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ANALYSIS OF ELECTRICAL PROPERTIES OF IRON CLAY BASED COMPOSITE RESISTORS

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ABSTRACT

A polynomial fit was used in analyzing the electrical properties of iron clay based composite resistor. The resistors were produced from natural materials taken from three cities in the south – west of Nigeria (Abeokuta, Ibadan and Lagos), and fabricated by a compaction method. The pressure of the mould = $1.00 \pm 0.02 \times 10^7$ N / m^2. The resistors have a constant thickness of 3.5 mm and varying lengths ranging from 3.00 mm to 10.00 mm. Comparison of variation of resistance with iron content, length, temperature for the three cities, varies from location to location depending upon the weight of the iron, temperature and length. Plots of graphs were made of resistance variations with temperature, length, and Iron content. A polynomial fit is done on the histogram in order to compare the graphs. A computer program was used to find the best-fit equation to describe these curves. The simplest that gave the satisfactory fit was a polynomial of the general form $R=a_0 + a_1T + a_2T^2$. The best-fit curve of temperature / resistance for all the cities is (even at different latitude and longitude) the polynomial fits of degree 10. The best-fit curve of length / resistance for all the cities at different latitude and longitude is the polynomial fits of degree 7. But at higher temperature of 1000°C, the polynomial fit is linear ($R = m*L + c$). The interesting thing about Iron composition / resistance curve is that even at different latitude and longitude the polynomial fits of degree 6 gives the satisfactory fit for all the curves. The result of the comparison done on the three cities by plotting a histogram of the variation of resistance with temperature, percentage weight of iron and length, fitting a polynomial can be explained by, the mode of control of the amount of impurities and defects present in the resistor for each city. Also on the composition, size, color, etc of the clay. The Ekotedo Ibadan clay is light brown, inorganic with some sands and trace of gravel –with trace of mica. The Ojota Lagos clay reddish brown, laterite, inorganic, sandy clay. Ijaye Abeokuta gray, inorganic mucaceons, salty clay with some sands and the fall in resistance and increase in temperature is mainly attributed to the removal of structural defects, which enhances the formation of a more physical continuous structure.

INTRODUCTION

The study of electrical properties are of concern for scientists trying to elaborate a comprehensive, quantitative and qualitative scheme of their behavior which are very appealing for designers of electronic circuit to have information on the components he uses and users of thick film hybrid circuits (HICs) and sensors – Prudenziati et al (1994) and Law (1979).

Resistors are devices specifically introduced into an electronic circuit to offer resistance to the flow of electric current. Resistors may be classified according to the general field of engineering in which they are used .We have the power resistors which are used in both the power and electronic fields of engineering, Instrument resistors are designed to provide a voltage drop of 5 mV when a stated current passes through them while standard resistors are used for calibration purposes in resistance measurements and integrated circuits – Faleke (1996) unpublished.

The various types of resistors commonly used nowadays are composite resistors, which are in wide use because of their low cost, high reliability and small size. Basically it is a mixture of resistive materials, usually carbon and a suitable binder molded into a cylinder. Copper wire leads are attached to the ends of the cylinder and the entire resistor is covered or protected by an elastic or ceramic jacket. Composition resistors are commonly used in the range from several ohms 10 - 20 MO and are available.

Our aim is to analyse the electrical properties of iron–clay composite based resistors by using a polynomial fit.

Structure and Characteristics of Composite Resistors.

Composite Resistors have three main constituents namely (i) The binder; (ii) The vehicle; and (iii) The conductive phase.

The Binder

The binder, which forms the insulating phase, consists of low melting point glasses. It holds the metal particles in contact and binds the structure together.

The Conductive phase

The conductive phase contains small metallic particles .The particle size; size distribution and particle shape have a significant influence on the electrical and physical properties of the resistor.

The Vehicle

The Vehicle of the resistor is in the form of organic solvent and plasticizer. It constitutes into one-thread of the composition weight and defines the printing characteristics of the paste or material.

Material collection

The sodium silicate binder, which acts as vehicle, was bought from the chemical laboratory at Ilorin. The iron fillings used for the cermets mixtures were of 99.9% purity (British Drug House limited). The clay sample used was collected at different locations in the south –western part of the country namely

(1) Ojota , Lagos. The clay in this place is reddish brown in color and laterite inorganic sandy

(2) Ijaye, Abeokuta .The clay is grayish in color, inorganic mucaceous silty with some sands.

(3) Ekotedo, Ibadan.The clay is light brown in color, inorganic with some sands and trace of gravel with trace of mica.

The iron and clay were weighed by using laboratory chemical weighing balance Gallenhamnp Mettler P165. The weighted iron filings and clay powder were mixed thoroughly into homogeneity inside a beaker. The mixture was stirred thoroughly with 2 or 3 drops of the silicate binder until the paste becomes thick with a very uniform texture. The paste was then loaded into the mould and compressed with mould cap. All mouldings were done at room temperature. The moulding was done for different percentages of iron and clay and different resistor were moulded .The diameter of the resistors are 3.5 mm. All the moulded resistors, which have been sufficiently dried at room temperature were subjected to firing at temperatures in the range 100 °C – 1000 °C. The firing period ranges from 30 mins to 180 mins.The Robin made volt-ohm-millimeter multimeter model1400, which is capable of reading d.c and a.c voltages, currents, and resistance measurements was used to measure the resistances of the resistors.

METHOD OF ANALYSIS

Relationship between two variables are unlikely to be linear- there are many other possibilities. A polynomial fit to the data is often a useful first step in trying to find a usable model. Polynomial regressions are also very useful for determining relationship among means after an analysis of variance. Plots were made of resistance variations with temperature, length and iron content.

A computer was used to find the best-fit equation to describe these curves. The simplest that gave the satisfactory fit was a polynomial of the general form $R=a_0 +a_1T+a_2T^2$.

Comparison of Variation of Resistance with Iron content for the three cities.

Fig.1 shows the comparison of variation of resistance with percentage weight of iron content at room temperature and at temperature of 300°C for Abeokuta, Ibadan and Lagos. Obviously, the resistance varies from location to location depending upon the weight of the iron and length. Generally the resistance of resistors for Abeokuta at 90% wt Fe is higher than that of Ibadan and Lagos for all the lengths. Resistances at lower lengths are less than those at higher lengths. Comparison of resistance of the resistor for the three locations shows that at 75%wt. Fe and 80%wt. Fe the value for resistance at Lagos is negligible compare to others for all the lengths. This might be due to the fact as iron content decreases at 75% wt .Fe to 80%wt.Fe.there is no value for resistor in lagos. The Resistance values for each cities increase again after the 75%wt.Fe.Generally one can say there is a decrease in resistance values for Abeokuta as the percentage weight of iron decreases. For Ibadan, initially there is a decrease in percentage weight of Iron up to 80% wt. Fe, increases at 75%wt. Fe and 70%wt. Fe and then decreases at 65%wt. Fe, there is an increase in resistance at 60%wt. Fe .For Lagos there is no values for resistance between 70%wt. Fe and 75%wt. Fe and it has the least values compare to others.

At Temperature = 300°C, for Abeokuta, one noticed that the resistance values for lengths 3mm to 7mm at 85%wt. Fe is very low in comparison to other cities. However, from subsequent longer lengths there were significant resistance readings. There is decrease in resistance values as percentage weight of Iron decreases. The resistance values for resistor from lengths 3mm to 8mm is low for Lagos clays.

Comparison of Variation of Resistance with Length for the three cities.

Comparison of variation of resistance with length at different percentage weight of iron content for Abeokuta, Ibadan and Lagos at room temperature and at temperature of 300°C are shown in Fig 2

For the three locations Resistance increases with length for 90%wt. Fe as observed in Fig. 2. In comparison to other cities, Lagos has the least resistance value which decreases with length at 90%wt. Fe, 85%wt. Fe, 80%wt. Fe and 75%wt.Fe.But at 70%wt. Fe, 65%wt. Fe, 60%wt. Fe its resistance values are higher than that of the others. Ibadan has higher values of resistance at 80%wt. Fe and 75%wt. Fe. At Temperature = 300°C.Abeokuta has higher values of resistance than the others. Lagos resistance values in all the percentage weight of iron is low and Ibadan has less values of resistance than Abeokuta. The resistance values for all the location do not depend on length.

Comparison of Variation of Resistance with Temperature for the three cities.

Fig 3 shows the comparison of variation of resistance with temperature for different percentage weight of iron content at Abeokuta, Ibadan and Lagos.

for 90%wt. Fe, Generally for all locations one noticed that there is no resistance values between the temperature 400°C to 700°C. There is increase in the resistance value as temperature increases from 28°C to 100°C for all the cities. As the temperature increases to 400°C there is decreases in resistance values for Ibadan and Abeokuta, Lagos does not have any resistance values at these temperature for all the lengths. One noticed that at 800°C it is only Lagos that has resistance value. As temperature increases from 900°C to 1000°C the resistance increases for all.

A polynomial fit is done on the histogram in order to compare the graphs shown in Fig. 1 one noticed that for T = 28°Cthe polynomial fit of the graph is degree 6 and correlation coefficient $R^2 = 1$ for all the cities. For T = 300°C the polynomial fit of the graph is degree 6, $R^2 = 1$ at lengths 3mm, 4mm, 6mm, 7mm, 9mm, 10mm. Whereas the polynomial fit for length 5mm, $R^2 = 1$ for Ibadan is degree 5 and length 8mm for Lagos is degree 5, $R^2 = 1$.Abeokuta and Lagos has a polynomial fit of degree 6, $R^2 = 1$ for 5mm length. Ibadan and Abeokuta has a polynomial fit of degree 6, $R^2 = 1$ for 8mm length.

Fig. 2, the polynomial fit of the graph is degree 7, $R^2 = 1$ for all the cities at T = 28°C and 300°C, except for Abeokuta at 90%wt. Fe which is linear.

Fig. 3, the polynomial fit of the graph is degree 10, $R^2 = 1$ for all the cities.

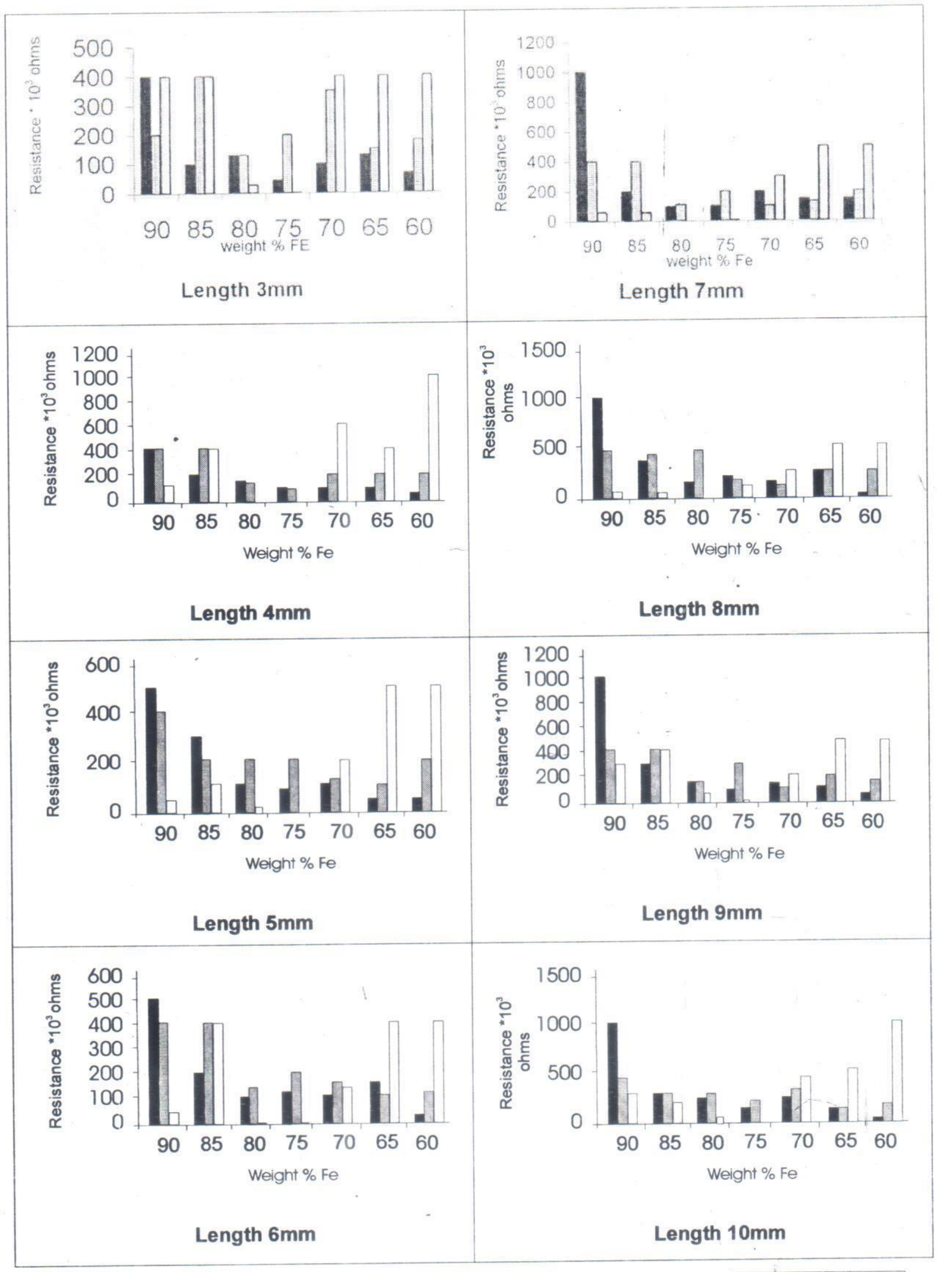

FIG 1: Variation of Resistance with Iron (Fe) content at Room Temperature at different locations

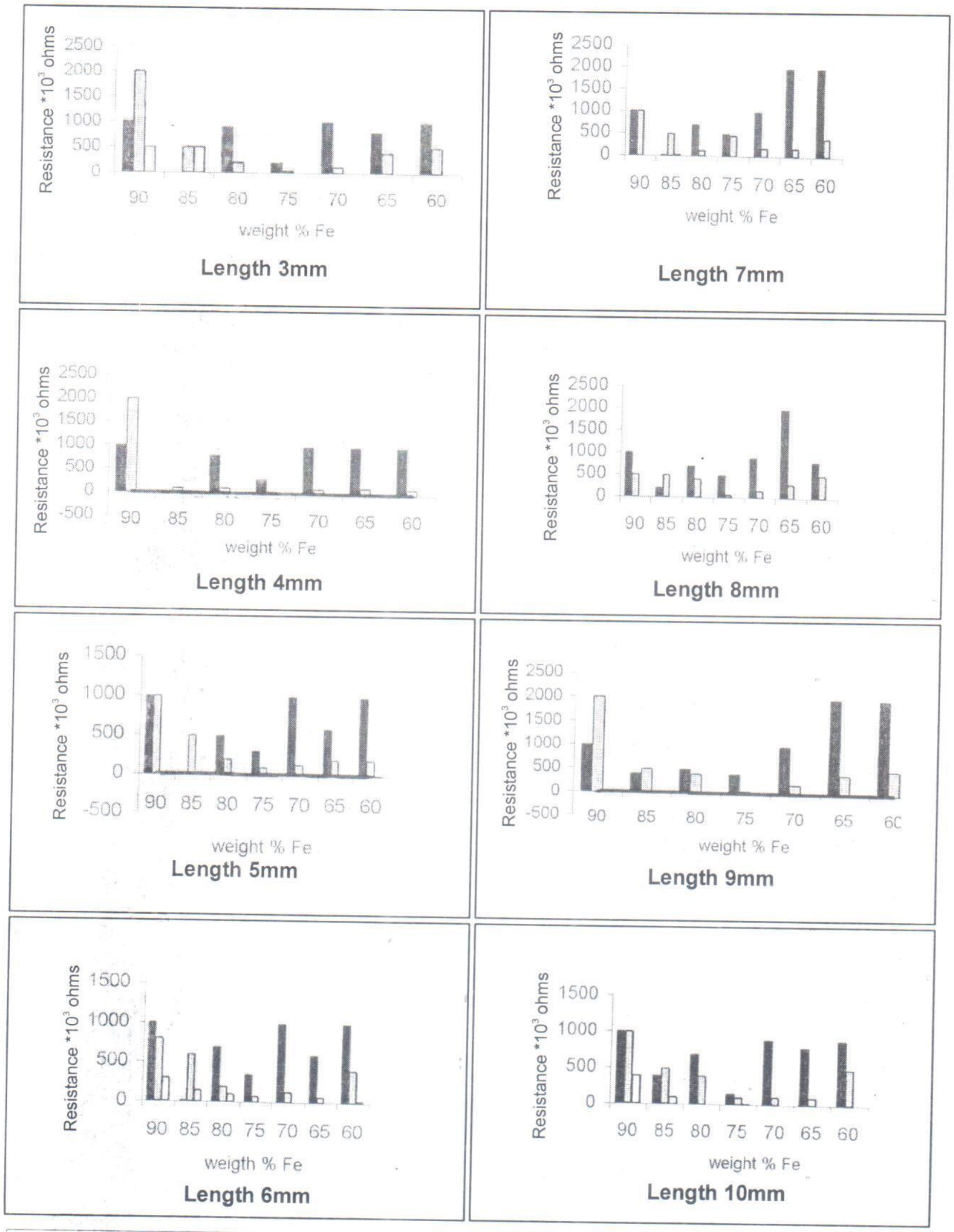

FIG. 2 Variation of Resistance with Iron (Fe) content at Firing Temperature of 3000C for different locations

Abeokuta
Ibadan
Lagos

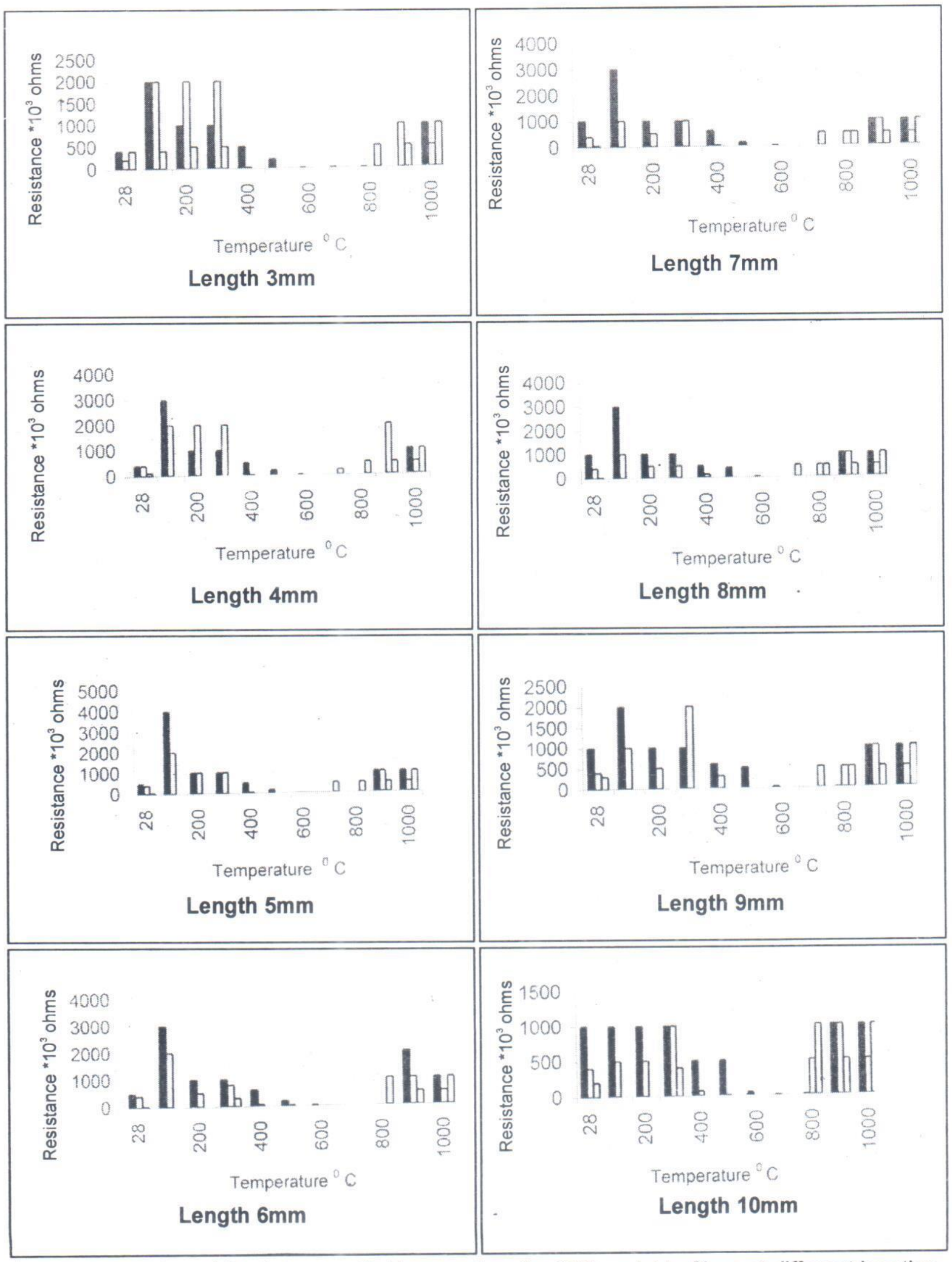

FIG. 3 Variation of Resistance with Temperature for 90% weight of iron at different location

Abeokuta Ibadan Lagos

RESULT

The result of the comparison done on the three cities by plotting a histogram of the variation of resistance with temperature, percentage weight of iron and length, fitting a polynomial can be explained by

1. The mode of control of the amount of impurities and defects present in the resistor for each city.
2. This might be due to the composition, size, color, etc of the clay. The Ekotedo Ibadan clay is light brown, inorganic with some sands and trace of gravel –with trace of mica. The Ojota Lagos clay reddish brown, laterite, inorganic, sandy clay. Ijaye Abeokuta gray, inorganic mucaceons, salty clay with some sands.
3. The electrical conductivity depends on transport phenomenon and the resistance affected by impurities collision with lattice atom and concentration of impurities and defects increase with increase in particle size.
4. The effect of temperature upon resistance is very different for different types of conductor. Metallic conductors show increase in resistance with increase in temperature i.e. positive temperature coefficient resistance semiconductors and insulators have negative temperature coefficient resistance.
5. There is modification of composition of the resistor due to reactions between the resistive material and terminations.
6. There is oxidation of the conductive material thus resulting in formation of a barrier layer.
7. Defects such as micro-cracks and variation of resistor thickness with size of particles may also result from volume changes occurring during processing.
8. The bulk conductivity depends on concentration of the conductive phase which implies that the higher the concentration the less the free path of the electrons and the more the magnitude of electron momentum.
9. The firing process affects the electrical resistance of the resistors studied. The fall in resistance and increase in temperature is mainly attributed to the removal of structural defects, which enhances the formation of a more physical continuous structure.
10. Changes in electrical resistance occur due to influence by geometry, firing temperature and percentage weight of iron.
11. Effects of different preparatory processes.
12. Changes in electrical resistance for the cities might be due to the scale of the axes chosen.

Conclusion

A polynomial fit was used in analyzing the electrical properties of iron clay based composite resistor. The simplest that gave the satisfactory fit was a polynomial of the general form
$R=a_0 +a_1T+a_2T^2$.

The similarities and differences in the comparison done on the three cities by plotting a histogram of the variation of resistance with temperature, percentage weight of iron, length and fitting a polynomial can be explain by the firing process which affects the electrical resistance of the resistors studied. The fall in resistance and increase in temperature is mainly attributed to the removal of structural defects, which enhances the formation of a more physical continuous structure. Changes in electrical resistance occur due to influence by geometry, firing temperature and percentage weight of iron and effects of different preparatory processes.

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