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Structural Modification and Mechanical Properties of Cu-3wt%Si-xwt%Sn Alloy

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ABSTRACT

The aim of this research was to investigate the structural modification and mechanical properties of silicon bronze doped with different concentrations of tin. The concentrations of tin adopted were 0.1, 0.3, 0.5, 0.8, 1 and 1.5% by weight. The samples were cast using permanent die casting method and prepared for structural analysis and mechanical tests. 100KN JPL tensile strength tester (Model: 130812) and portable dynamic hardness testing machine (Model: DHT-6) were used to investigate the percentage elongation, ultimate tensile strength and hardness of the developed alloys respectively. The microstructure of the developed alloys was analysed using an optical metallurgical microscope (Model: L2003A) and scanning electron microscopy (SEM). The structural analysis of the control sample (Cu-3wt%Si) revealed the presence of segregated primary silicon and coarse intermetallic phase (Cu_3Si). The surface morphology of the doped alloys consisted of refined and modified intermetallic phase of spherical pattern in the alloy structure. Results of the mechanical tests showed that the percentage elongation, ultimate tensile strength and hardness of the alloy improved significantly by addition of 0.1wt%Sn. The ultimate tensile strength and hardness of the alloy increased with increase in tin content with corresponding decrease in percentage elongation.

Keywords: Surface morphology, tensile strength, hardness, intermetallic phase

I. INTRODUCTION

Copper-based alloys have gained an increasing demand in engineering applications mostly in chemical, petroleum, automotive and power generating industries [1]. This is because of its combination of excellent properties such as corrosion resistant, ductility, malleability, non-magnetism, wear resistance, machinability; good thermal and electrical conductivities [2]. Commercially, pure copper is very soft, ductile and malleable with low tensile strength, containing up to about 0.7% total impurities [3]. Various engineering applications demand high strength, therefore substantial increase in strength of pure copper is paramount in order to increase its applications [4]. Silicon bronze is among the most widely used copper-based alloys because of its combination of corrosion resistance, strength, and formability [5]. It is mostly used in production of electrical conduits, valve stems, tie rods, fasteners, marine and pole-line hardware, nuts, bolts, screws, rivets, nails, and wire [6].

This research was propelled by the interest to modify the segregated primary silicon and coarse copper silicide (Cu_3Si) phases present in slowly cooled silicon bronze, which have detrimental effect on the mechanical properties of the alloy. Ohkubo et al., [6] reported the existence of six (6) major intermetallic phases in Cu-Si alloy system at both high and room temperature. ε, γ and η'' are the room temperature intermetallic phases while α, β and κ are the high temperature intermetallic phases. Ketut et al., [5] established in the study of the effect of silicon content on the mechanical and acoustical properties of silicon bronze alloys for musical instruments that the mechanical properties and damping capacity of Cu-Si alloy system were higher than Cu-20wt.%Sn alloys. Mattern et al., [8] reported the presence of different meta-stable phases such as η, σ and κ on rapidly quenched silicon bronze. The study also established that room temperature phase, ε was suppressed by rapid quenching. Puathawee et al., [9] revealed that addition of tin to Cu-Si-Zn alloy increased the amount of beta (β) and gamma (γ) phases in the alloy structure. An optimum hardness of 123.4 HV was obtained by 60Cu-0.5Si-39.5Zn alloy. Study by Božica et al., [10] has shown that the rapidly solidified Cu-1.2Ti-3$TiSi_2$ powder microstructure was characterized by the presence of fine, dispersed primary $TiSi_2$ particles and high super saturated solid solution. The study indicated that the microstructure of the studied alloys was not completely homogenous but rather exhibited the presence of homogenous fluctuations in the range of 5–10µm. Cu-1.2Ti-3$TiSi_2$ powder yielded much higher microhardness values compared with the Cu-1.2Ti powder, owing to primary $TiSi_2$dispersoides formed during atomization.

II. MATERIALS AND METHOD

Pure copper and pure silicon were the base materials for this research while tin of 99.99% pure was the dopant. The dopant was added in concentrations of 0.1, 0.3, 0.5, 0.8, 1 and 1.5wt%. Permanent die casting technique was adopted for producing the alloys samples used for this research. For the control sample, the required amount of pure copper wire was melted in a bailout crucible furnace and the predetermined amount of silicon powder wrapped in an aluminium foil was added to the copper melt and stirred vigorously to ensure homogeneity. The mixture was superheated and the control sample was cast. The remaining melt was doped with the different concentrations of tin and cast. The samples were machined to the required dimensions and stored for the mechanical tests.

III. RESULTS AND DISCUSSION

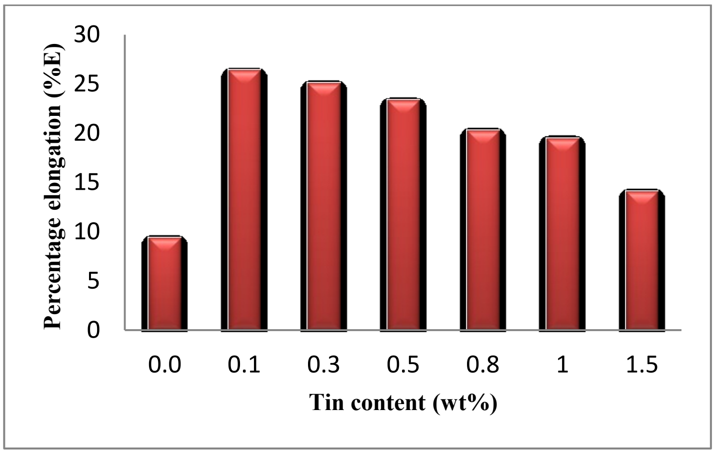

Figure 1: Effect of tin content on the percentage elongation of silicon bronze

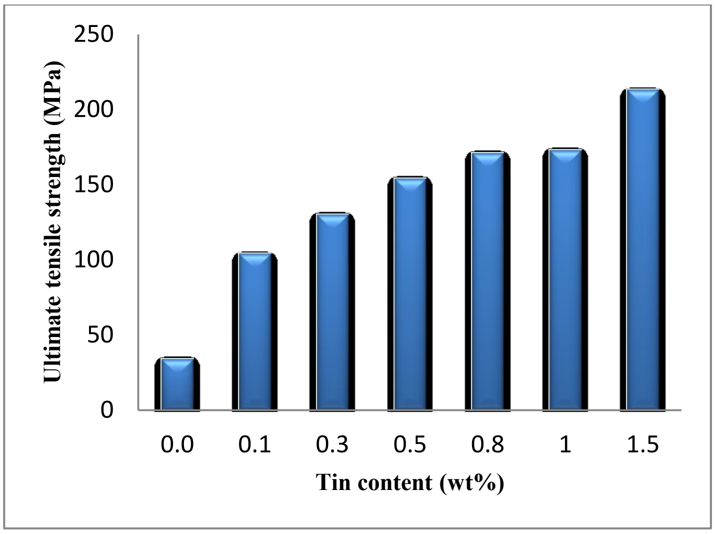

Figure 2: Effect of tin content on the ultimate tensile strength of silicon bronze

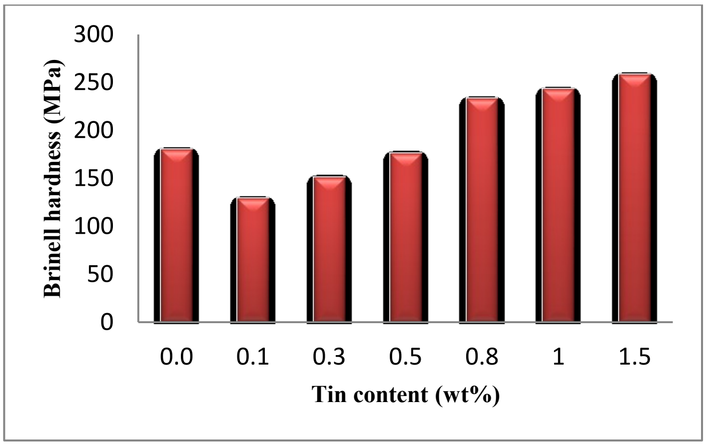

Figure 3: Effect of tin content on the hardness of silicon bronze

The percentage elongation, ultimate tensile strength and the hardness of silicon bronze doped with different concentrations of tin are presented in Figures 1-3. It was evidenced in Figures 1 and 2 that addition of 0.1wt% to Cu-3wt%Si significantly improved the percentage elongation and ultimate tensile strength of the alloy. The hardness of the developed alloy decreased with addition of 0.1wt% tin, but increased significantly with increase in tin content up to 0.8wt%. The ultimate tensile strength and hardness increased with increase in tin concentration with corresponding decrease in percentage elongation. This trend in mechanical properties was quantified by the microstructural changes as evidenced in Figures 4-10.

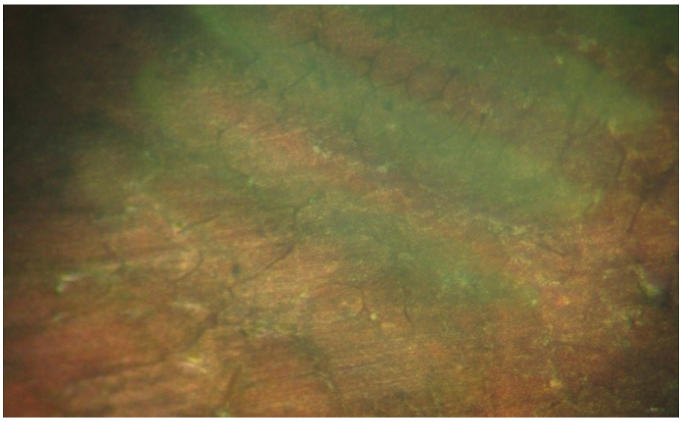

Figure 4: Micrograph of Cu-3wt%Si alloy

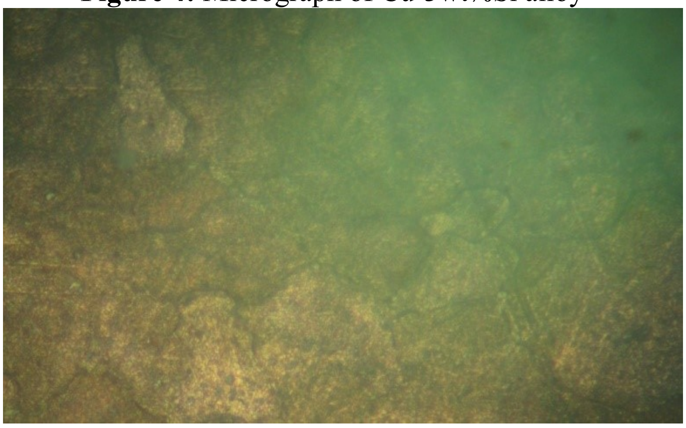

Figure 5. Micrograph of Cu-3wt%Si-0.1wt%Sn alloy

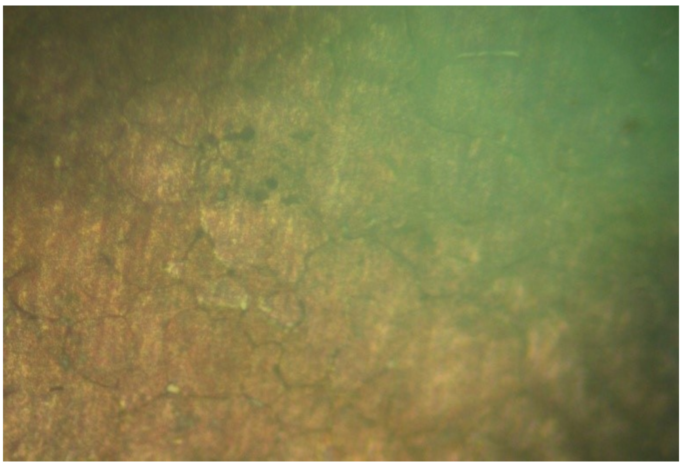

Figure 6. Micrograph of Cu-3wt%Si-0.5wt%Sn alloy

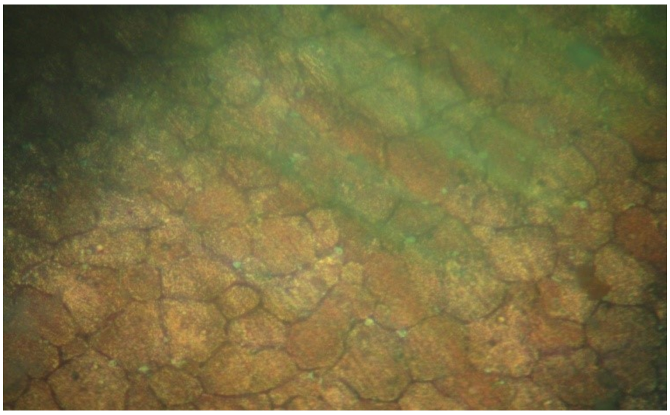

Figure 7. Micrograph of Cu-3wt%Si-1wt%Sn alloy

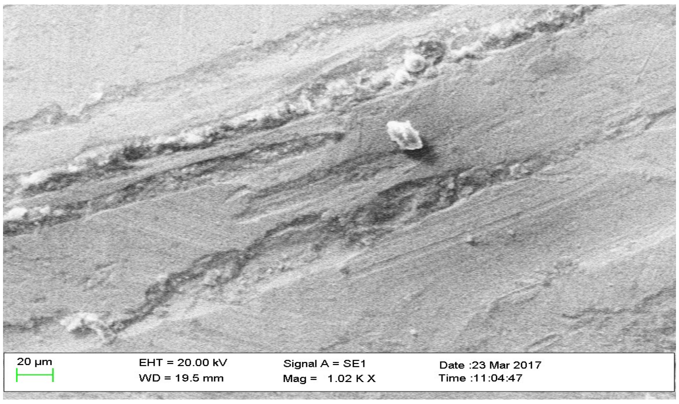

Figure 8: Micrograph (SEM) of Cu-3wt%Si alloy

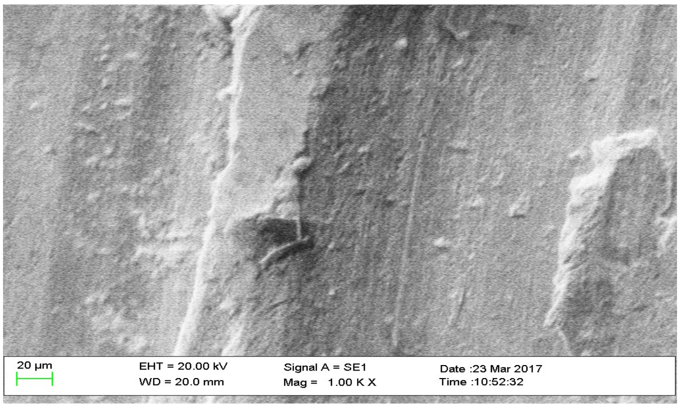

Figure 9: Micrograph (SEM) of Cu-3wt%Si-1wt%Sn alloy

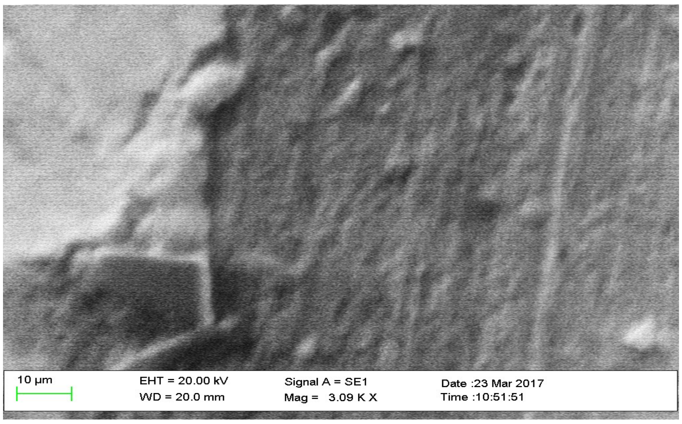

Figure 10: Micrograph (SEM) of Cu-3wt%Si-1.5wt%Sn alloy

The surface morphology of Cu-3wt%Si-xwt%Sn is presented in Figures 4 -10. The optical and scanning electron microscopy analyses of the control specimens presented in Figures 4 and 8 revealed the presence of segregated primary silicon and coarse Cu_3Si intermetallic phase. The micrographs of the doped alloy revealed the presence of spherical intermetallic compound evenly dispersed in the alloy structure. Increase in concentration of tin decreased the size of the dendritic primary silicon and modified the intermetallic phase, thereby created more grain boundaries, which ultimately increased the ultimate tensile strength and hardness of the developed alloy with corresponding decrease in percentage elongation.

IV. CONCLUSION

The structural modification and mechanical properties of Cu-3wt%Si-xwt%Sn alloy has been studied in details using standard techniques. The following conclusions were drawn from the results of the analysis:

1. The low mechanical properties of Cu-Si alloy system were because of the presence of the segregated primary silicon and coarse intermetallic phase in the alloy structure.
2. The amount and size of the segregated primary silicon in Cu-3wt%Si alloy system were decreased significantly by addition of tin.
3. Addition of 0.1wt% tin to Cu-3wt%Si alloy system significantly improved the percentage elongation and ultimate tensile strength of the alloy. This was because of the formation of spherical intermetallic phase in the alloy structure.
4. The significant improvement in the percentage elongation, ultimate tensile strength and hardness of Cu-3wt%Si alloy system was attributed to the decrease in size, refinement and modification of the segregated primary silicon and coarse intermetallic compound in the alloy structure.

V. ACKNOWLEDGEMENT

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VI. REFERENCES

[1]. Garcia P., Rivera S., Palacios M. and Belzunce J. (2010) Comparative Study of the Parameters Influencing the Machinability of Leaded Brasses. Engineering Failure Analyses, Vol. 17, pp. 771-776.

[2]. Shabestari S.G. and Moemeni H. (2004) Effect of Copper and Solidification Conditions on the Microstructure and Mechanical Properties of Al-Si-Mg Alloy. Journal of Materials Processing Technology, Vol. 153, pp. 193-198.

[3]. William D. N. J. (2010) Metallurgy of Copper Based Alloys, Copper Development Association, Inc., pp. 1-3.

[4]. Zhang Werwen, Xia Wei, Wen Li-ping, WU Yuarrbiao and Pan Guoru (2003) Mechanical Properties and TribologicalBehavior of a Cast Heat Resisting Copper Base Alloy. J.Cent. South Univ. TECHNO. (Journal CSUT). 9(4):235- 239.

[5]. Ketut G. S. I, Soekrisno R., Made M. I. and Suyitno (2011) Mechanical and Damping Properties of Silicon Bronze Alloys for Music Applications. International Journal of Engineering & Technology IJET-IJENS, 11 (06): 81-85.

[6]. Kulczyk M., Skiba J., Przybysz S., Pachla W., Bazarnik P., Lewandowska M. (2012) High Strength Silicon Bronze (C65500) Obtained by Hydrostatic Extrusion. Arc hives of Metallurgical and Materials, 57 (3): 859-862.

[7]. Ohkubo Y., Matsumoto K. and Nagai K. (2005) Acceleration of Cu Surface Precipitation from Bulk by Adsorbed Organic Molecules. Japanese Journal of Applied Physics, 44:3793-3797.

[8]. Mattern N., Seyrich R., Wilde L., Baehtz C., Knapp M. and Acker J. (2007) Phase Formation of Rapidly Quenched Cu-Si Alloys. Journal of Alloys and Compounds, vol. 429, pp. 211-215.

[9]. Puathawee S., Rojananan S. and Rojananan S. (2013) Lead-Free Cu-Si-Zn Brass with Tin Addition, Advanced Materials Research, Vol. 802, pp. 169-173.

[10]. Bozica D., Dimcicb O., Dimcica B., Cvijovica I., Rajkovic V. (2008) The Combination of Precipitation and Dispersion Hardening in Powder Metallurgy Produced Cu-Ti-Si Alloy. Materials Characterization, vol. 5 9, pp. 1122-1126.