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Study the Structure and Electrical Properties of Sn-9Zn-1Ag Solder Alloy

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Abstract

In this paper, we studied the structure and electrical properties of the alloy of composition Sn-9Zn-1Ag solder alloy as example of metallic materials that is used in electronic applications. The alloy exhibited three phase mixtures, tetragonal Sn as a solid solution and Zn phase and AgZn intermetallic compound. The lattice parameters, a, and C of the tetragonal Sn were also calculated. The ternary alloy exhibited Ohmic behavior. Also, we described its variation with temperature and determined the temperature coefficient of resistivity (TCR).

Keywords: Sn-9Zn-1Ag solders, resistivity, TCR, structure

1. Introduction

Soldering is one of the most important joining processes although it is the oldest metal joining process, yet it is very vital and useful in space age of modern technology. The advances in transistors, diodes and specially integrated circuits have been revolutionized in electronic manufacturing throughout the world. These components are of very little values as individual components and to be use, they must be electrically connected to each other and mechanically to the printed circuit board by the so-called solder alloys. It based on the tin-lead alloys because of their unique combination of material properties and low cost.

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The popularity of these alloys is due to their relatively low melting point, aggressive bonding characteristics, good wicking tendencies and good electrical continuity. But due to the toxicity of lead, a registration has been proposed to replace the use of lead from a wide variety of applications.

The main replacement element is tin as a main component which combined with other elements such as; silver, zinc, bismuth, and copper. These alloys may be either, binary, ternary or quaternary alloys. The process of choosing a certain one depends mainly on some characteristics such as; the melting temperature, availability in sufficient quantities, good electrical/thermal conductivity, easy reparability, low cost and the environmental issues related to the toxicity. Vianco in 1993, Glazer in 1995, Dreyer & Muller in 2000, Abell & Shen in 2002, Gouda & Kamal in 2012, have intensive their researches to improve the lead free solders. In the present paper we are going to study the structure and electrical properties of the Sn-9Zn-1Ag ternary alloy as a simple example of the lead-free solder alloy.

2. Experimental Work

The alloy of composition Sn-9Zn-1Ag solder alloy was prepared by melting pure tin first. Then immersed the calculated quantities of the solid Zn and Ag metals, then let the mix to be melted and shaking it several times to ensure homogenization of the mixture has been occurred. Then let the alloy to be solidified by casting technique and the cold rolling into sheets of about 1mm thickness and 3 mm width. To study the structure of the alloy, a shimadzu X-Ray diffract-meter (DX-30) with a Cu-K_α radiation with Ni-filter in the angular range 2θ, ranging from 20 to 100 in continuous mode which includes the strongest diffraction signals. The condition for the occurrence of the diffraction spectrum is given by Bragg's law; $N \lambda = 2 d_{hkl} \sin \theta$, where, d_{hkl} is the spacing of the *hkl* crystal planes, θ is the angle of scattering. The magnitude of the inter-planer spacing (*d*) is a direct function of the miller indices for the plane. For the tetragonal system, it is given by; $1/d^2 = (h^2 + k^2) / a^2 + l^2/c^2$, where *a*, and *c* are the lattice parameters of the unit cell. X-ray diffraction technique with Cu-K_α radiation was used. Electrical resistivity was also calculated from the I-V curve using a simple circuit of Ohm's law. Furthermore, the circuit was connected to a heater plate to determine the temperature coefficient of resistivity.

3. Results and Discussion

3.1 XRD Analysis of the Sn-9Zn-1Ag Ternary Alloy

A metallic alloy is a combination of two or more metals. It may consist of a single phase or mixture of phases and these phases may be of different types depending on the alloy composition and the used cooling rate. X-ray diffraction pattern is a tool for investigation of the fine structure of metallic matter. The key to the interpretation of the X-ray diffraction pattern is the fact that; each phase produces its own pattern independently. Thus a single phase alloy produces a single pattern while the pattern of a two-phase alloy consists of two superimposed patterns, one due to each phase.

Fig.1 shows the X-ray diffraction pattern of the Sn-9Zn-1Ag ternary alloy. It shows that, the pattern contains several peaks due to the solid solution Sn with some dissolved Zn and Ag atoms. In addition there are four X-ray diffraction lines due to Zn phase as illustrated in table (1). Also, there is a single X- ray diffraction line due to the intermetallic compound AgZn phase. It has been appeared at $2\theta = 97.49^{o}$. Details of these phases are presented in table (1). The lattice parameters, *a,* and C of the tetragonal Sn were calculated. It was found that, the lattice parameter, *a* is equal to 5.93 Å, which is large value compared with that of pure Sn (5.83 Å). This increase may be attributed to trapping of Zn and Ag atoms in the Sn matrix.

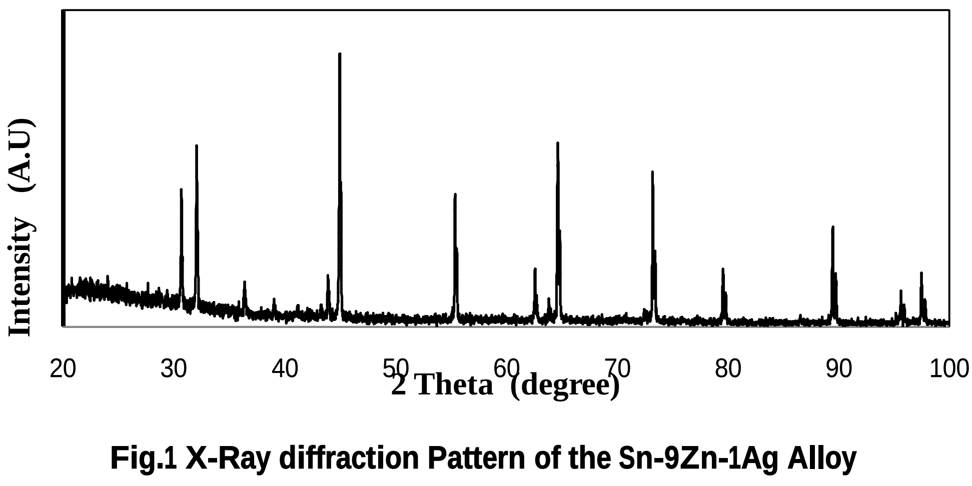

Fig.1 X-Ray diffraction Pattern of the Sn-9Zn-1Ag Alloy

3.2 Electrical Properties

Fig.2 shows the current-voltage relationship of the Sn-9Zn-1Ag ternary alloy. It shows a linear relation indicating that, the alloy is Ohmic material. The electrical resistivity of the alloy sample was first calculated many times and the average value was taken into account. It was found that, the electrical resistivity is equal to 33.1 ± 2 μΩ.cm. After that, the alloy sample was connected to a heater plate and recording the values of the voltage versus temperature in the range of the room temperature to 80 ºC at constant current. Fig.3 shows the variation of the measured voltage with temperature in the range of 20 to 80 ºC. Also, the values of electrical resistance were calculated in this range of temperature and the result is illustrated in Fig.4.

Table 1: Details of the Phases Presented in the Sn-9Zn-1Ag Ternary Alloy

2θ	θ	d_{hkl}	I / I_o	hkl	Observed Phases
30.69	15.35	2.963	50.2	200	Sn
32.07	16.04	2.750	66.3	101	Sn
36.39	18.20	2.467	12.8	002	Zn
39.05	19.53	2.305	12.9	100	Zn
43.93	21.97	2.059	18.6	220	Sn
44.97	22.49	2.014	100	211	Sn
55.39	27.70	1.657	48.6	301	Sn
62.61	31.30	1.482	21.2	112	Sn
64.67	32.34	1.453	67.4	400	Sn
73.23	36.62	1.306	56.7	420	Sn
79.57	39.79	1.204	21.2	312	Sn
89.49	44.75	1.100	36.5	104	Zn
95.63	47.82	1.041	13.3	202	Zn
97.49	48.75	1.027	19.8	602	AgZn

In addition, the electrical resistivity was also calculated and the result is illustrated in Fig.5. It shows a linear increase of electrical resistivity from 33.1 to 48 μΩ.cm in this range of temperature. This increase may be attributed to the disturbances in the lattice order due to the thermal vibration which may cause scattering for conduction electrons.

Furthermore, the temperature coefficient of resistivity (α) was also calculated and found to be 7.5 x 10^{-3} C^{-1}, which is a lower value compared with that of the eutectic lead-tin commercial alloy as reported earlier in the researched work of Gray in 1957.

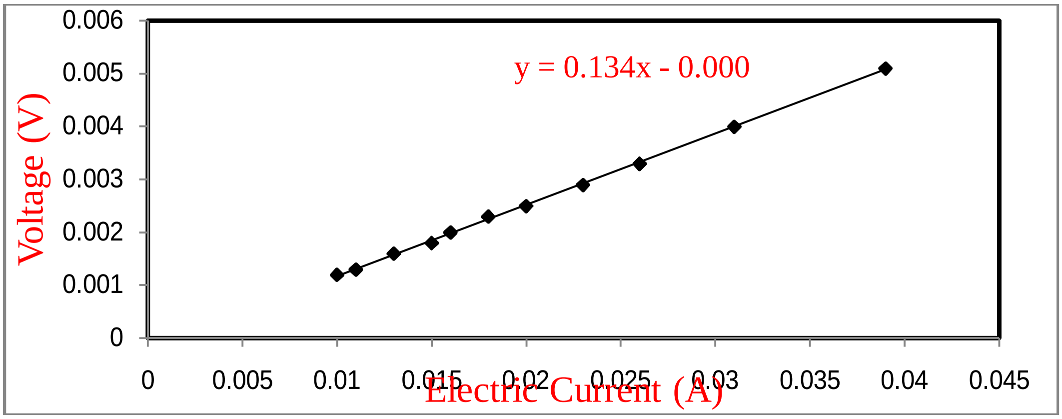

Fig.2: Voltage Versus Current Relation of the Sn-9Zn-1Ag Ternary Alloy

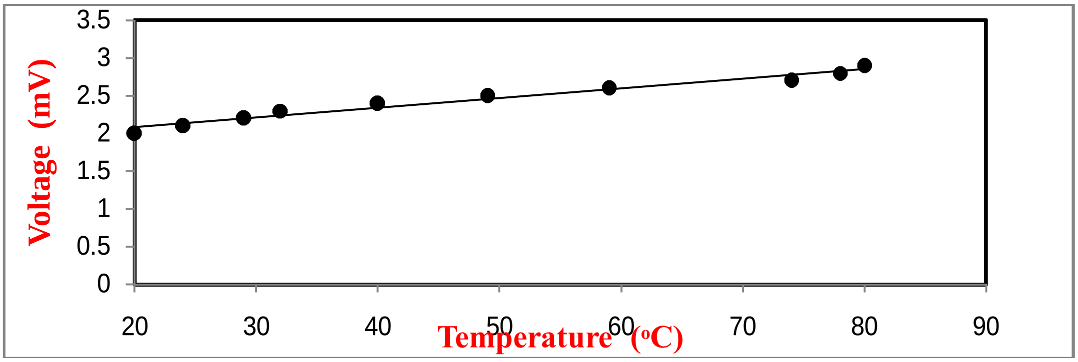

Fig.3: Voltage Versus Temperature of the Sn-9Zn-1Ag Ternary Alloy

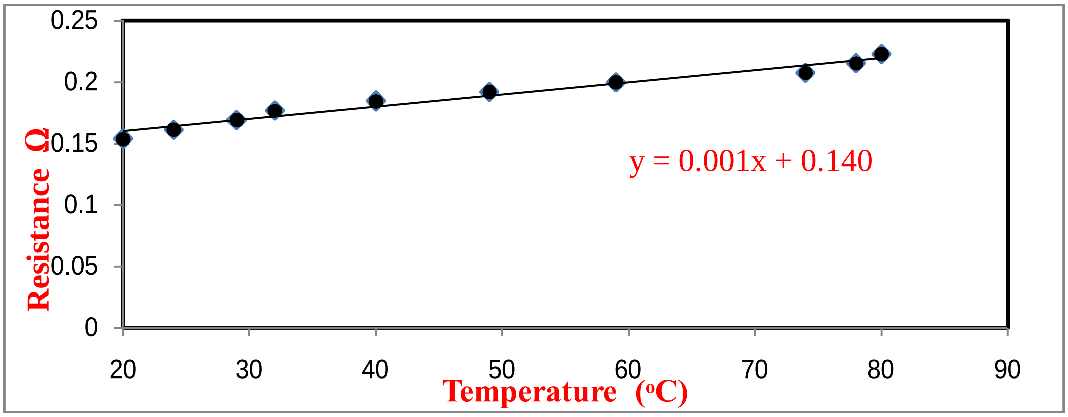

Fig.4: Electrical Resistance Versus Temperature of the Sn-9Zn-1Ag Ternary Alloy

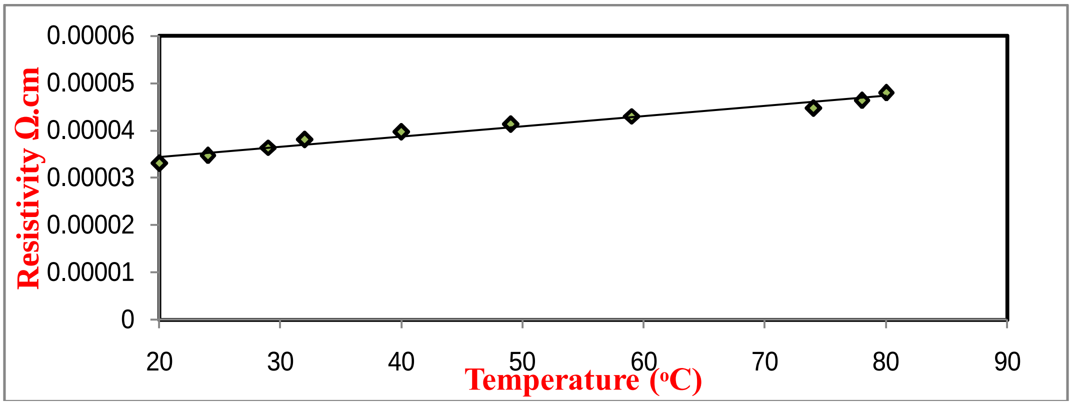

Fig.5 Electrical Resistivity Versus Temperature of the Sn-9Zn-1Ag Ternary Alloy

Conclusion

In this project, the structure and electrical resistivity of the Sn-9Zn-1Ag ternary alloy has been studied and analyzed. The results can be summarized in the following notes:

a. The alloy exhibited three phases mixture; tetragonal Sn as a solid solution, Zn phase and AgZn intermetallic compound. The lattice parameters a, and C of the tetragonal Sn were calculated and found to be of higher values of pure Sn.
b. The ternary alloy exhibited Ohmic behavior It has electrical resistivity 33.1 μΩ.cm at room temperature.
c. The resistivity increases linearly with temperature.
d. The temperature coefficient of resistivity was calculated and found to be 7.5×10^{-3} C^{-1}.

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