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Influence of Cu Addition on the Transient Creep Characteristics of Sn–9Zn-1.5Ag Solder Alloy

Dr. Mahmoud Youssef Salem
Head of Physics Department, Faculty of Science, New Valley University, 72511, El-Kharga, Egypt.
mahmoudsalem778@gmail.com

Abstract

This paper develops methods to explore the influence of Cu increments on disfigurement temperature T and the applied stress σ on transient creep characteristics. The materials used in the present study are Tin-9Zinc-1.5Silver and Tin-9 Zinc-1.5 Silver-0.7Copper alloys. Creep tests is performed under five different stresses ranging from 15.22 to 23.35 MPa and 4 unlike experimentation temperatures from 333 to 393 K near the transformation temperatures. The coefficients β and n for transient creep is evidently depended on the creep test conditions, T and stress σ. The coefficients β is reduced by growing T and/or load while n is raised by rising T regardless of the applied stress σ. The two samples presented extra contained phases of the intermetallic compound IMCs, Ag3Sn AgZn, during solidification. An important refinement in the creep resistance is recognized by supplement 0.7Cu to the ternary Tin-9 Zinc-1.5 Silver solder alloy .i.e. Tin-9 Zinc-1.5 Silver-0.7 Copper alloy is more strengthening than Tin-first alloy.

Keywords: Creep resistance; Transient; Microstructure; Sn-Zn-Ag-Cu.

Introduction

Sn-Zn samples are not expensive; they have perfect treatment advantage like as depressed fusion point, good intensity, and altitude ductility, good thermal and electrical properties. The consequence of silver increasing, heat; and used load on test behaviour of Tin-9Zinc samples; in the industry; it is clear that the great magnitude of silver can organized great essential $Silver_3$Tin consequences, that may decrease the flexibility of the solders; thus samples give minimal fundamental diameter of β-Tin stage; perfect strain, by an influence of transient creep [1,2].

Considerable investigation were performed on the mechanical characteristics of the alloys connection and found appropriate through response of Tin–Zinc samples; different outer last strata in reset passage in altitude- heat treatment [3–6], study characteristic of Tin–Zinc- fundamental samples at altitude- degree; It is imperfect to estimating precision concerning samples connects [7,-9]. Therefore; Tin-Zinc-samples require more evolution and progression in effective utilize. The coordinated realizations are very important for knowing creep attitude for Tin-Zinc-Silver samples. Therefore, regardless of premature supported consequences, at present a broad paper for emphasized Zinc was found-including samples experience of essentially small corrosion impedance; slight moistening characteristics, in any case for treatment approximation utilized [7,10,11].

Recent results presented that Sn-9Zn alloys with silver content higher than 0.5Ag is represented at minimal intensity within minimum hardening average whereas; agreeable intensity is recognized because of presence about no soft Silver-Zinc agreement moreover; more fine, improved classification about Zinc-pure shapes [12]. Furthermore rising silver component during Tin-9Zinc resort to decrease low melting texture owing into structure about great magnitude fragments owing to Silver-Zinc interface [13]. Microstructure also; apportionment about this stage is strongly leads into strain-time conductance for used sample. It is referred that sample behaviour owing into pure beside of organized diffusion owing to little distributed molecules for last cases [14].

Tin-Silver–Cupper (SAC) is suggested as the ultimate remarkable lead-free solders for almost employment, particularly in surface mount technology (SMT) [15]. The hard SiC (additive like the nucleus places through essential construction about Silver-$_3$Tin phase) molecules; also more pure inter metallic compound is resistance disturbance glide, therefore resulted in an intense reinforcement influence in the samples [16,17]. The mechanical behaviour measurements indicated significant improvement in yield strength with the addition of 0.35% SiC nanoparticles. Tin-Indium-copper samples influence was predictable as important due to; it has small dissolving in β-Sn phase; also experience small evolution as well thickens [18].

II Experimental Procedures

Tin-9Zinc-1.5Silver and Tin-9Zinc-1.5Silver-0.7Copper alloys is constructed using tin, zinc, silver, and cupper all of very high purity. Conventional magnitude for duple sample which good hodgepodge with calcium-Chlorine wax for restrain reaction within steel style; it preserved about one handerd degree over fusion point in connection with Silver. The samples were twisted to wires of length about 0.05 m and diameter about radius $0.8x\ 10^{-3}$ m. The wires samples were annealed at 170 ^{0}C for 120 min. to removed cold rolling effect presented within dragging; subsequently quietly freeze untill R.T. with a fixed refrigeration control about 0.002 degree per second. Therefore; measurements to whole specimen; the specimen is take into account is fully compressed [19]. The experiment is achieved by commonplace strain-time experimental instrument provided to computer equipped with accuracy about 0.0001 before connected with Scanning Electron Microscope notification for pre-tested patterns, pattern is inspectd; subsequently etching with 2% HCl, 3% HNO3 and 95% ethanol. The chemical analytical is symbolized in Table 1.

Table1: Chemical construction for tested samples.

Solder alloy	Tin	Zinc	Silver	Copper
Sn-9 Zn-1.5Ag	89.5	9	1.5	0
Sn-9Zn-1.5 Ag-0.7Cu	88.8	9	1.5	0.7

Δε

III. Results and Discussion

The first stage of creep εtr is demonstrated by (1) [20]:

$$(\text{Strain})tr = \beta(\text{time})^n \quad (1)$$

The n; also β not variable reposed within certain condition.

3-1-Creep curves of alloys.

Fig.1-4 represented creep curves of the investigated specimen described as strain % versus time at constant stress in for different four testing for four different temperatures starting from 60 $C^{0\ to}$ 120 C^0 and through five loads presented in Figs from 15.22 until $23.35x\ 10^6$ Pascal.

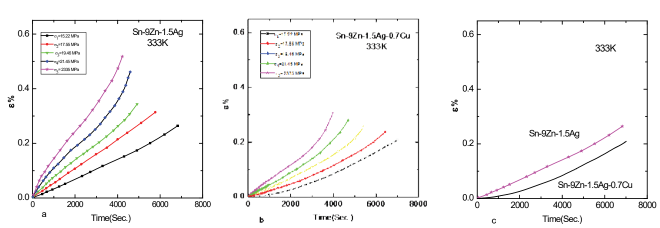


Fig.1: Isothermal Creep Curves at 323 K, a) for Sn-9Zn-1.5Ag, b) for Sn-9Zn-1.5Ag-0.7Cu at different applied stresses, and c) Comparison of creep for two alloys at 333 K.

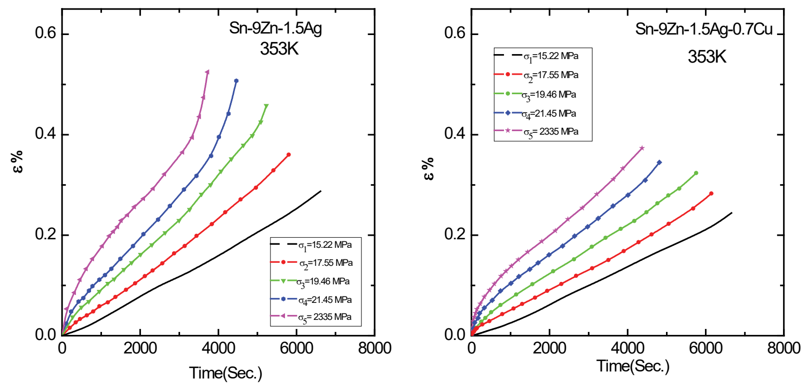


Fig.2: Isothermal Creep Curves at 353 K, at different applied stresses for Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu alloys.

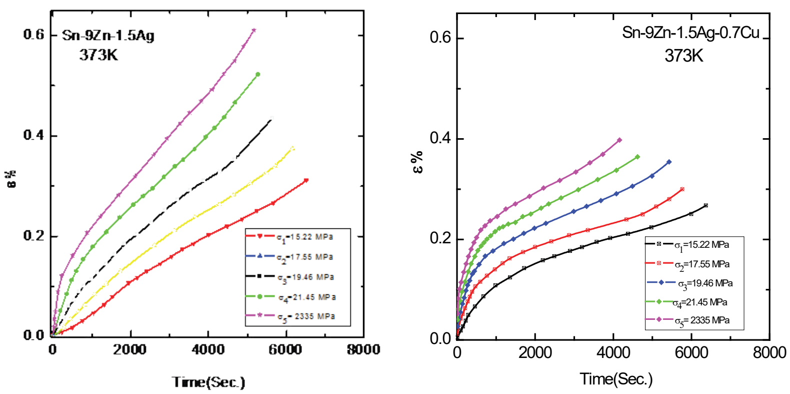


Fig.3: Isothermal Creep Curves at 373 K, at different applied stresses for Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu alloys.

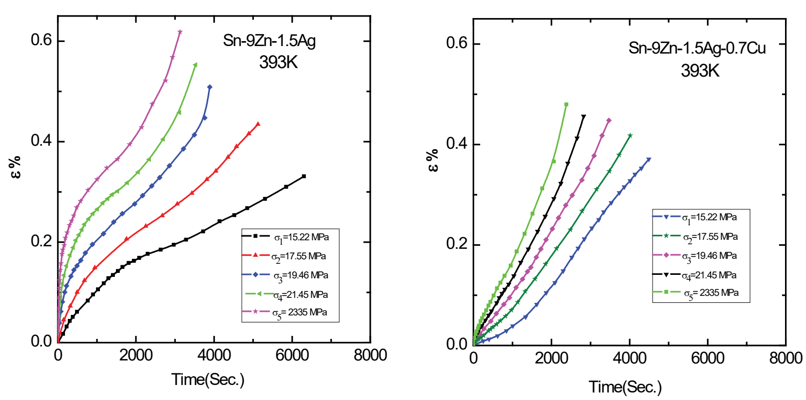


Fig.4: Isothermal Creep Curves at 393 K, at different applied stresses for Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu alloys.

To rapprochement the influence of slight addition of Copper on Tin-9Zinc-1.5Silver Figure.1 symbolized strain-time characteristics for two examined specimen at fixed temperature = 333 K, it is obvious that the ternary 0.7 Copper made the alloy more strengthening; it is shown that Tin-9Zinc-1.5Silver-0.7Copper is more strengthening upper Tin-9Zinc-1.5Silver alloys i.e. Tin-9Zinc-1.5Silver is more superplastic above Tin-9Zinc-1.5Silver-0.7Copper. The appropriateness of ln(strain)tr versus ln(time) leads to upright scheme as represented by Figure 5-8. My study denotes existence of turnover degree is presented. Otherwise, the parameter from Eq.(1) is evaluated by using gradient of Figure 1; it is establish that be elongated of 0.58 until 1.1 owing to Tin-9Zinc-1.5Silver, extended beginning at 0.5 until 0.9 to Tin-9Zinc-1.5Silver-0.7Copper; it is shown that the value of n for the first sample is higher than the second sample; it is demonstrated in Table 2; also in Figure.9.

The y-axis value of ln equation (1) = 0 implies strain-time parameter β; it is demonstrated by using equation.(2)[20,21]

$$ln\beta = \{ (\ln time_2)(Strain)_{tr_1} - (\ln time_1)(Strain)_{tr_2} \} / \{\ln time_2 - \ln time_1\} \quad (2)$$

The value of parameter β was constructed to be of account from -11.22 to -4.66, -12.9 to -6.5, for the alloys as shown from Fig.10.

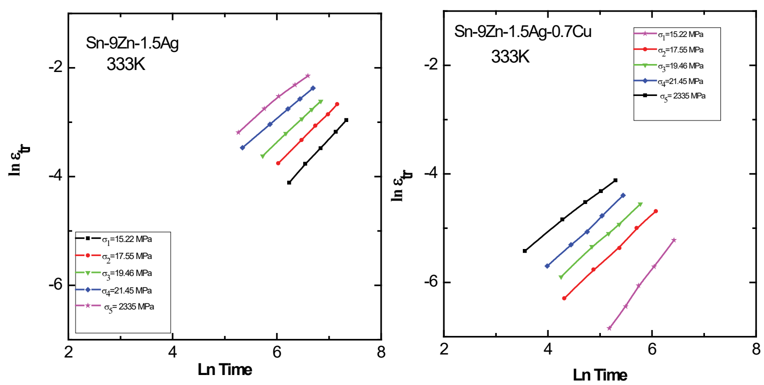


Fig.5: Relation between lnεtr and lnt Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu alloys. at 333K and different stresses.

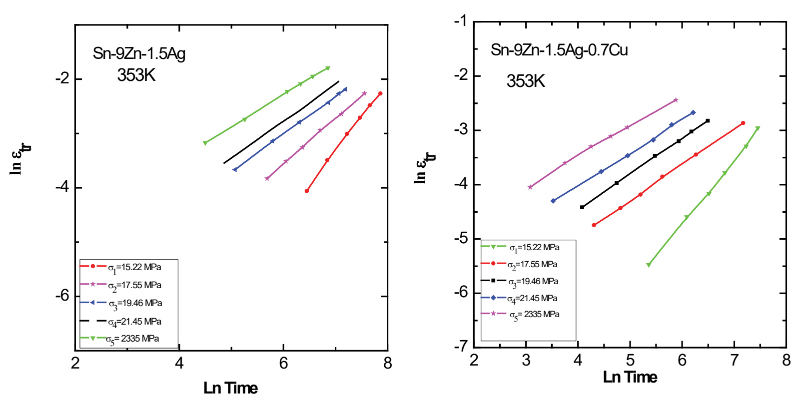


Fig.6: Relation between lnεtr and lnt Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu alloys. at 353K and different stresses.

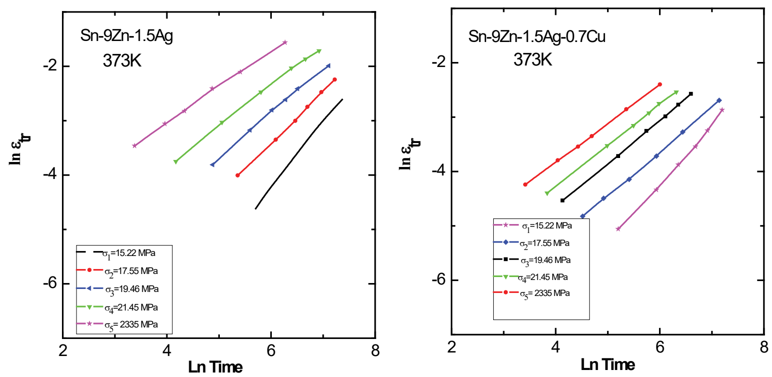


Fig.7: Relation between ln⍰tr and lnt Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu alloys. at 373K and different stresses.

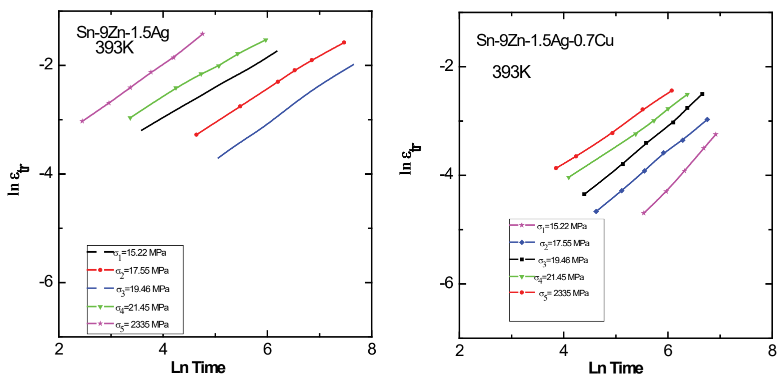


Fig.8: Relation between ln⍰tr and lnt Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu alloys. at 393K and different stresses.

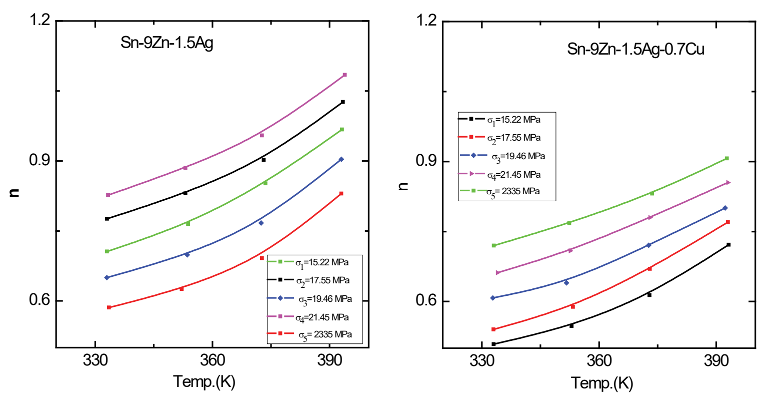


Figure 9. The temperature dependence of the parameters, n, at different applied stresses for Sn-9Zn-1.5Ag, and Sn-9Zn-1.5Ag-0.7Cu alloy.

The y-axis value of ln equation (1) = 0 implies strain-time parameter β; it is demonstrated by using equation. (2)[20,21]

$ln\beta = \{ (ln\ time_2)(Strain)tr_1 - (ln\ time_1)(Strain)tr_2 \} / \{ln\ time_2 - ln\ time_1\}$ (2)

The value of parameter β was constructed to be of account from -11.22 to -4.66, -12.9 to -6.5, for the alloys as shown from Fig.10.

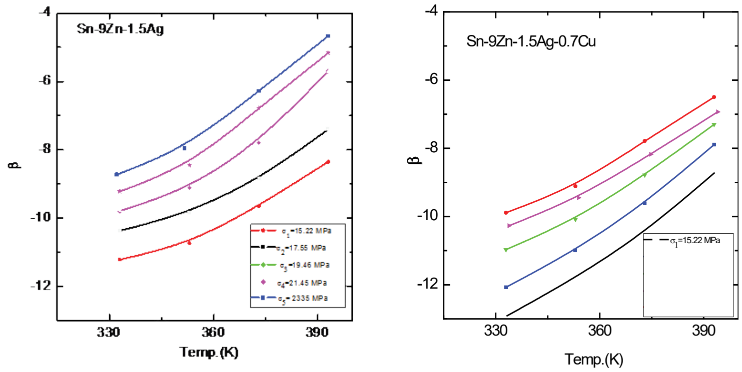


Figure 10. The temperature dependence of the parameters, β, at different applied stresses for Sn-9Zn-1.5Ag, and Sn-9Zn-1.5Ag-0.7Cu alloy.

3-2-The activation energy of alloys.

Eventually activation enthalpy of first part of strain-time Q_{tr} is predestined employed (3).

$Strain_{tr} = strain_0 + time^n \exp\{-Qtr/KT\}$ (3)

Activation enthalpy of transient state is about 13.8: 18.45 KJ/mol for the Sn-9Zn-1.5Ag alloy and about 19.66:22.85 KJ/mol for the Sn-9Zn-1.5Ag-0.7Cu alloy in the two degree zone; it is explained in Figs.11,12; it is evident that the A.E. of 1st sample is lower than that of 2nd sample; therefore the second sample is more strengthening than first sample. Cu addition made the first sample not soft (harder) see Fig.11, 12.

Table2. *Creep parameters of the examined samples.*

Experimental alloys	A.E ($kJmol^{-1}$)	β	n
Tin-9Zinc-1.5Silver	13.8: 18.45	-11.22 : -4.66	0.58 : 1.09
Tin-9Zinc-1.5 Silver -0.7Copper	19.66:22.85	-12.90 : -6.50	0.50 : 0.90

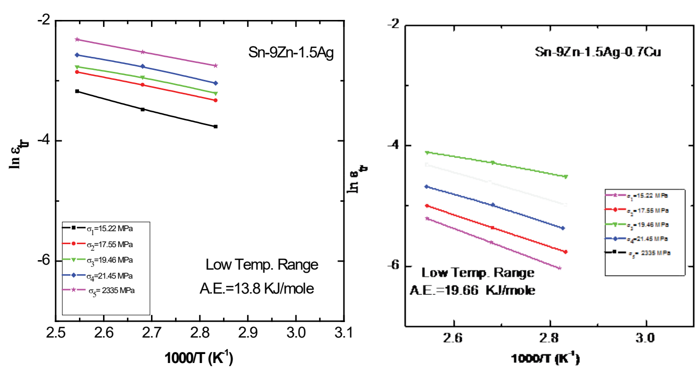


Figure 11. Relation between $ln\varepsilon_{tr}$ and 1000/T at different applied stresses for Sn-9Zn-1.5Ag, and Sn-9Zn-1.5Ag-0.7Cu alloy at low temperature range.

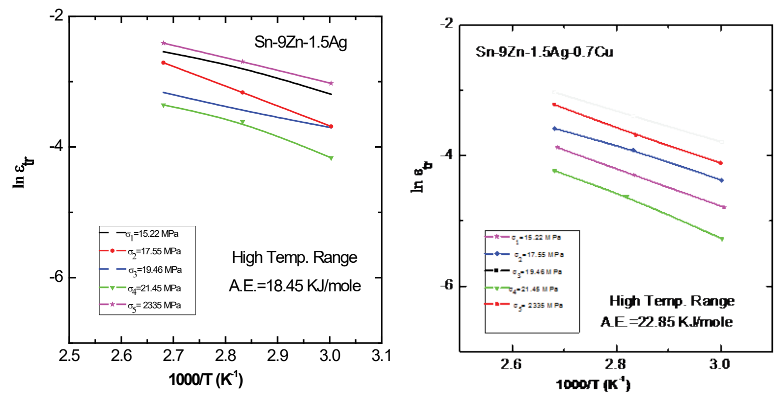


Figure 12. Relation between lnε_{tr} and 1000/T at different applied stresses for Sn-9Zn-1.5Ag, and Sn-9Zn-1.5Ag-0.7Cu alloy at high temperature range.

3-3- linkage of rupture time and Stress.

Fig.13 illustrated the relation through ln($time_f$) versus the load ln(stress); it is illustrated at 333, 353; also at and 393 K. From figure; we conclude so as to ln(t_f) is higher for Tin-9Zinc-1.5Silver-0.7Copper however; thus the Tin-9Zinc-1.5Silver, accordingly prospective i.e. Tin-9Zinc-1.5Silver specimen high in strain than the 2nd sample. Parameter laceration is generally from four to twelve (as in the equation: $time_f = A$ Stress-m, where A is degree- conditioned coefficient [2,22]). Therefore, the stress coefficient of the rupture time magnitude was nearly about value n amount for low force per area control strain time examined [23]. Subsequently, the 1st sample displayed the greatest $\dot{\varepsilon}_{min}$ and then smallest t_f whilst; the influences of Cu extension on increasing t_f were generally similar to those on decreasing $\dot{\varepsilon}_{min}$. Yet, another creep attitude in the sample was linked for deposition castigating influence for inter metallic compounds particles. In case of 2nd, alloy impedance of strain-time is arrived particularly at scattering for $Copper_6Tin_5$ within the β-Sn matrix. The minimum concentrations of $Copper_3Tin$ inter metallic compounds within β-Tin form; therefore zone for basically pure Tin. The spare contrast for 1st sample must lead to minimize strain-time shredding period for Tin-9Zinc-1.5Silver samples (see Fig.13). In case of Tin-9Zinc-1.5Silver-0.7Copper alloy, the $Silver_3Tin$ and $Copper_6Tin_5$ inter metallic compounds constituted in this specimen, made two various function. They were strengthening the alloy matrix, then, lowering the zone fraction of fine Sn. Two parameters will resist the consistence of many dislocation accumulate within confines; also within all forms. Then, aim for reinforcing strain-time existence, greater; the volume for pure inter metallic compounds, preferable strain-time impedance is declared by V.Igoshev et al. [24]. Subsequently, existence for Tin regions is essential in silver welding and variation of dispersion of inters metallic compound leads to rise in the life time of Sn-9Zn-1.5Ag-0.7Cu than the other.

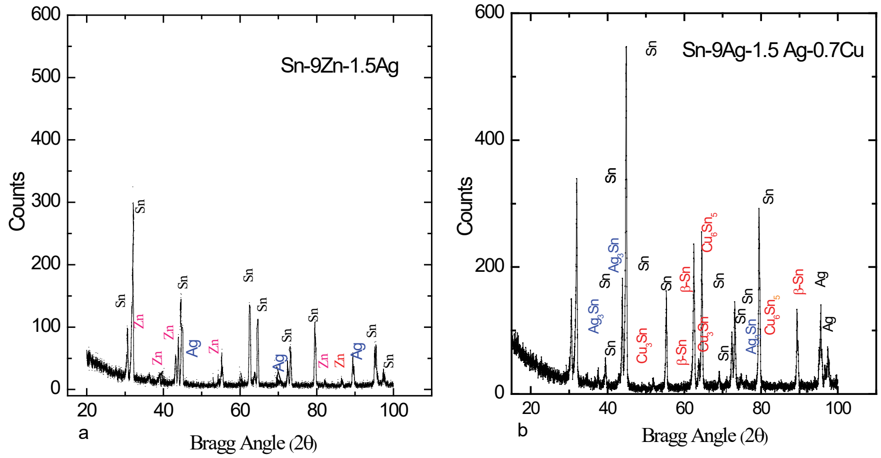


Figure 13. Relation between $\ln t_f$ and $\ln\sigma$ for Sn-9Zn-1.5Ag and Sn-9Zn-1.5Ag-0.7Cu at 333 K, 353 K, and 393 K.

To identify the initial phases, the as-cast Tin-9Zinc-1.5Silver, also; Tin-9Zinc-1.5 Silver-0.7Copper has been inspected using X-Ray Diffraction, it is demonstrated in Fig.14. The Tin-9Zinc-1.5Silver alloy is approaching in Fig.14a it constituent from β-Tin form, also Silver$_3$Tin inter metallic compound. Second samples including Silver and Copper including inter metallic compounds for Silver$_3$Tin and Copper$_6$Tin$_5$, through β -Tin morphology.

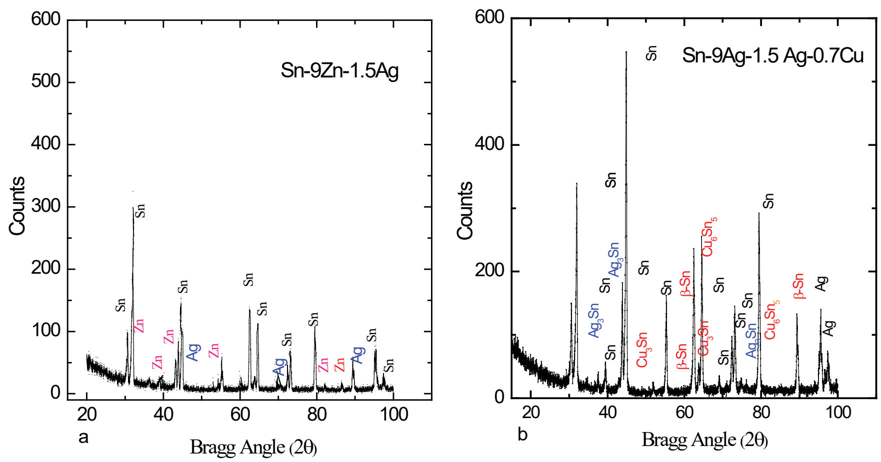
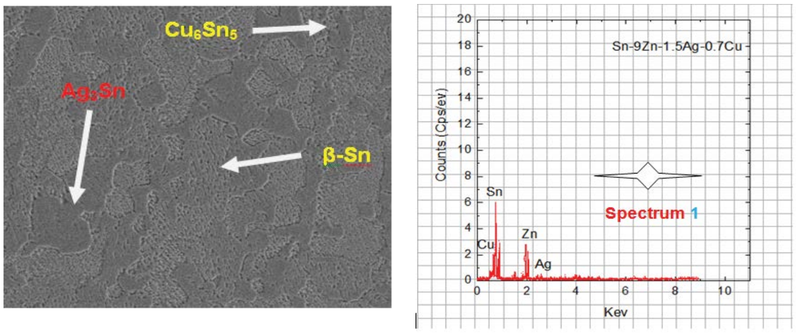


Fig. (14) a. XRD Pattern for Sn-9Zn-1.5Ag alloy where Ag, Zn, and Sn appear and (b) for Sn-9Zn-1.5Ag-0.7Cu mainly composed of β-Sn phase exhibited additional IMCs such as Ag_3Sn, Cu_6Sn_5.

Fig.15 showed Energy-dispersive X-ray spectroscopy (EDS) of the alloys; the pure residual scattered zones during β-Tin form. Residual value is determined utilizing X-Ray Diffraction such Silver$_3$Tin morphology. It is seen that idealistic constituent to 2nd alloy system including of essential β -Tin grains with Silver$_3$Tin and Copper$_6$Tin$_5$ eutectic zone. Low melting area will be more pure, therefore Silver posses little degeneration with in β-Tin face therefore; all Siver residues such Silver$_3$Tin morphology or fine Silver. During this search, the exclusive

Silver$_3$Tin is similiar. Pure residual were spotted all fundamental-Tin petites.



El AN Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [wt.%]
2.9	96.44	96.97	Sn 50 L-series	93.22
0.3	0.56	0.23	Zn30L series	0.23
0.2	2.56	2.33	Ag 47 L-series	2.23
0.1	0.7	0.7	Cu L-Series	0.7

Total: 100.00

Fig.(15) a: Represented SEM images of the tested alloys, the microstructure composed of β-Sn areas, fine Ag_3Sn precipitates. In Fig.3.b, EDS analysis of the tested alloys.

Fig.16. represent Transmission Electron Microscope (TEM) photo of the examined alloys.(a); black band evidence for Scanning Electron Microscope using Energy-dispersive X-ray spectroscopy (EDX) that exposed the presence for Silver in the ultimate intensity, microstructure composed of light gray areas of Ag_3Sn and black lattice-as low melting zones aboutβ -Tin pellet confines, At Figure.(b), conventional composition of Copper was found to improve the microstructure, mechanical properties and are able to refine the grain size, there are Silver$_3$Tin inter metallic compounds IMCs, the Copper$_6$Tin$_5$ inter metallic compounds IMCs are doing such different nucleation places in case of β-Tin branches. Fig.(17): Represented Differential scanning calorimetry (EDS) and Thermo gravimetric (TGA)analysis, it is shown that heat flow is decreased with increasing temperature.

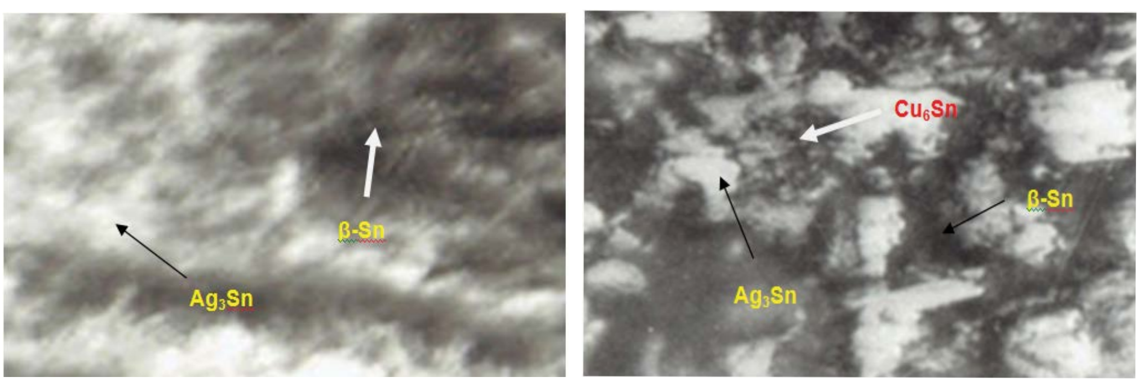


Fig.(16): TEM images of the tested alloys.(a); microstructure composed of light gray areas of Ag_3Sn and dark network-like eutectic regions ofβ -Sn grain boundaries, In Fig.(b), the appropriate content of Cu was found to improve the microstructure, mechanical properties and are able to refine the grain size, there are Ag_3Sn IMCs, the Cu_6Sn_5 IMCs might act as heterogeneous nucleation sites for β-Sn dendrites.

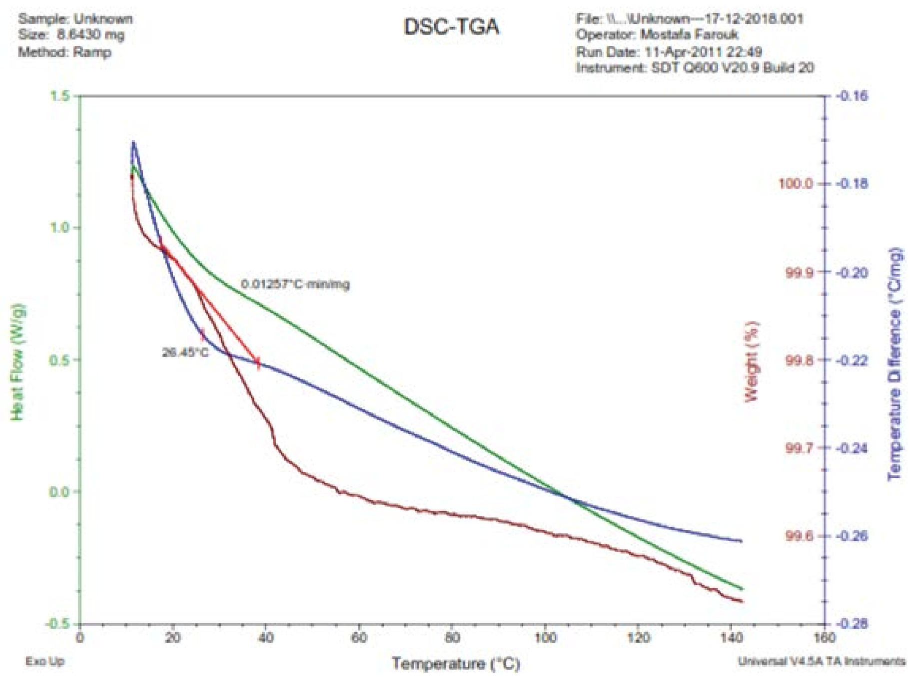


Fig.(17): Represented Differential scanning calorimetry (EDS) and Thermogravimetric (TGA)analysis, it is shown that heat flow is decreased with increasing temperature.

Conclusion

(1) Addition of 0.7 wt%Cu seems to change the microstructure of the second alloy and it becomes more strengthening than the first alloy.

(2) It is clear that the value of n for the first sample is higher than the second.

(3) It is explicit that the activation enthalpy of 1 st sample is minimize than that of 2 nd sample; thus the second sample is more strengthening than first sample. Cu addition made the first sample not soft (harder).

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