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# Effect of Composition on Work Hardening Coefficient of Bismuth-Lead Binary Alloy

K. A. Mistry, I. B. Patel, A. H. Prajapati

***Abstract*—**In the present work, the alloy of Bismuth-lead is prepared on the basis of percentage of molecular weight 9:1, 5:5 and 1:9 ratios and grown by Zone- Refining Technique under a vacuum atmosphere. The EDAX of these samples are done and the results are reported. Micro hardness test has been used as an alternative test for measuring material's tensile properties. The effect of temperature and load on the hardness of the grown alloy has been studied. Further the comparative studies of work hardening coefficients are reported**.**

***Keywords*****—**EDAX, hardening coefficient, Micro hardness, Bi-Pb alloy.

## I. Introduction

An alloy is a substance that has metallic properties and is composed of two or more chemical elements, of which at least one is metal. Authors have grown Bismuth-lead alloys by Zone- Refining Technique on the basis of percentage of molecular weight 9:1, 5:5 and 1:9 ratios. Zone refining is only one of a class of techniques known as zone melting in which a molten zone is passed down a solid rod. Zone melting is used routinely to collect impurities in high purity materials. Energy dispersive X-ray spectroscopy an analytical technique used for the elemental analysis or chemical characterization of a sample. There for the EDAX of the grown alloys are carried out. The results of EDAX are discussed in the result. Materials need to be evaluated through micro hardness for a variety of reasons. Various instruments are generally calibrated on use by using test specimen, test blocks of known hardness. There are typical scales and associated instruments which are used to determine the material hardness. Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Physically, hardness is the resistance offered by a material to localized plastic deformation caused by scratching or by indentation. The hardness estimated from the scratch test is on the Mhos scale. The Mhos scale which ranged from 1 on the soft for talc and 10 for diamond. The indentation hardness is measured as the ratio of applied load to the surface area of the indentation.

Quantitative hardness techniques have been developed over the year in which a small indenter is forced into the surface of material to be tested, under controlled condition of load and rate of applied applications. In the present work, the micro hardness of the grown alloys are measured by Vaiseshika Vicker's micro hardness tester. Vickers Hardness is a measure of the hardness of a material, calculated from the size of an impression produced under load by a pyramid shaped diamond indenter. The work hardening coefficient (n) of the material is related to the load (P) by the relation $P=ad^n$, Where 'a' is an arbitrary constant. The work hardening coefficients of the grown alloys are investigated.

## II. Experimental

### *A. Materials*

The materials used for the present work are Bismuth and lead. Bismuth has a high electrical resistance, and has the highest Hall Effect of any metal. Bismuth rich alloys (>50 wt %) have the unique feature that they expand on solidification [1].

When Bismuth is alloyed with other metals such as lead, tin or cadmium, it forms low-melting alloys, which are extensively used for safety devices in fire detection and extinguishing systems [2], [3].

Lead and its alloys can be fabricated by almost all commercial processes. It can, for instance, be extruded, drawn, rolled, cast, stamped, and spun and can be applied as a coating to other metals. Thick layers of lead can be bonded to steel or other metals to form lead claddings.

### *B. Sample Preparation*

Bi-Pb alloy was prepared on the basis of percentage of molecular weight 9:1, 5:5 and 1:9 ratio. These samples were carefully melted in the oxidation furnace and shaken well in zone tube. These samples are successfully grown by Zone-Refining Technique under a vacuum atmosphere ($\sim 4 \times 10^{-2}$ mbar). The metals were melted together in a quartz tube which is 1.5 meter long and 2 cm diameter. The Electric motor which has very low rpm and having speed of 1.5 cm/hr, 1 cm/hr, 0.5 cm/hr and 0.25 cm/hr connected to the heating coil with very low friction trolley. The one end of the trolley is connected to the motor and the other end of this trolley is connected to the load. A series of molten zone passes in uniform one direction and also set the temperature up to melting temperature inside the tube. Apparatus of Zone - Refining Technique is shown in Fig. 1. Samples grown by zone refining techniques are shown in Fig. 2.

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Fig. 1 Zone - Refining Apparatus

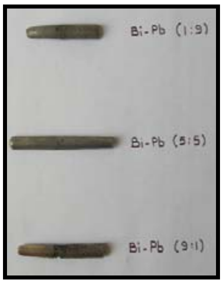


Fig. 2 Bi-Pb alloy

The EDAX of the grown alloys are investigated and discussed in the result section.

*C. Testing Methods*

To study the effect of temperature on the hardnesses of grown alloys the heating coil is used. The line diagram of the coil is 0.5 cm with 6 cm in length. In order to determine the effect of temperature on the micro-hardness of the grown alloys, they were carried out from temperature 303 K at an interval of 5 K by keeping the load of 0.020 kg, loading time of 10 seconds [4]. The arrangement is shown in Fig. 4. The graph of Hardness vs. temperature is plotted as shown in Fig. 7. Then the effect of different loads from 0.005 kg at the interval of 0.005 kg by keeping constant temperature and loading time of 10 seconds is studied [5], [6]. The graphs of Hardness Vs Load are plotted as shown in Fig. 8.

The work hardening coefficient (n) of the material is related to the load (p) by the relation

$$P=ad^{n} \quad (1)$$

where 'a' is an arbitrary constant. From (1)

$$\log p=\log a+n \log d \quad (2)$$

By comparing (2) with

$$y=mx+c, \quad (3)$$

where, y=log p, x=log d and m=n=slop of the graph which represents the work hardening coefficient [7]-[9]. So from graphs of log p Vs log d, the work hardening coefficients are calculated n discussed in the result part.

## III. Results and Discussion

EDAX is a qualitative analysis and conformation test of mixture of two metals. Energy dispersive X-ray spectroscopy of the grown alloys is shown in Fig. 3. Data are shown in Table I.

TABLE I
DATA FROM EDAX

| Bi-Pb Composition | | | | | |
|---|---|---|---|---|---|
| 9:1 | | 5:5 | | 1:9 | |
| Weight % | Atomic % | Weight % | Atomic % | Weight % | Atomic % |
| 77.54-22.46 | 77.39-22.61 | 93.68-6.32 | 93.63-6.37 | 20.07-79.93 | 19.93-80.24 |

Average length of grown binary alloys is nearly equal to 75 mm and weight of these alloys is nearly equal to 30-50 gm. When the compositions of both metals are equal, then good rod is obtained.

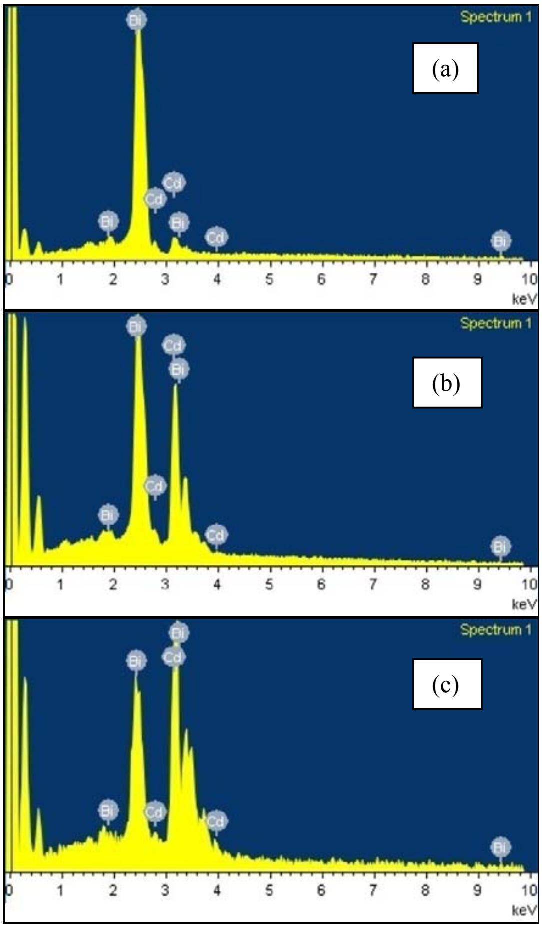


Fig. 3 (a) EDAX for Bi-Pb (9:1) (b) EDAX for Bi-Pb (5:5) (c) EDAX for Bi-Pb (1:9)

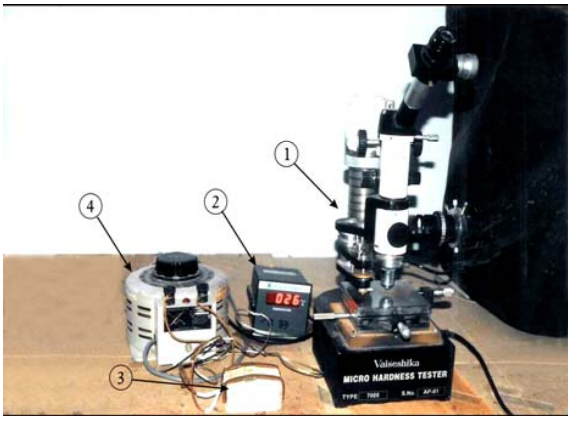


Fig. 4 Arrangement for varying temperature 1. Micro hardness tester 2. Temperature sensor 3. Heating coil 4. Variac

Fig. 5 Vaiseshika Vickers's micro hardness tester

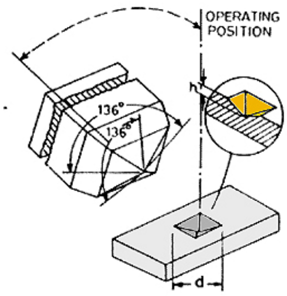


Fig. 6 Pyramid shaped diamond indente

Fig. 7 shows that the micro hardness of the alloys decreases with increase in temperature and Fig. 8 shows that the micro hardness of the alloys increases with increase in load.

From Figs. 9-11, the work hardening coefficient of 5-5 composition is higher than 1-9 and 9-1 compositions.

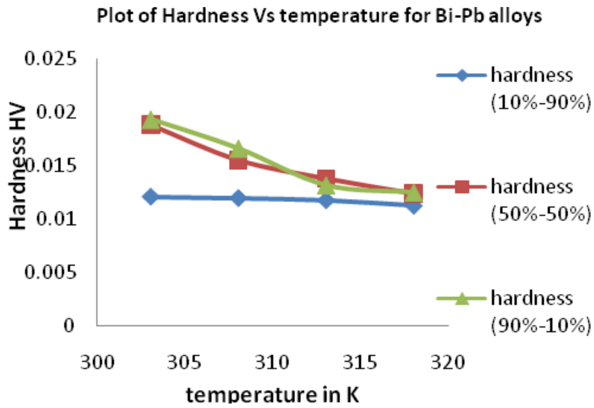


Fig. 7 Hardness vs. Temperature

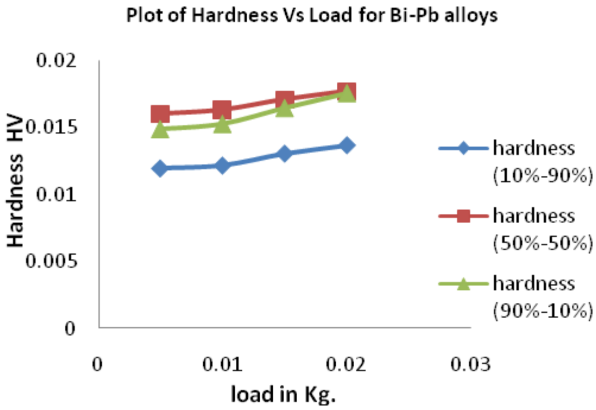


Fig. 8 Hardness vs. Load

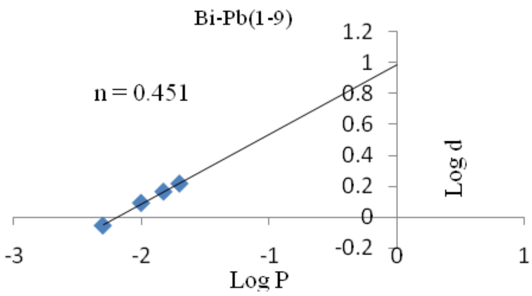


Fig. 9 Plot of Log d vs. Log p for (1:9) Bi-Pb

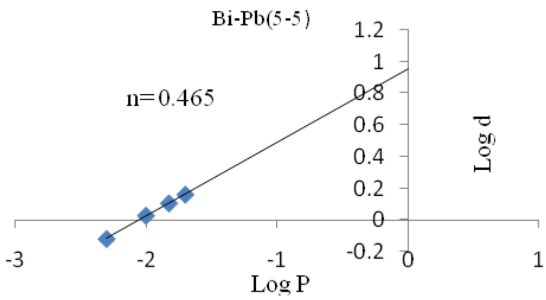


Fig. 10 Plot of Log d vs. Log p for (5:5) Bi-Pb

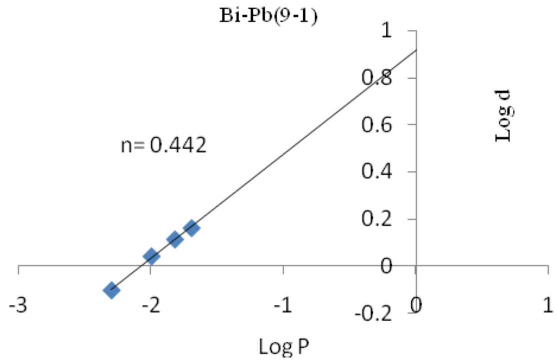


Fig. 11 Plot of Log d vs. Log p for (9:1) Bi-Pb

## IV. Conclusion

The work hardening coefficient of 5:5 Bi-Pb alloy is 0.465 which if approx 0.5. The work hardening exponent (n) is known to be a good indicator for the work formability of materials. A material with a higher ‘n’ value is preferred for manufacturing processes which involve plastic deformation [10].

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