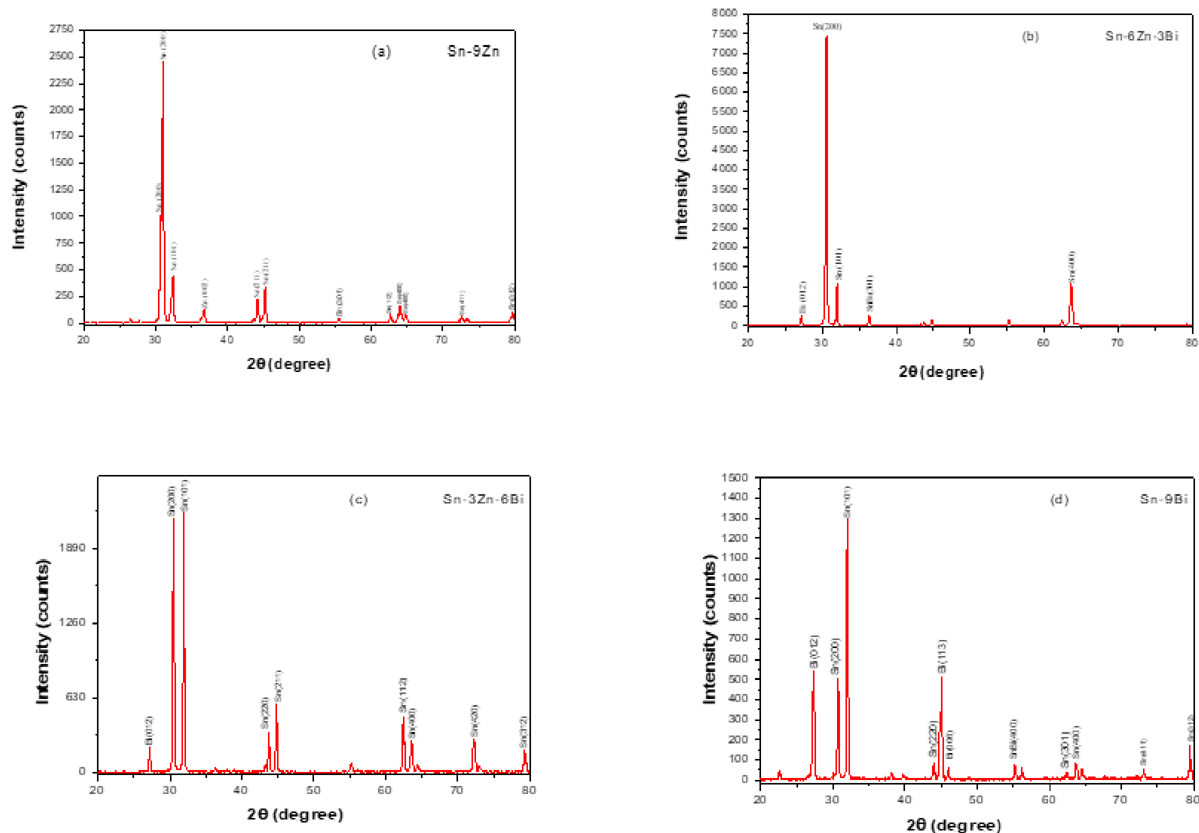


Fig 2. Configurations of XRD of four so1der alloys (a) Sn-9Zn, (b) Sn-6Zn-3Bi, (c) Sn-3Zn-6Bi and (d) Sn-9Bi

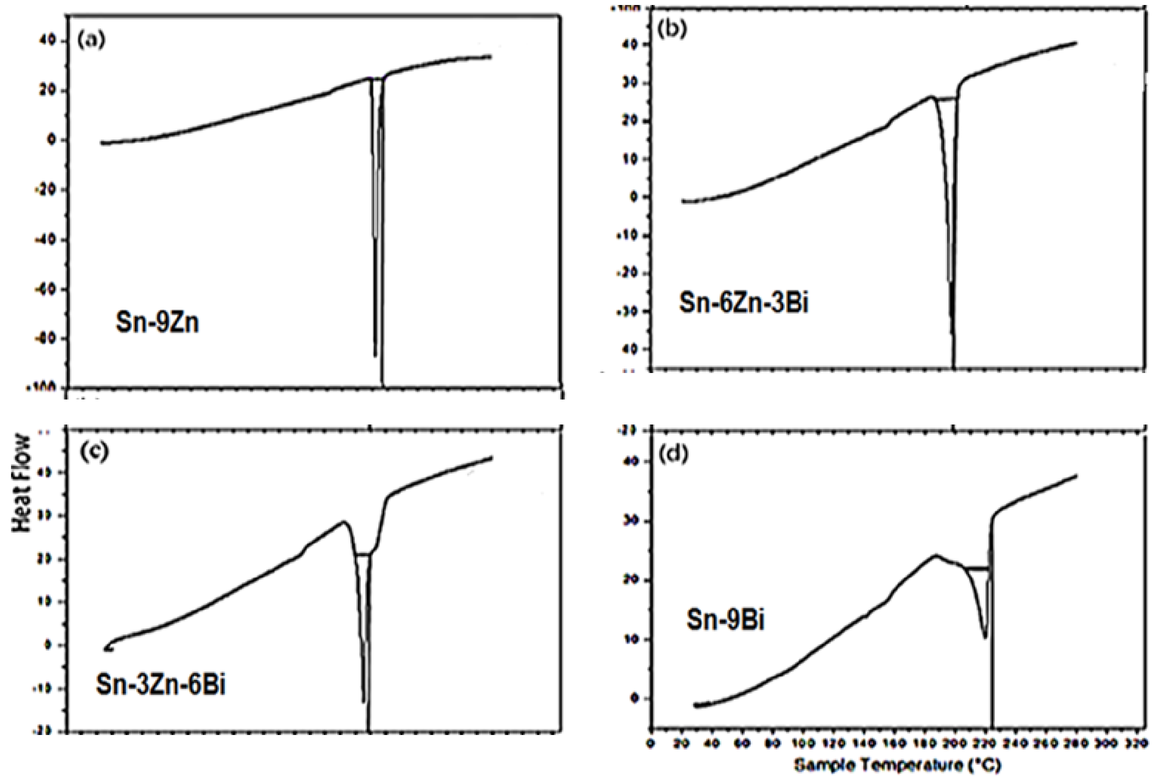


Fig 3. DSC graphs of the four heated solders matrices at a rates of scanning of (5 ºC/min). (a) Sn-9Zn, (b) Sn-6Zn-3Bi, (c) Sn-3Zn-6Bi and (d) Sn-9Bi

Table 1 Lattice parameter of the unit cell, unit- cell volume and crystal size of the solder alloys

Alloy	a (Å)	c (Å)	c/a	Unit- Cell volume V (Å)^3	Average particle size Å
Sn-9Zn	5.7965	3.2272	0.5567	108.4333	454.7261
Sn-6Zn-3Bi	5.8454	3.3744	0.5773	0.2995	330.0030
Sn-3Zn-6Bi	5.8611	3.3557	0.5725	108.2785	555.7107
Sn-9Bi	5.8158	3.2317	0.5557	109.3072	500.2895

Table 2 The contact angle of the solders in the copper base

Alloy	Contact angle (ϴ°)
Sn-9Zn	42.5±3
Sn-6Zn-3Bi	41±3
Sn-3Zn-6Bi	39.5±2

Table 3 Comparison of melting temperature (Tm), pasty range (Tend−Tonset), specific heat (C_p) and heat of fusion (ΔH) for the prepared solder alloys

Solder alloy	Melting Point °C	Pasty Range °C	Cp specific heat j/g	ΔH j/g
$Sn_{91}Zn_9$	203	7	-0.452	0.0152
$Sn_{91}Zn_6Bi_3$	199	11	-0.014	0.0181
$Sn_{91}Zn_3Bi_6$	196	9	10.031	0.0194
$Sn_{91}Bi_9$	220	12	-8.721	0.0117

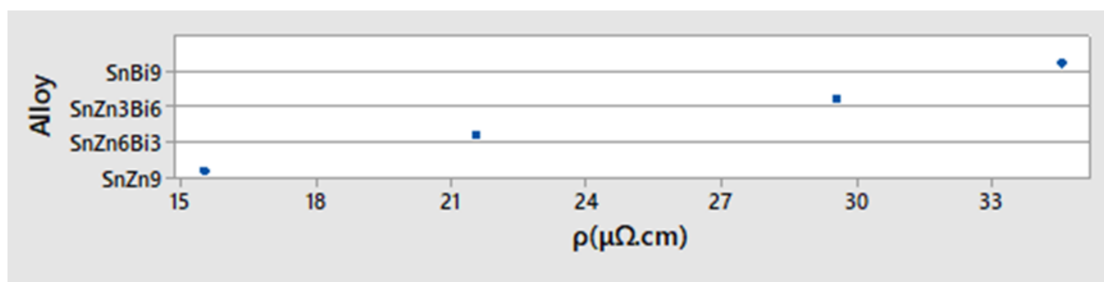


Fig 4. Electrical resistivity ρ (μΩ.cm) of the solders

7. Conclusion

The results can be represented as resulting controllers:

- The effects of doing this with different bismuth amounts on the crystalline structure, precious stone configuration and wettability and physicochemical parameters have been investigated.
- Analysis of the XRD show that similar to those of the base alloy were tetragonal Sn's grid parameters with specific amounts of Bi addition.
- Bi could adding Obvious its wetting is enhanced by the Sn-9Zn solder and its dissolution temperature is reduced to 6% Bi.
- With expanding bismuth rates the pale range could be extended to illustrate that Bi addition needs control. The solders showed a valuable outcome because the pale range of their solders That was only marginally just above values of 7 ° C for Sn-9Zn and near as possible with that of the euthetic Sn-Pb alloy (11.5 ° C).
- Because of an activity of the tried to speed bismuth-stage and/or the SnBi IMC as dispersing focal points for electrons that they play as conductors electric resistivity of the base alloy at room temperature was marginally enlarged through the addition to Bi.
- from above the Sn91Zn3Bi6 alloy has best solder properties as low melting temperature, pasty range and contact angle

References

[1] Xiao, Zhengxiang, et al. "Properties and microstructure of Sn-9Zn lead-free solder alloy bearing Pr." Journal of Materials Science: Materials in Electronics 22.6 (2011): 659-665.

[2] Kar, Abhijit, et al. "Effect of copper addition on the microstructure and mechanical properties of lead free solder alloy." Materials Science and Engineering: A 459.1-2 (2007): 69-74.

[3] Kamal, M., and EL Said Gouda. "Enhancement of solder properties of Sn- 9Zn lead- free solder alloy." Crystal Research and Technology: Journal of Experimental and Industrial Crystallography 41.12 (2006): 1210-1213.

[4] Cheng, Shunfeng, Chien-Ming Huang, and Michael Pecht. "A review of lead-free solders for electronics applications." Microelectronics Reliability 75 (2017): 77-95.

[5] Chen, Xi, et al. "Study on the properties of Sn–9Zn–xCr lead-free solder." Journal of Alloys and Compounds 460.1-2 (2008): 478-484.

[6] Wu, CM Lawrence, et al. "The properties of Sn-9Zn lead-free solder alloys doped with trace rare earth elements." Journal of electronic materials 31.9 (2002): 921-927.

[7] Wu, C. M. L., et al. "The wettability and microstructure of Sn-Zn-RE alloys." Journal of Electronic Materials 32.2 (2003): 63-69.

[8] Kim, Young-Sun, et al. "Effect of composition and cooling rate on microstructure and tensile properties of Sn–Zn–Bi alloys." Journal of alloys and compounds 352.1-2 (2003): 237-245.

[9] Chen, WenXue, et al. "Effects of rare earth Ce on properties of Sn–9Zn lead-free solder." Journal of Materials Science: Materials in Electronics 21.7 (2010): 719-725.

[10] Song, Jenn-Ming, Nai-Shuo Liu, and Kwang-Lung Lin. "Microstructures, thermal and tensile properties of Sn-Zn-Ga alloys." Materials Transactions 45.3 (2004): 776-782.

[11] El-Daly, A. A., et al. "Thermal and mechanical properties of Sn–Zn–Bi lead-free solder alloys." Journal of Alloys and Compounds 484.1-2 (2009): 134-142.

[12] Zhou, Jian, Yangshan Sun, and Feng Xue. "Properties of low melting point Sn–Zn–Bi solders." Journal of alloys and compounds 397.1-2 (2005): 260-264.

[13] Rijab ,Mustafa Ahmed. " STUDY THE EFFECT OF (Ti) ADDITION ON THE MICROSTRUCTURE OF EUTECTIC Al-12%Si ALLOY . " Diyala Journal of Engineering Sciences. 2-1 (2009): 96-108 .

[14] Zhao, Tianyi, and Lei Jiang. "Contact angle measurement of natural materials." Colloids and Surfaces B: Bio interfaces 161 (2018): 324-330.

[15] El-Bediwi, Abu Bakr, Amira El-Shafei, and Mustafa Kamal. "Influence of Adding Bi\or Bi-In on Structure and Required Properties of tin-Copper Lead Free Solder Alloy." (2014).

[16] Jang, Pyungwoo. "Effects of Annealing on Structure and Magnetic Properties of Fe-Si-Al Flakes." Korean Journal of Metals and Materials 56.9 (2018): 680-685.

[17] K. Nogita, M.A.A.M. Salleh, S. Smith, Y. Wu, S.D. Mcdonald, A.G.A. Razak, S. Liu, T. Akaiwa, T. Nishimura, International Conference on Electronics Packaging (2017), pp. 1–7.

[18] Shalaby, RIZK MOSTAFA. "Wettability and electrical properties of Bi-Sn based lead free solders alloys." Int. J. Phys. Res 3 (2013): 1-6.

[19] Villars, Pierre, Alan Prince, and Hiroaki Okamoto. Handbook of ternary alloy phase diagrams. Vol. 5. Materials Park, OH: ASM international, 1995.

[20] Chen, Sinn-Wen, et al. "Phase diagrams of Pb-free solder and their related materials systems." Lead-Free Electronic Solders. Springer, Boston, MA, 2006. 19-37.

[21] Al-Ezzi, Athil, et al. "Effect of Bismuth Addition on Physical Properties of Sn-Zn Lead-free Solder Alloy." Journal of Electronic Materials 48.12 (2019): 8089-8095.

[22] Jayesh, S., and Jacob Elias. "Experimental Investigations on Impact Toughness and Shear Strength of Lead Free Solder Alloy Sn–0.5 Cu–3Bi–xAg." Transactions on Electrical and Electronic Materials (2020): 1-7.