Technical Report

Investigating the Effect of Pb-Sb-Cu Alloy Casting Techniques on Its Electrical Properties

Chukwuka I . Nwoye

Department of Materials and Metallurgical Engineering, Nnamdi Azikiwe University, Awka, Nigeria.
chikeyn@yahoo.com

Abstract: The effect of Pb-Sb-Cu alloy casting techniques on its electrical properties was investigated following casting of the alloys using using three different techniques; Technique A, Technique B, Technique C and cooling of the alloys after casting in the furnace and determining their electrical properties. Technique A, involves simultaneous addition of Cu powder and pouring of the molten Pb-Sb into the mould. Techniques B, involves addition of Cu powder intermittently as pouring of Pb-Sb into the mould was going on and Technique C involves pouring a stirred mixture of heated Pb-Sb alloy and powdered Cu into the mould. Copper addition to the base alloy was dispersion of the copper powder within the Pb-Sb matrix. The results of the investigation indicate that the electric current flow, conductivity, power dissipation, electrical resistance and resistivity from Techniques A, B and C alloys show a sinusoidal variation with each technique's alloy. This implies that these electrical properties from each technique's alloy are lowest and highest at different Cu additions. This is a clear indication that different electrical properties can be imparted to the three different casting techniques depending on the optimum concentration of Cu required in the matrix to produce Pb-Sb-Cu alloy. Furthermore, the best technique for casting efficiently functional electrical components is dependent on the optimum concentration of Cu required in the matrix to permit achievement of maximum values of the associated electrical properties.
[Chukwuka I. Nwoye. **Investigating the Effect of Pb-Sb-Cu Alloy Casting Techniques on Its Electrical Properties**. Report and Opinion 2010;2(12):61-65]. (ISSN: 1553-9873).

Keywords: Effect, Casting Techniques, Electric current flow, Pb-Sb-Cu Alloy.

1. Introduction

Several research works (Blumenthal, 1944. Rollason and Hysel, 1940; Nwoye, 2000) have been carried out to improve the electrical conductivity of Pb-Sb alloy used as wet cell battery heads. Blumenthal, (1944) discovered that addition of cadmium enhances the electrical conductivity of Pb-Sb alloy tremendously. It was however, stated that the alloy cannot find application in battery heads and plates because Cd is very radioactive and causes a volatile and explosive reaction when in contact with sulphuric acid for a long time.

It has been reported (Geiss and Peretti, 1962) that addition of indium to Pb-Sb alloy increases the corrosion resistance of the alloy. Indium is added to the Pb-Sb alloy by ionic exchange through electrolytic process where indium is the anode and Pb-Sb, the cathode.

Several studies (Ezenwa, 1987; Weaver, 1935) have been carried out on lead-antimony alloy by addition of Sn to improve its mechanical properties and corrosion resistance. Results of the investigation indicate that addition of Sn to the Pb-Sb matrix increases both the tensile strength, hardness and corrosion resistance of the alloy. This makes Pb-Sb-Sn alloy suitable for coating tanks and pipes.

Arsenic addition to Pb-Sb-Sn alloy has been found (Sodacha and Kerr, 1972) to increase the corrosion resistance of the alloy due to its ability to reduce oxidation during service by formation of oxide film on the matrix.

Rollason and Hysel, (1940) reported that addition of silver to Pb-Sb alloy increases very significantly the electrical conductivity of the alloy. It was however, stated that this increase does not give a stable value due to impurities in the Ag. It was stated that these impurities are Au, As, Sn, Cu and S. He further posited that these impurities create an unstable electrical field in the alloy of Pb-Sb-Ag. It is believed that this short coming has made the use of this alloy for battery heads and plates impossible since it obscures the precise electromotive force of the electrolyte in the battery.

Nwoye (2000) found that addition of copper powder by dispersion to Pb-Sb alloy improves the electrical conductivity of alloy greatly. It is believed that this breakthrough was possible because Cu used, had high purity level (99.8%).

It has been reported (Ijomah, 1992) that the higher the temperature applied to metals and alloys, the greater the bonds broken, and the higher the level of conductivity attained. The same report indicates that the resistivity of engineering materials such as metals and alloys is dependent on the temperature at which the material is exposed. The report (Ijomah,

1992) concluded that increase in temperature of materials reduces its resistivity.

Ijomah (1992) reported that the energy gap; minimum additional energy which a bonding electron must acquire to leave the bond and, hence become free to conduct electricity decreases with increasing temperature and impurity content. The report also revealed that the resistivity increases with increase in the energy gap.

The aim of this research work is to investigate the effect of Pb-Sb-Cu alloy casting techniques on its electrical properties

In this work, copper powder was added to the Pb-Sb melt by dispersion.

2. Materials and methods

ALLOY PREPARATION:

The materials used are antimonial lead scraps and electrolytic copper powder of grain size < 425μm. They antimonial lead collected were melted together in order to obtain a fairly uniform composition of lead antimonial alloy, in case of any variation in antimony content. The melting operation was carried out at the forge, followed by casting of the alloys in sand mould and cutting to various sizes for use in the actual alloying. They melting crucible was of 260mm long, 200mm wide mild steel of about 100mm breadth with handle for carriage.

MOULD PREPARATION:

The preparation of the mould was done by first sieving the sand for aeration and mixing 6% moisture to give good green strength. The mould box of dimension 300mm wide, 100mm breadth and 500mm long was made from cast metal frame. A long hollow cylindrical pipe of 85mm long and 9mm diameter was used as the pattern for the cast. The mould was allowed to dry.

CASTING TECHNIQUES:

A weighed quantity of lead antimony alloy (500g) was placed on the crucible and then placed inside the furnace. Techniques A, B and C were used to produce the first, second and third batch of the Pb-Sb-Cu alloys respectively. Technique A involved simultaneous addition of Cu powder and pouring of the molten Pb-Sb into the mould. Technique B involved addition of Cu powder intermittently as pouring of Pb-Sb into the mould was going on while Technique C involved pouring a stirred mixture of Cu powder and Pb-Sb alloy heated to 425^0C, into the mould. The Control alloys were cast by just pouring only the molten Pb-Sb into the mould (Conventional Technique).

CAST ALLOYS COOLING:

Cast alloys from each of the techniques were cooled in the furnace.

HEAT TREATMENT:

They cast alloys were cut to lengths:0.075m before being heat treated at a temperature of 180^0C to relieve stresses incurred during solidification of the alloys. The heat treatment was also carried out to homogenize the microstructure of the alloys prior to the impact testing process.

ELECTRICAL MEASUREMENTS:

Following the heat treatment process, electric current, I flowing through the alloy measured and other electrical properties associated with current flow calculated using appropriate equations. The electromotive force from the dry battery equals 2.9V, being voltage supply to the alloys. Current was allowed to flow through the alloys for five minutes, and the power dissipated during the process calculated for all alloys produced using three techniques. This is to ascertain the power dissipating capacity of the alloys. The tested specimen were thereafter melted and their temperatures recorded correspondingly against their respective values of electric current, resistance, resistivity, conductivity and power dissipation.

CALCULATION OF ELECTRICAL PARAMETERS

According to Ohm's law

$$R = V/I \quad \text{(Okeke,1987)} \quad (1)$$

Where

R = Resistance of the alloy (Ω)

V = Voltage supply to the alloy (V)

I = Current flowing through the alloy (A)

The resistance of the alloy was calculated using equation (1). Also, the resistivity of the alloy was calculated using the equation;

$$\rho = RA/L \quad \text{(Okeke,1987)} \quad (2)$$

Where

ρ = Resistivity of the alloy (Ωm)

L= Length of the alloy material (m)

A = Cross sectional area of the alloy (m^2)

The cross sectional area of the alloy material was calculated using the equation;

$$A = \Pi D^2/4 \quad (3)$$

Where

Π = 22/7 Substituting these values into

D = 0.9cm; (Diameter of cross- section of the sample)

Substituting these values into equation (3)

$A = 6.364 \times 10^{-5}\ m^2$

Also, the conductivity of the alloy was calculated as the reciprocal of the resistivity;

$$\alpha = (\rho)^{-1} \quad \text{(Okeke,1987)} \qquad (4)$$

$$\alpha = (RA/L)^{-1} \qquad (5)$$

Where

α = Conductivity of the alloy $(\Omega m)^{-1}$

Power dissipated as current flow through the alloy was calculated using the equation;

$$P = IVt \quad \text{(Okeke,1987)} \qquad (6)$$

Where

P = Power dissipated by the alloy (W)

t = Time elapse within which power was dissipated (s)

3. Results and discussion

Results of chemical analysis carried out on the materials used (as shown in Table 1) indicate that antimonial lead contains about 3.3% Cu in addition to Pb and Sb present. The percentage composition of the powdered Cu used is as received.

Table 1:Chemical composition of materials used

Material	Pb (%)	Sb (%)	Cu (%)
Antimonial Lead	92	4.7	3.3
Copper powder	-	-	99.80

Effect of casting techniques on the electrical properties of Pb-Sb-Cu alloy

Figure 1 shows that electrical current flowing through Pb-Sb-Cu alloys, cast using Techniques A, B and C depict a sinusoidal variation with each technique's alloy. This implies that current flowing through each technique's alloy is lowest and highest at different Cu additions. This is an indication that the flow of current characterizing from each technique can be exploited for specific purposes. However, the variation of these current flows is insignificant.

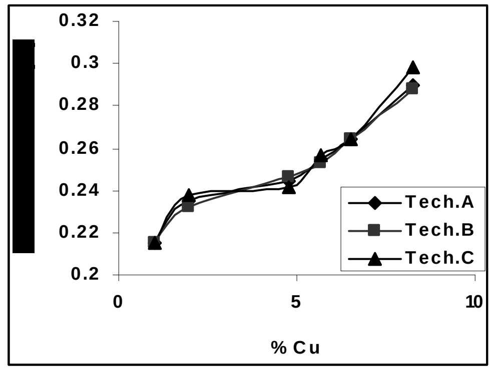

Figure 1: Effect of casting techniques on the flow of electrical current through Pb-Sb-Cu alloy

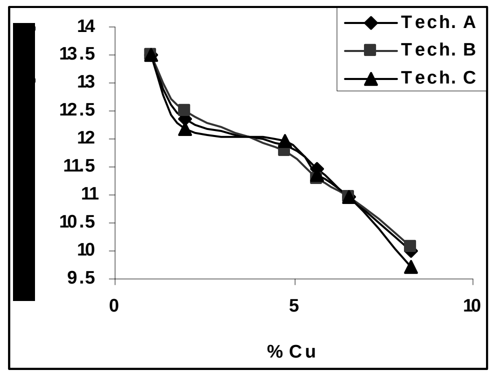

Figure 2: Effect of casting techniques on the electrical resistance of Pb-Sb-Cu alloy

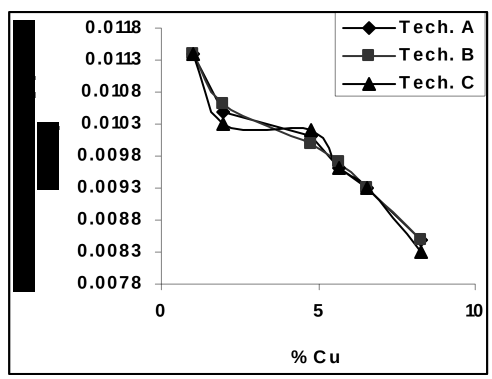

Figure 3: Effect of casting techniques on the electrical resistivity of Pb-Sb-Cu alloy

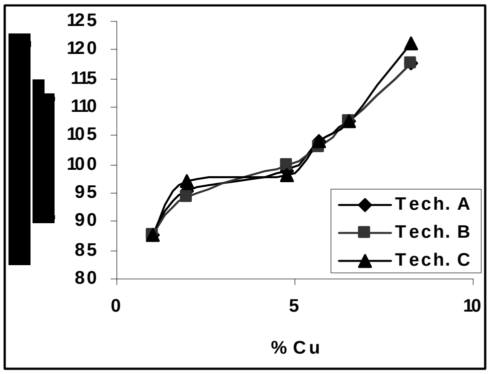

Figure 4: Effect of casting techniques on the electrical conductivity of Pb-Sb-Cu alloy

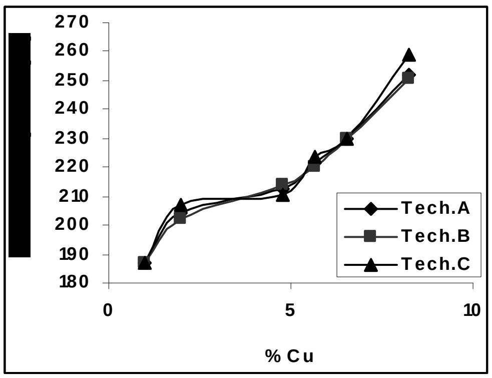

Figure 5: Effect of casting technique on the power dissipation through Pb-Sb-Cu alloy

Equations (1), (2), (4)-(6) show that electrical resistance, resistivity, conductivity and power dissipation are all derivative from current flow, considering the voltage supply. Therefore since electrical conductivity and power dissipation have direct relationship with current flow, it follows (from Figures 4 and 5) that the sinusoidal variation with each technique's alloy as in the case of current flow also prevails for electrical conductivity and power dissipated by Techniques A, B and C. This also implies that electrical conductivity and power dissipation through each technique's alloy is lowest and highest at different Cu additions. Conversely, comparison of equations (1) and (2) indicates that electrical resistance and resistivity are derivatives from electric current flow and depict inverse relationship with the later. Figures 2 and 3 show that the sinusoidal variation in the electrical resistance and resistivity of Techniques A, B and C alloys also prevails but in an inverse manner to that from current flow, conductivity and power dissipation. (Figures 1, 4 and 5). Figures 2 and 3 also indicate that the electrical resistance and resistivity of Techniques A, B and C alloys are lowest and highest at different Cu additions.

It is pertinent to state that for all electrical properties investigated, the variation in Techniques A, B and C alloys for electrical current, resistance, resistivity, conductivity and power dissipation is insignificant.

Conclusion

The electric current flow, conductivity, power dissipation, electrical resistance and resistivity from Techniques A, B and C alloys were found to show a sinusoidal variation with each technique's alloy. This implies that these electrical properties from each technique's alloy are lowest and highest at different Cu additions. This is an indication that different electrical properties can be imparted to the three different casting techniques depending on the optimum concentration of Cu required in the matrix to produce Pb-Sb-Cu alloy. This means that the best technique for casting efficiently functional electrical components is dependent on the optimum concentration of Cu required in the matrix at which maximum value of the electrical property is achieved.

Acknowledgement

It is the intention of the author to publish this work culled from his M. Eng. Thesis in honour of Prof. Sylvanus I. Okeke of Nnamdi Azikiwe University, Awka as a memorial research piece credited to his numerous publications in recognition and appreciation of his unequalled supervisory role during this research work.

Correspondence to:
Dr. Chukwuka Ikechukwu Nwoye
Department of Materials and Metallurgical Engineering, Nnamdi Azikiwe University P.M.B 5025, Awka, Anambra State, Nigeria.
Cellular phone: +234 0806 800 6092
Email: chikeyn@yahoo.com

References

[1]Blumenthal B, Effects of Silver on the Electrical Conductivity of Lead-Antimony Alloy, Trans. Amer. Inst. Min. Met, England, 1944:149-156.
[2]Rollason EC, and Hysel VB. Effect of Cadmium on the Electrical Conductivity of Lead-Antimony Alloy, J. Inst. Metals, London, 1940:59-66.
[3]Nwoye CI. Effect of Copper Powder Dispersion on the Electrical Conductivity of Lead-Antimony Alloy, M. Eng. Thesis, Nnamdi Azikiwe University, Awka, 2000.
[4]Geiss DR. and Perrtti EA. Effects of Indium on the Corrosion Properties of Lead-Antimony Alloy, J. Less-Common Metals, Italy, 1962:4-7.
[5]Ezenwa ZO. Equilibrium Studies of Lead-Tin-

Antimony Alloys, B.Eng. Project Report, Enugu State University of Science & Technology, Enugu, 1987:17-22.
[6]Sodacha JP, and Kerr HW. Effects of Arsenic on the Corrosion Properties of Lead-Antimony-Tin Alloy, J. Inst. Metals. Japan, 1972:100-110
[7]Ijomah MNC. The Structure and Properties of Engineering Materials, Christon Publishers, Awka,1992: 56-58.
[8]Okeke PC. Introduction to Physics, Gerek Publishers, Enugu. 1987: 85-93.

8/5/2010