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Micro-structure and physical properties of Sn- Sb-Cu based bearing rapidly solidified alloys

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ABSTRACT

Effects of modification structural on electrical resistivity, elastic modulus, internal friction and hardness of $SnSb_{10}Cu_2X_2$ (X= Pb, Zn, Se, Ag and Cd) rapidly solidified alloy has been investigated. Modification structural, changing the matrix lattice parameters and volume unit cell with forming intermetallic compounds, affects on all measured properties. The $SnSb_{10}Cu_2Pb_2$ alloy has betters properties for bearing applications.

KEYWORDS

Microstructure;
Electrical resistivity;
Elastic modulus;
Internal friction;
Hardness.

INTRODUCTION

Bearings are used in all types of machinery, engines and mechanisms of supporting and controlling the motion of rotating, sliding or reciprocating parts. Rotating parts that are supported and controlled by bearing are usually called shafts, spindles or axles. Bearing are designed to serve their purpose with a minimum of friction, power loss, generation of heat and are added in this requirement by suitable lubrication. Bearings are classified into metal and non-metal alloys. White metals or Babbitt metals are typically tin based (88% Sn, 4% Cu, 8% Sb) or lead based (80% Pb, 14% Sb, 6% Sn). Tin based alloys are usually more expensive, have better wear resistance, stand higher loads and are not as brittle and are more corrosion resisting than lead based bearings. Several investigators[1-17] studied the correlation of structure with mechanical, electrical and thermal properties of metallic bearing materials. The aim of the present work was to investigate the influence of modification structural on electrical resistivity, elastic modulus, internal friction and hardness of $SnSb_{10}Cu_2X_2$ (X= Pb, Zn, Se, Ag and Cd) rapidly solidified alloys.

EXPERIMENTAL WORK

The samples used in the present work are Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) were melted in a muffle furnace using tin, antimony, copper, cadmium, selenium and silver of purity better than 99.5 %. The resulting ingots were turned and re-melted four times to increase the homogeneity. From these ingots, long ribbons of about 4 mm width and ~70 μm thickness were prepared by a single roller method in air (melt spinning technique). The surface velocity of the roller was 31.4 m/s giving a cooling rate of $\sim 3.7 \times 10^5$ K/s. The samples then cut into convenient shape for the measurements using double knife cuter. The internal friction Q^{-1} and the elastic constants of used alloys were determined using the dynamic resonance method. The value of the dynamic Young modulus E is determined by the following relationship[18-20]:

$$\left(\frac{E}{\rho}\right)^{1/2} = \frac{2\pi L^2 f_0}{kz^2}$$

Where ρ the density of the sample under test, L the length of the vibrated part of the sample, k the radius of gyration of cross section perpendicular to its plane of motion, f_0 the resonance frequency and *z* the constant depends on the mode of vibration and is equal to 1.8751. Plotting the amplitude of vibration against the frequency of vibration around the resonance f_0 gives the resonance curve, the internal friction, Q^{-1}, of the sample can be determined from the following relationship:

$$Q^{-1} = 0.5773\frac{\Delta f}{f_0}$$

Where Δf the half width of the resonance curve

Vickers hardness number at different loads, 10, 25 and 50 gf, with constant indentation time, 5 sec, of used alloys were measured using Vickers micro-hardness tester (Model - FM- 7- Japan).

RESULTS AND DISCUSSION

X-ray diffraction patterns, Figure 1, and its analysis show that, the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) rapidly solidified alloys have body central tetragonal of tin phase, with different inter-metallic compounds, SnSb/or SnSb and Ag_3Sn in, imbedded in the Sn matrix depending on the alloy composition. Also the lattice parameters, (a and c), crystal size and unit cell volume values of Sn matrix are varied de-

TABLE 1a : Lattice parameters, (a and c), crystal size (L) and volume unit cell, (V) of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys

Alloy	a Å	c Å	c/a	V(a^2.c) Å^3	L Å
Sn-10Sb-2Cu-2Pb	5.5	3.22	0.59	97.53	232.96
Sn-10Sb-2Cu-2Zn	5.83	3.163	0.543	107.5	208.19
Sn-10Sb-2Cu-2Ag	5.85	3.19	0.5455	109.09	110.88
Sn-10Sb-2Cu-2Se	5.85	3.175	0.543	108.62	190.02
Sn-10Sb-2Cu-2Cd	5.9	3.139	0.54	107.7	313.33

TABLE 1b : Strengthening phases in Sn matrix of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys

Sample	Grain size Å of Sn matrix	Strengthening phases
$SnSb_{10}Cu_2Pb_2$	242.71	SnSb
$SnSb_{10}Cu_2Ag_2$	233.43	SnSb Ag_3Sn
$SnSb_{10}Cu_2Se_2$	229.65	SnSb
$SnSb_{10}Cu_2Cd_2$	219.6	SnSb
$SnSb_{10}Cu_2Zn_2$	215.9	

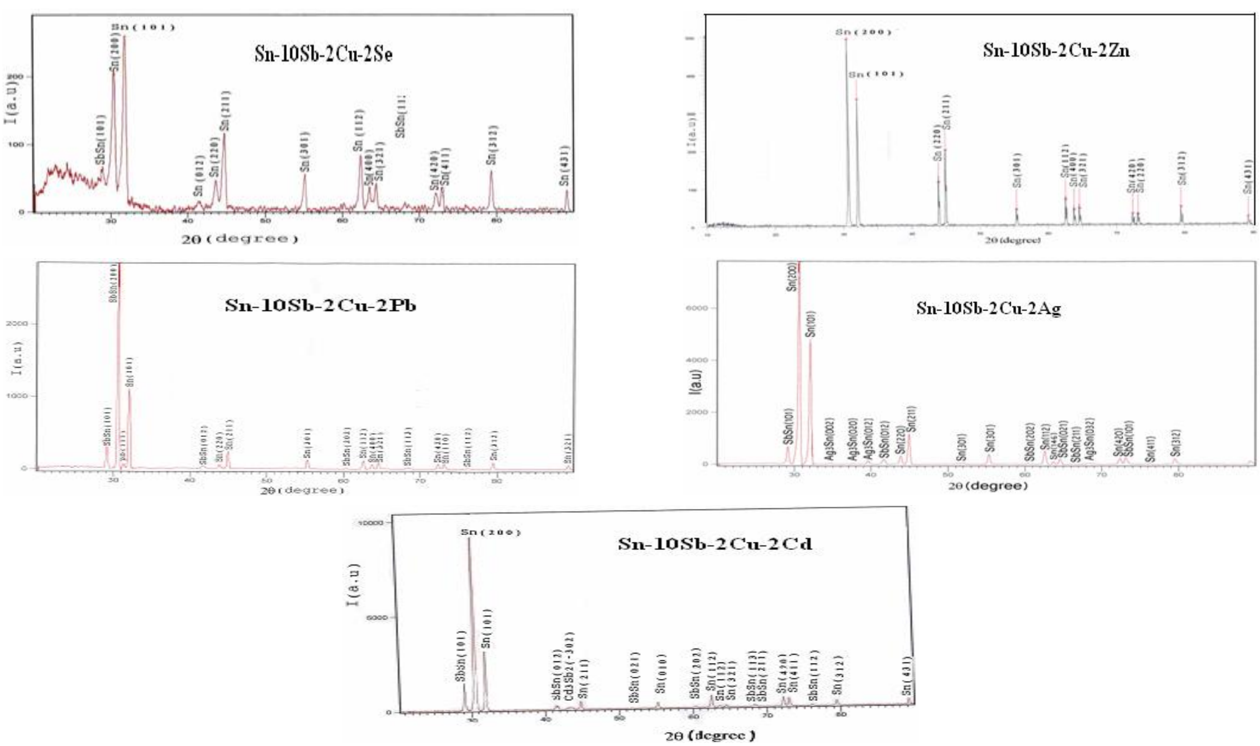

Figure 1: X-ray diffraction patterns for the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys.

pending on the alloy composition as seen in TABLE 1a and TABLE 1b.

Electrical resistivity and temperature coefficient of resistivity, T.C.R, values of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys is varied as seen in TABLE 2. These variations due to the changing in the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys matrix structural such as lattice parameters, crystal size, dissolving atoms and forming inter-metallic compounds which affects on scattering center for the conduction electrons.

Elastic modulus and internal friction values, TABLE 2, of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys are varied. These variations may be because he changing in the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys matrix structural such as lattice parameters, crystal size, dissolving atoms and forming intermetallic compounds which affects in the matrix bonding affecting their elastic modulus value.

TABLE 2 : Electrical resistivity, internal friction Q^{-1}, Modulus of elasticity E and temperature coefficient of resistivity T.C.R for the Sn_{90-x}-$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys.

Alloy	Resistivity	Q^{-1}	E	T.C.R
Sn-10Sb-2Cu-2Pb	38.23±4.92	0.049	30.4±8.5	0.05
Sn-10Sb-2Cu-2Zn	44.8±2.3	0.082	24.46±4.5	0.006
Sn-10Sb-2Cu-2Ag	49.6±1.07	0.097	28.8±3.5	0.00167
Sn-10Sb-2Cu-Se	55.17±6.39	0.06	27.4±3.7	0.004
Sn-10Sb-2Cu-2Cd	59.64±3.09	0.054	18.04±3.9	0.0012

Electrical resistivity values of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys versus temperature are shown in Figure 2a. Electrical resistivity of $PbSb_{13}X_2$ (X=0, Sn, Cd, Cu/ Sn or Cu/ Cd) alloys are increased linearly with temperature. Also Figure 2b shows the temperature coefficient of resistivity of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys is varied, which is sensitive to micro-structural changing, depending on the alloy composition.

Vickers hardness number at different indentation loads, 10, 25 and 50 gf, at constant indentation time, 5 sec, of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys is varied as shown in Figure 3a. These variations due to modification structural such as crystal size, dissolving atoms and strengthening phases, SnSb/or SnSb and Ag_3Sn in, imbedded in the matrix. Also the diagonal length at different loads, D, due the indenter effective is varied as shown in Figure 3b.

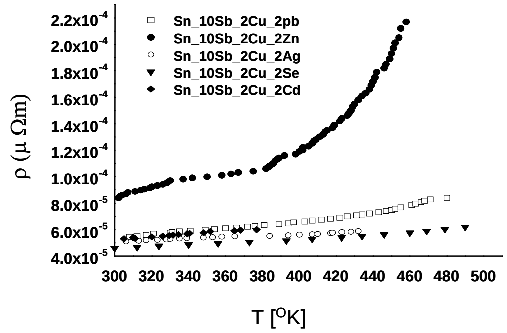

Figure 2a : Electrical resistivity values of the Sn_{90-x}-Sb_{10} Cu_2X_2(X=Pb, Ag, Cd, Se and Zn) alloys versus temperature

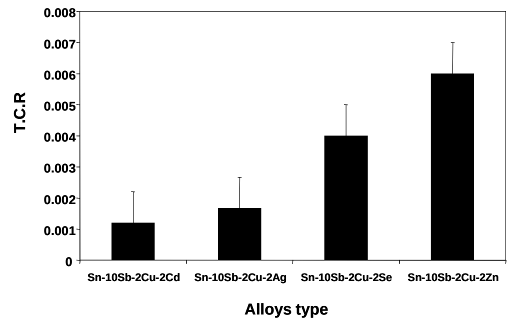

Figure 2b: The temperature coefficient of resistivity of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys

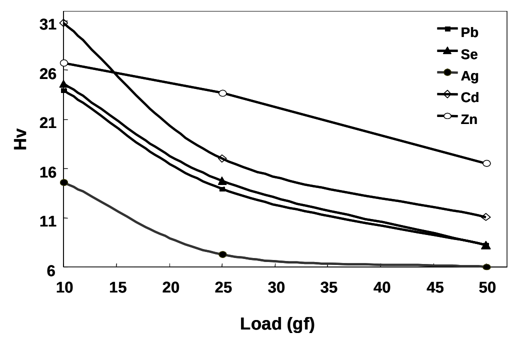

Figure 3a : Vickers hardness number at different indentation loads, 10, 25 and 50 gf, and constant indentation time, 5 sec, of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys

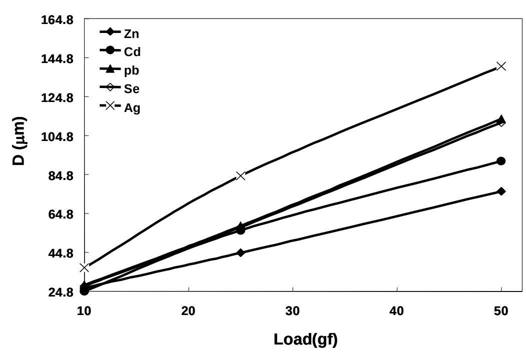

Figure 3b : The diagonal length at different loads, D, due the indenter effective of the Sn_{90-x}– $Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) alloys (3b).

CONCLUSIONS

Physical properties such as electrical resistivity, elastic modulus, internal friction and Vickers hardness number, of the Sn_{90-x}–$Sb_{10}Cu_2X_2$(X=Pb, Ag, Cd, Se and Zn) rapidly solidified alloys are sensitive to the modification structural of its matrix alloys. The Sn_{90-x}–$Sb_{10}Cu_2Pb_2$ alloy has better properties as a bearing alloy/or bearing applications.

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