DOI: https://doi.org/10.24297/jap.v20i.9161

Effect of the modification structure for Newton's metal on some its properties for industrial applications

Eman Kashita

Educational Services, Qassim University, Ministry of High Education, Kingdom of Saudi Arabia

Abstract

Newton's metal is important for industrial applications that is the reason for studying the effect of modified structure of it's on mechanical and thermal properties. Microstructure, mechanical properties such as elastic modulus Vickers hardness, internal friction and melting temperature of $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ alloys have been studied and analyzed.

X-ray analysis of these alloys show that, it contained different phases with formed a solid solution. Elastic modulus variable decrease, melting temperature varied, internal friction and Vickers hardness increased due to modified Newton's metal ($Bi_{50}Pb_{31.2}Sn_{18.8}$) alloy.

Key words: - Vickers hardness, internal friction, elastic modulus, melting temperature, structure

1. Introduction

Fusible alloys have low melting points compositions as bismuth, lead, tin, cadmium, or indium, which used in many applications such as fusible element in safety devices [1-3] and alarms, radio-opaque contrast medium in x-ray, solder and nuclear medicine as a shielding block [4]. Microstructure, thermal parameters, internal friction, wettability and electrochemical corrosion behavior for bismuth- tin based alloy, Bi30Sn50Sb10Al5Zn3Cu2, Bi25Sn61Sb5Zn4Al3Ag2, and Bi20Sn60Sb7Al5Zn3Cd3Cu2 alloys were studied by different experimental techniques. The results show that, properties for Bi- Sn alloys based changed after adding alloying elements [5, 6].

Several studies [7- 16] covered structure, mechanical and thermal properties of bismuth based or tin based alloys with studying the effect of alloying elements on their properties. The aim of this research is to study the effect of modified structure on mechanical and thermal properties of bismuth based alloys.

2. Materials and methods

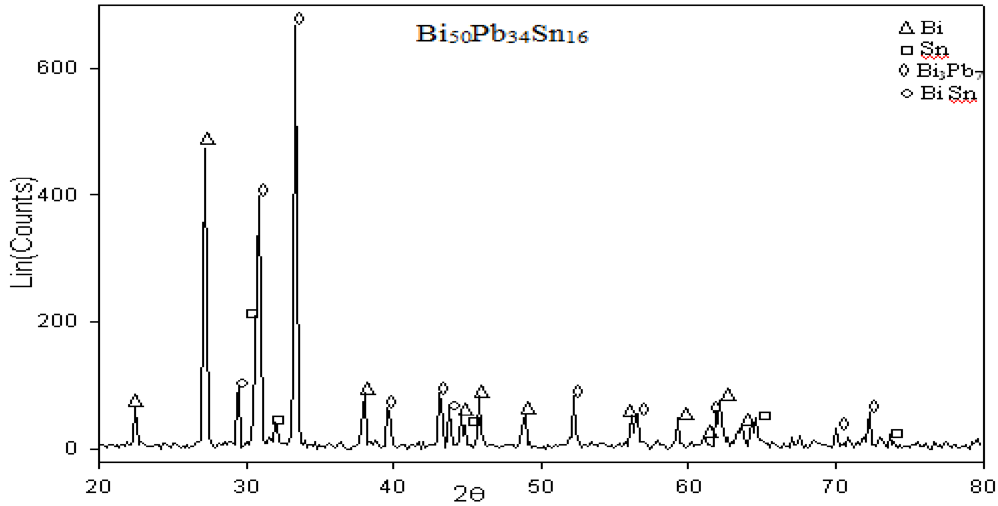
Bismuth, tin and lead metals with purity more than 99.9 % were used to prepare $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ alloys. These alloys (mixed metals by weight percentage) are melted and then normal casted on substrate. The samples are prepared in convenient shape for all tests. Microstructure for alloys is performed using Shimadzu X–ray Diffractometer, (Dx–30, Japan) Cu–Ka radiation with l=1.54056 Å at 45 kV and 35 mA and Ni–filter, in the angular range 2q ranging from 0 to 100° in continuous mode with a scan speed 5 deg/min. The differential scanning calorimetry (DSC) thermographs are obtained by Universal V4. 5A TA Instrument with heating rate 10 k/min in the temperature range 0-400 °C. Micro-hardness test of used specimens were conducted using a digital Vickers micro-hardness tester, (Model FM–7, Tokyo, Japan), applying a load of 100 gm for 5 seconds via a Vickers diamond pyramid. Ten measurements were recorded for each sample and then the mean value of all measurements was used. The internal friction and dynamic elastic modulus measurements of used samples were carried out with the modified dynamic resonance, which vibrates electro dynamically and is based on a standing-wave phenomenon [17- 20].

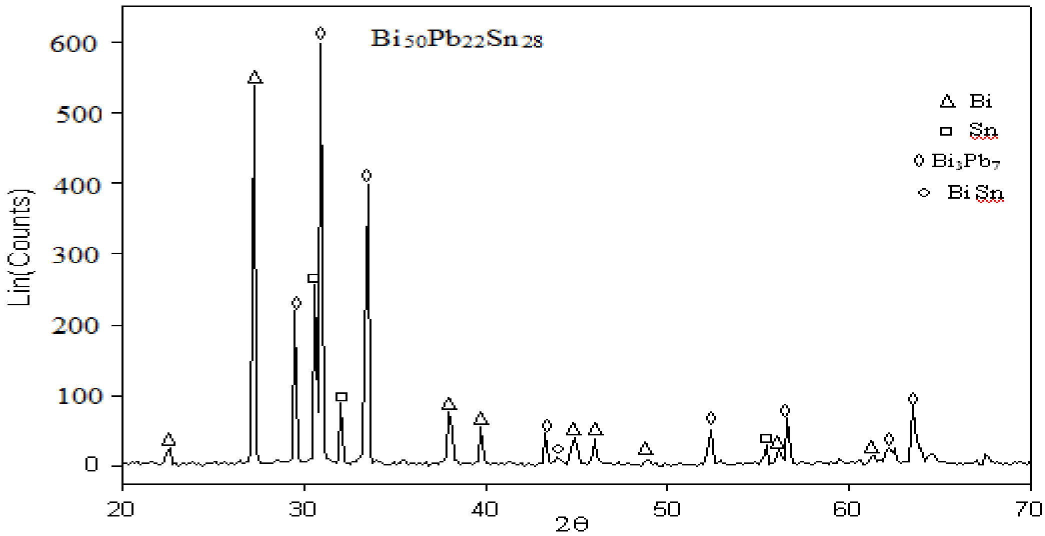
3. Results and discussion

3.1 Microstructure

X-ray analysis

Figure 1 shows x-ray diffraction patterns of $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ alloys. From x-ray diffraction patterns, $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ alloys have sharp lines of rhombohedral crystals of bismuth, body-centered tetragonal tin, body-centered tetragonal bismuth–tin (agree with the results of [21, 22] and hexagonal crystal of Bi_3Pb_7 inter-metallic compound which is agree with the results show by Kil-Won Moon et al [23]. The x-ray analysis show that, feature for formed phases such as crystallinity (peak intensity), crystal size (peak broadness) and orientations (peak position, 2θ) for $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ changed due to modified structure (increased Sn content with deceased Pb content). That is because these atoms dissolved in matrix alloy formed a solid solution and\or undetected phases





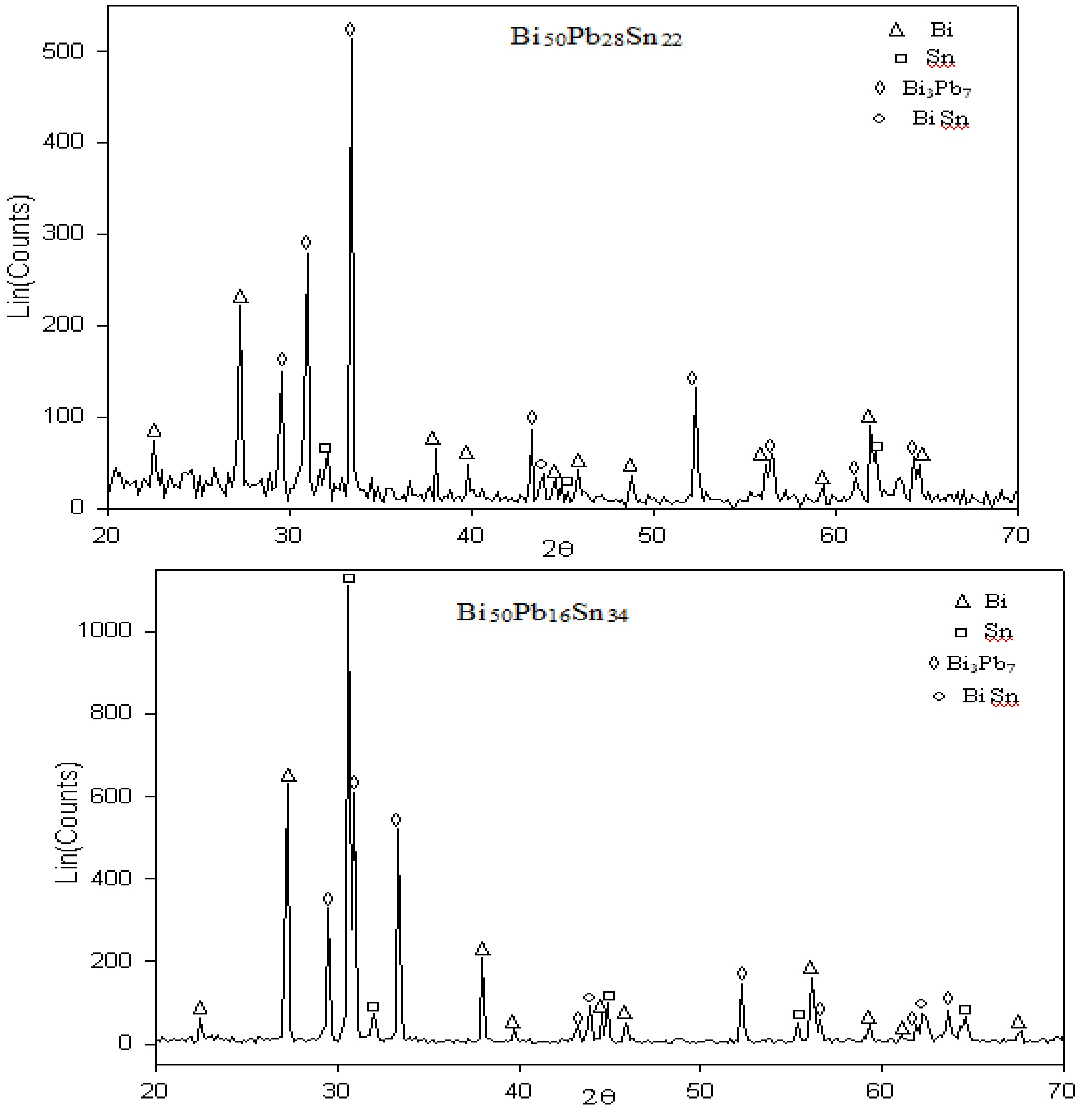


Figure 1: x-ray diffraction patterns of bismuth based alloys

Thermal properties

Thermal analysis depend on the nature of solid phase and on its temperature. It is used to study solid state transformations as well as solid liquid reactions. The DSC thermographs are obtained with heating rate 10 °C /min in the temperature range 0- 400 °C. The melting temperature of $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ alloys is presented in Table 1, which is dependent on its composition.

Table 1: melting temperature of bismuth based alloys

Alloys	Melting point °C
$Bi_{50}Pb_{34}Sn_{16}$	97
$Bi_{50}Pb_{28}Sn_{22}$	95
$Bi_{50}Pb_{22}Sn_{28}$	94

Internal friction

The internal friction is determined from the resonance peak-width technique which is preferred than the other method of free decay curve which suitable for low values of internal friction. The internal friction value Q^{-1} of Bi based alloys, listed in Table 2, is affected by the alloy composition. That means, it is sensitive to the internal structure (mobile atoms in the matrix which increase or decrease the resonance frequency and the motion time).

Table 2: internal friction of bismuth based alloys

Alloys	Internal friction (Q^{-1})
$Bi_{50}Pb_{34}Sn_{16}$	66±3.22
$Bi_{50}Pb_{28}Sn_{22}$	68.68±1.72
$Bi_{50}Pb_{22}Sn_{28}$	88.86±7.43
$Bi_{50}Pb_{16}Sn_{34}$	94±3.58

Vickers hardness

Table 3 shows Vickers hardness value for $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ alloys. It is increased by increasing tin content with decreasing lead content that means the hard inclusions in the matrix surface increased.

Table 3: Vickers hardness of bismuth based alloys

Alloys	Vickers hardness (HV) Kg/mm^2
$Bi_{50}Pb_{34}Sn_{16}$	10.7±0.83
$Bi_{50}Pb_{28}Sn_{22}$	11.1±0.43
$Bi_{50}Pb_{22}Sn_{28}$	12.79±1.1
$Bi_{50}Pb_{16}Sn_{34}$	14.79±1.54

Elastic modulus

Elastic modulus value for $Bi_{50}Pb_{34}Sn_{16}$, $Bi_{50}Pb_{28}Sn_{22}$, $Bi_{50}Pb_{22}Sn_{28}$ and $Bi_{50}Pb_{16}Sn_{34}$ alloys decreased by increasing Sn content and decreasing Pb content as listed in Table 4. It is increased by increasing tin content with decreasing lead content that means the hard inclusions in the matrix surface increased.

Table 4: Elastic modulus of bismuth based alloys

Alloys	Elastic modulus (E)
$Bi_{50}Pb_{34}Sn_{16}$	16.86±1.1
$Bi_{50}Pb_{28}Sn_{22}$	15.379±0.76
$Bi_{50}Pb_{22}Sn_{28}$	14.65±0.41

Conclusion

In this work lead content in used alloys decreased by 53%, that's mean the toxicity decreased, healthy environmental, for industrial applications. Internal friction and Vickers hardness increased but elastic modulus decreased for bismuth based alloys at tin increase with lead decrease.

References

[1] M.T. McCormack, Y. Degani, H.S. Chen, W.R. Gesick, J. JOM, 48 (1996) 54

[2] I. Manna and S.K.Pabi, Phys. Status Solidi A, 123 (1991) 393

[3] J. Perkins and G.R. Edwards, J. Mater. Sci., 10 (1975) 136

[4] C.R .Blackwell and K.D. Andmunson, Med. Dosimetry, 15 (1990) 127

[5] A.B. El-Bediwi, S. Bader, F. Khalifa, Global Journal of Physics, 4: 3 (2016) 480

[6] A.B. El-Bediwi, S. Bader, F. Khalifa, IJSRSET, 2: 2 (2016) 1267

[7] A.B. El-Bediwi and M.M. El-Bahay, Radiat. Effect Defects Solids 159 **(**2004**)** 133

[8] M. Kamal and A.B. El-Bediwi, Radiat. Effect Defects Solids, 159 (2004) 651

[9] A.B. El-Bediwi, E. Said Gouda and M. Kamal, A.M.S.E, Modeling C, 65 (1) 2004

[10] A.B. El-Bediwi, M.M. El-Bahay and M. Kamal, Radiat. Effect Defects Solids 159 **(**2004) 491

[11] M. Kamal, M.B. Karman and A.B. El-Bediwi, U. Scientist Phyl. Sci. 9**:** 2 (1997) 164

[12] M. Kamal, A.B. El-Bediwi and M.B. Karman, J. Mater. Sci.: Mater. Elect. 9 **(**1998) 425

[13] A.B. El-Bediwi, A.M.S.E. 75**:** 3(2002) 1

[14] M. Kamal, M. El-Tonsy, A.B. El-Bediwi *et al.*, Phys. Stat. Sol. (a) 201: 9 (2004) 2029

[15] M. Kamal, A.B. El-Bediwi and T. El-Ashram, J. Mater. Sci. Mater. Electr. 15 (2004) 211

[16] M. Kamal, M.S. Meikhail, A.B. El- Bediwi *et al.*, Radiat. Effect Defects Solids 160: 37 (2005)

[17] E. Schreiber, O.L. Anderson, N. Soga, in Elastic Constant and their Measurements (McGraw-Hill, New York, (1973), pp.82-125

[18] S. Timoshenko and J.N. Goodier, in Theory of elasticity, 2nd ed. (McGraw-Hill, New York, 1951) p.277

[19] K. Nuttall, J. Inst. Met. 99 (1971) 266

[20] C. Zener, in Theory of D_o for atomic diffusion in metals, J. Appl. Phys. 22 (1951) 372

[21] R.H. Kane, B.C. Gleissen, N.J. Grant. Acta Metall, 14 (1966) 605

[22] V. Bhattacharya, E. Yamasue, K.N. Ishihara, K. Chattopadhyay, Acta Metall, 53 (2005) 4593

[23] K.W. Moon, W. J. Boettinger, U.R. Kattner, C.A. Handwerker and D.J. Lee, J. Electron. Mater. 30 (2001) 45