

Investigation of Creep Behaviour of Lanthanum Doped Tin-Silver Lead Free Solder

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ABSTRACT: Tin-Silver (Sn-Ag) lead free alloys were the first lead free product applied as substitutes over Tin-Lead (Sn-Pb) eutectic solders which have a long history of use in electronics industry. Creep Resistance of the solder joint is one of significant mechanical properties which play an important role in determining its long term reliability as joints are subjected to high level of strains during operation. The aim of this study is to improve the creep life of 96.5Sn3.5Ag wt% solder alloy at 25°C by doping it with RE element, Lanthanum (La). The obtained results revealed that creep life of 96.0Sn3.5Ag0.5La wt% has been significantly improved (100%) when compared with 96.5Sn3.5Ag wt% at a constant stress of 18MPa. Micro structural evaluation has not been focused.

KEYWORDS: Lead Free Solder, Lanthanum, Electron Dispersive Spectroscopy, Creep

I. INTRODUCTION

Electronics manufacturing industry is one of the most competitive and developing industry of the world. The aim of electronics manufacturing industry is to design and develop electronic parts or products like televisions, cell phone, computers etc for sale in market. A lot of money has been put into research and developing smart devices like semiconductor chips have expanded this industry even further. Electronic industry plays an important role in improving economic conditions around the world [1].

Till recently, since the beginning of electronic industry (Sn-Pb) alloys are used for soldering applications due to a variety of material properties like good wettability and low cost [1]. But due to growing awareness regarding Lead toxicity and its adverse effects on environment, Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) directives in Europe and the U.S Environmental Protection Agency has abandoned manufacturing of lead based electronic products [2]. The motivation to remove toxic lead from electronic accessories due to international legislations has made development of Lead free solders a challenging task for Material Researchers [3].

Due to better Creep resistance, Ductility and Thermal resistance, (Sn-Ag) and Tin Silver Copper (SAC) lead free alloys were the first lead free product applied as substitutes over Sn-Pb eutectic solders in the electronic industry [3-8]. Some of the common additives doped in Tin rich lead free solders to refine microstructure are Bismuth (Bi), Copper (Cu), Zinc (Zn), Antimony (Sb), Indium (In) and Silver (Ag) [9]. The addition of some alloying elements resulted in improving wettability, increase in hardness and tensile strength, solid solution strengthening to original Sn matrix and improving melting temperature [10]. But it should also be noted that addition of few alloying elements have resulted in decreasing vibrational fatigue resistance [11] and corrosion resistance of parent Sn-Ag alloys [12]. These serious issues made Researchers to think about the addition of Vitamins of Materials called Rare Earth Additives as doping elements in parent Sn-Ag alloys [13]. It has been found experimentally that RE-doped Lead free solders have better wettability and more refined microstructure than original ones [14].

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II. WHY CREEP IS IMPORTANT

The capability of a solder joint to remain functional in high temperature environments such as automotives and oil exploration applications is a matter of great concern [13]. The two most common modes of solder joint failure are fatigue and creep [13]. Solder joint serves both as an electrical inter-connect as well as a mechanical bond between package elements [15]. During operation, electronic equipment generates heat and joined materials experiences internal stresses and strains due to constraints in Coefficient of Thermal Expansion (CTE). The onset of Creep depends on homologous temperature (ratio of working temperature (in Kelvin scale) to melting temperature (in Kelvin scale) (T/T_m) i-e if ($T/T_m > 0.5$) creep will occur [16]. Since operating service temperature is very high so these stresses may cause creep deformation in solder joints which ultimately decrease the mechanical strength of the Solder joint [17]. One of the main limiting factors in Lead free solder joints is that they undergo Creep even at room temperature as T_m is too low [14]. It is important to minimize creep because it is a permanent deformation and joint will not recover its original shape [15].

III. WHY RE- DOPED TIN SILVER LEAD FREE SOLDERS

The eutectic point of Ag-Sn phase diagram is 96.5Sn3.5Ag. It has melting point of 221°C and shows good wetting characteristics. Rare Earth elements refine the grain size as well as absorbed at Grain boundaries and restrain their movement which is one of the main mechanisms of creep [6 - 18]. This research will provide a basic idea of changes in creep life of Lanthanum doped Sn-3.5 Ag alloy at room temperature.

IV. EXPERIMENTAL RESULTS

1 kilogram of Sn (99.83% pure) and 50 grams Ag (98.96 % pure) were purchased from FS CORPORATION Lahore and 15 grams of La (99.5% pure) has been purchased from Atomic Energy Commission Pakistan. The solid Sn and Ag were mixed and melted in a graphite crucible at 990°C for 30 minutes placed in a non- inert vacuum Chamber or Box Furnace. The red hot crucible was then taken out from furnace with the help of steel prongs and La has been added in the melt and stirred with the help of steel rod. The crucible was again put in furnace at 990°C and temperature was maintained for one hour and thirty minutes for homogenization of La in melt. Stirring was done after every 30 minutes to ensure proper homogenization. The melt was then Die casted and specimens were obtained. EDX for composition analysis was performed on EDS (Oxfordins Inca-200).

V. RESULTS AND DISCUSSION

Electron Dispersive Spectroscopy

The EDS peak of 96.5 Sn3.5Ag wt% is shown in figure 1.

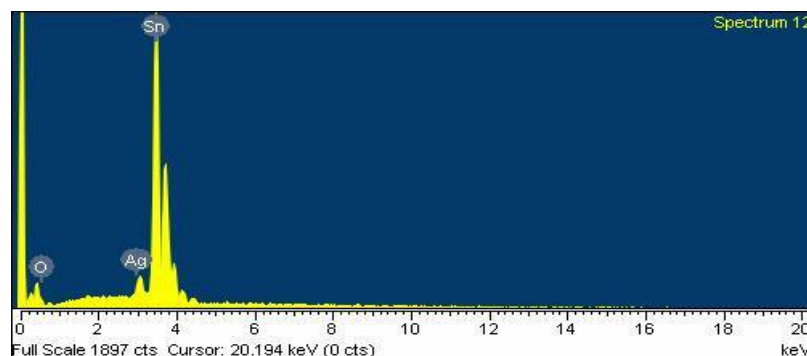


Fig 1: EDS peaks of 96.5Sn 3.5Ag wt%

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The above pattern shows that all the elements of composition (Sn and Ag) has been detected.

The EDS peaks of 96.0 Sn3.5Ag 0.5 La wt% is shown in figure 2.

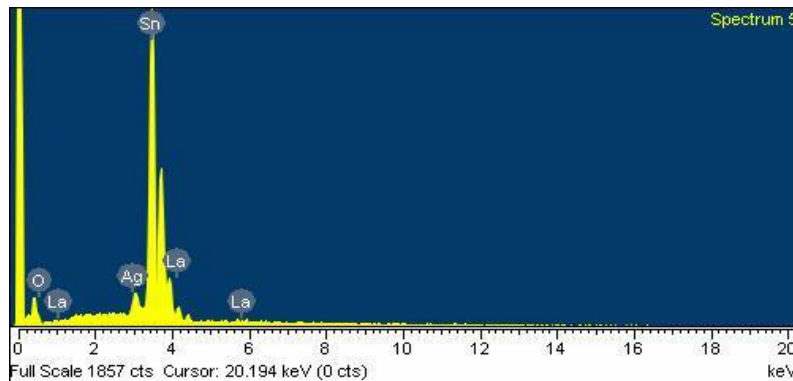


Fig 2: EDS peaks of 96.0 Sn3.5Ag 0.5 La wt%

The above pattern shows that all the elements of composition (Sn, Ag and La) has been detected.

In both the results an extra peak of Oxygen is present which shows that oxidation has been taken place during melting in the available furnace. Exact composition of 96.5 Sn3.5Ag wt% and 96.0Sn3.5Ag0.5La wt% achieved is shown in table 1 and 2 respectively.

Table 1: Exact elemental composition of 96.5 Sn3.5Ag wt%

<i>Element</i>	<i>Weight (%)</i>
Sn	95.27
Ag	3.27
O	1.47
Total	100

It can be seen clearly that oxidation has definitely alters the exact percentages of the elements present in the composition

Table 2: Exact elemental composition of 96.0Sn3.5Ag0.5La wt%

<i>Element</i>	<i>Weight (%)</i>
Sn	95.87
Ag	3.5
La	0.35
O	0.28
Total	100

Creep tests are performed by applying a constant load or stress and the corresponding strain rate (% deformation) produced is measured by extensometer. The creep analysis help engineers to predict solder material that may serve for long time as a joint between substrate and solder [18]. The specimen of thickness 2mm used for creep testing is shown in figure 3

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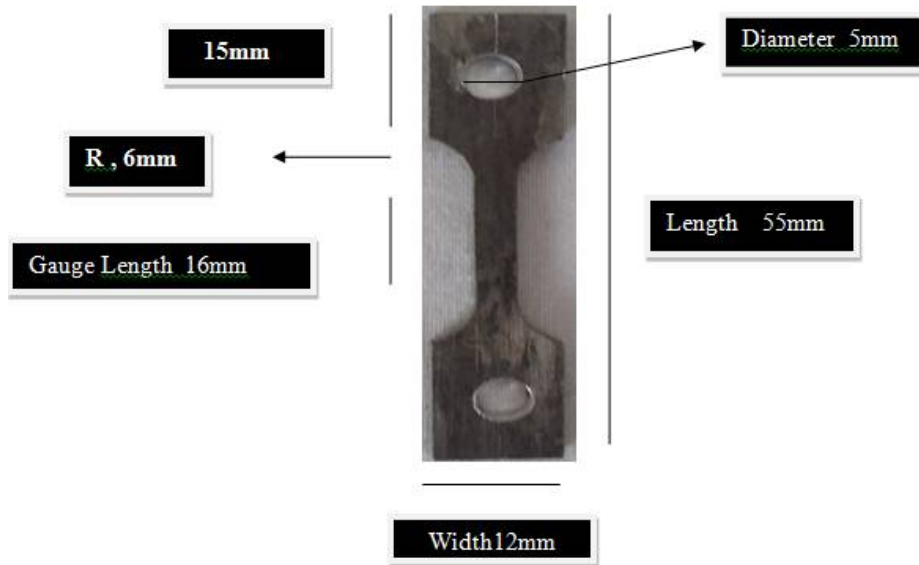


Fig 3: Creep test specimen

Fig 4 shows curves of 96.5 Sn 3.5 Ag wt% and 96.0Sn 3.5 Ag 0.5 La wt% at 25°C and at a constant stress of 18MPa.

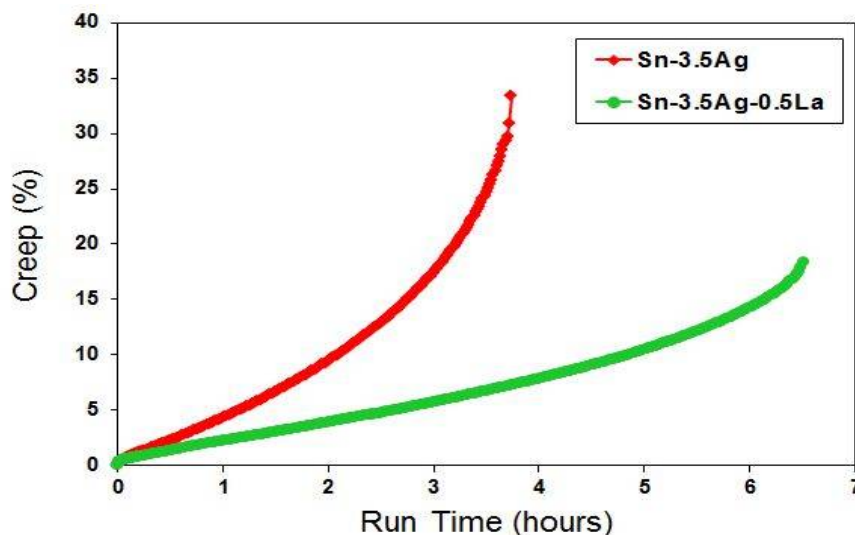


Fig 4: Creep curves of 96.5 Sn 3.5 Ag wt% and 96.0Sn 3.5 Ag 0.5 La wt%

It is clear from the above curves that creep life of 96.0Sn 3.5 Ag 0.5 La wt% is more than six hours while that of 96.5 Sn 3.5 Ag wt% is less than six hours. Improvement in both time and strain to failure has been observed. This result is in consistent with [16] in which the modification in creep curve of Sn-3.5Ag has been observed by adding RE elements. It is actually due to agglomeration of RE elements at the grain boundaries and also at the boundaries between

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different phases which prevents mobility of dislocations as well as micro cracks nucleation [18]. This resulted in improving creep life of 96.0Sn 3.5 Ag 0.5 La wt% as compared to 96.5 Sn 3.5 Ag wt%.

VI. CONCLUSION

The main results of the experimental work are:

- i. The oxidation during melting has disturbed the actual ratio of the elements present in the composition.
- ii. The actual compositions achieved were 95.27Sn 3.27Ag 1.47 O and 95.27Sn 3.5Ag 0.35La 0.28O.
- iii. The addition of La in 96.5Sn 3.5 Ag wt% doubles its creep life.

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