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Effect of Coloration on the Electrical Conductivity of Arabic Gum using Instrumentation Method

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Abstract:- Due to the high viscosity of Arabic gum (AG) and its suspension characteristics, it is applicability is found in medical, lithographic, textiles, paints and cosmetics industries. However, its workability with respect to color has not been investigated. The advancement in technology and the drive to develop new frontiers in the fabrication of electronic components using environmentally friendly material has driven this research to understand the effect of color variation in the conductivity and resistivity of AG. Instrumentation method was used to determine the electrical conductivity and resistivity of the AG sample with respect to color variations. The result obtained shows that, AG (black) has the highest conductivity of 7.56 µS/m. whereas AG (white) has the lowest conductivity of 4.55 µS/m. However, the results for resistivity were vice versa. It is concluded that in the fabrication of communication devices, AG (Black) is more suitable for the fabrication of semiconductor materials due to its high conductivity and low resistivity value.

Keywords:- *Arabic Gum, Electrical Conductivity, Electrical Resistivity, Colour Variations and Electronic Applications*.

I. INTRODUCTION

Arabic Gum (AG) is produced from many species of Acacia, of African origin. AG is a natural polymer, that plays an important role in our daily live. AG is the most important commercial polysaccharides, and it is probably the oldest food hydro-colloid currently in use. AG is high molecular weight polymeric compounds, composed mainly of carbon core mixed in heterogeneous manner, including some metals in ionic forms, for example {Ca+2 , Mg+2 , K+ }, as salts of macromolecules (Fadel, 2008; Elhadi *et al.*, 2012). The physicochemical composition of AG can vary with its source, the age of the trees from which it was obtained, climatic conditions and soil environment (Elzain *et al.*, 2012).

AG are used as an element in many applications, viz. food, pharmaceutical, cosmetic, and paper industries as reported by (Tan, 2004; Bhushette & Annapure, 2018; Zhang *et al.*, 2019; Rosland *et al.*, 2019). In the food industry, AG is being mostly used either as an emulsifier, a foaming agent or an encapsulating material. AG is believed to have a higher ability to hydrate, swell, dissolve, and interact with water; resulting in an improved effectiveness in emulsion stability (Al-Assaf *et al.*, 2007; Li *et al.*, 2018; Moradi & Anarjan, 2019; Rosland *et al.*, 2019). It is widely used as emulsifiers in the manufacture of soft drinks and oil-in-water emulsions, such as the orange-oil beverage (Tan, 2004; Pua *et al.*, 2007; Rosland *et al.*, 2019). As a foaming agent, AG is mostly used in confectionary and beverages due to its rheological properties and higher solubility characteristics (Makri & Doxastakis, 2006; Walsh *et al.*, 2008; Jiang *et al.*, 2013).

Tiwari (2007), fabricated an electrically active, water-soluble radical copolymer of AG with redox property. With a battery of high-end technical characterization, the shelf-life and electrical conductivity of the copolymer was monitored. Results held possibilities of their application in the fabrication of semiconductor sensor devices. Zhang *et al*. (2009), studied that AG coating on magnetic iron oxide nano-particles (MNP) enhanced the colloidal stability and provided reactive functional groups suitable for coupling of bioactive compounds.

However, this study has taken a distinct approach, in concern to find new applications for AG, such as: manufacture of electronic circuits, semiconductors, optical sensors, solar cells, capacitors, resistors.

The electrical resistivity of a material is a number describing how much that material resists the flow of electricity. Resistivity is measured in units of ohmmeters (Ωm). If electricity can flow easily through a material, that material has low resistivity. If electricity has great difficulty flowing through a material, that material has high resistivity. This means a high resistivity is the same as a low conductivity, and a low resistivity is the same as a high conductivity. Equation 1, was used to calculate the electrical resistivity of the samples.

$$\rho = \frac{1}{\sigma}$$

Where σ is electrical conductivity (µS/m) and ρ is electrical resistivity (Ωm).

Electrical resistivity is a key physical property of all materials. It is often necessary to accurately measure the resistivity of a given material.

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II. MATERIALS AND METHODS USED

AG in it natural form was bought from Dakingari commercial market in Kebbi State, Nigeria. One of its physicochemical properties of AG is color which is referred as a preliminary characterization. The materials used in this research are measuring cylinder, weighing balance, plastic containers, and thermometer and OAKLON Conductivity Meter C11 series.

A. *Sample Preparation*

The AG samples were bought at Dakingari, Suru Local Government Area of Kebbi State, Nigeria. The samples were classified into three proportions (i.e White, Red and Black) it was then hand cleaned to remove foreign particles. The measuring cylinder and weighing balance were used to measure both the volume and weight of the sample respectively. Three different container of 100 ml was used for distilled water and 100 g of the sample were mixed together to form a solution at room temperature. Shown in Figure 1 are the prepared samples of AG.

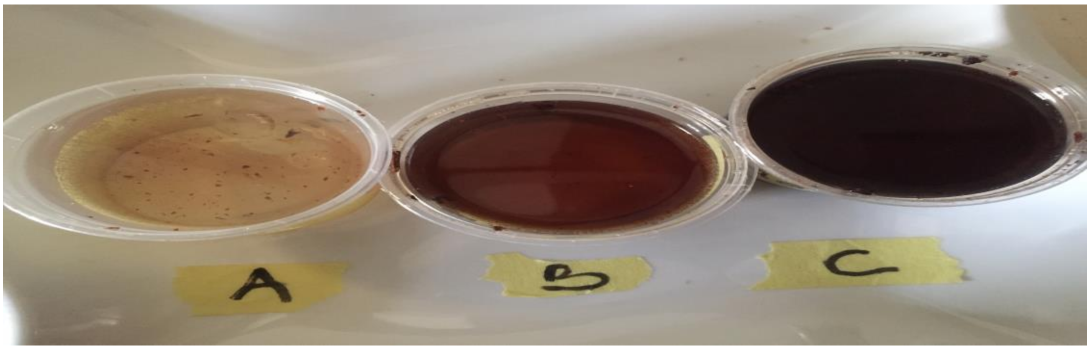

Fig. 1: Prepared AG samples (A) AG White (B) AG Red and (C) AG Black

The samples were left to dissolve for 24 hours to enable complete dissolution (Makri & Doxastakis, 2006; Walsh *et al.*, 2008; Jiang *et al.*, 2013; Rosland *et al.*, 2019). The three samples were prepared using the same procedures. The details of the sample composition, temperature is shown in Table 1.

Table 1: The Sample Composition

Sample	Composition	Temperature (^{0}C)
AG (White)	100 ml of distilled H_2O + 100 g of AGW	25.0
AG (Red)	100 ml of distilled H_2O + 100 g of AGR	25.0
AG (Black)	100 ml of distilled H_2O + 100 g of AGB	25.0

III. EXPERIMENTAL

Analysis of electrical conductivity was determined using OAKLON Conductivity meter C11 Series at room temperature for all the samples. For each of the sample, the conductivity meter was deepened into the solution containing the sample and the value for the conductivity was recorded.

The same procedure was repeated for the other two samples. To avoid error from machine and human, five different readings were taken. The average of the readings was then computed. All measurements were undertaken at room temperature. The recorded results were analyzed using Microsoft excel software, where parameters such as conductivity and resistivity were computed and plotted in a graph.

IV. RESULTS AND DISCUSSION

The measured and recorded values for the electrical conductivity for the three samples are represented in the graph shown in Figure 2.

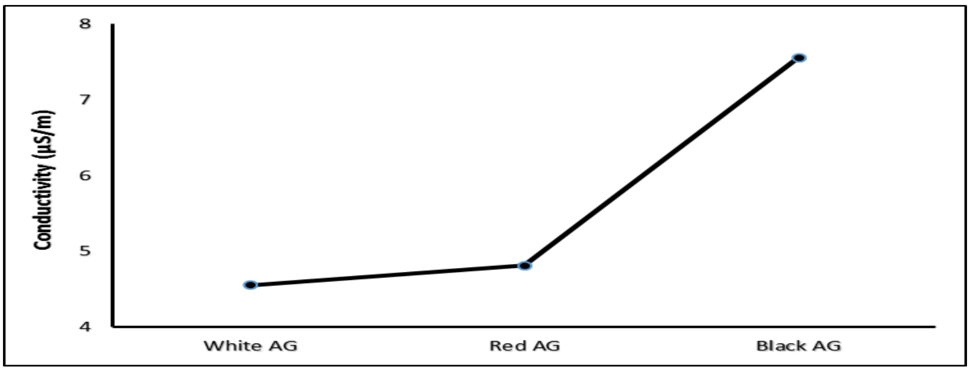

Fig. 2: Electrical Conductivity of AG Samples

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Careful observation showed that AG black had the highest conductivity while AG white had the lowest. The result affirms the theory that stipulates that the properties of polymer can be altered through the variation of size, shape and color distribution. Mondal *et al.* (2008) and Li *et al.* (2018), reported that the electrical properties of polymers can be modified significantly through incorporation of foreign body into the polymer matrix also in agreement with work reported by (Rosland *et al.*, 2019). The highest value of conductivity exhibited by AG black may be attributed to the composition and concentration of AG it is also in agreement with result reported by (Mokhtar, 2016).

V. RESISTIVITY OF THE SAMPLES

The values obtained for the conductivity were used to calculate the value of resistivity of the samples. To achieve the target, equation 1 was used for the computation. The graph shown in Figure 3 is the representation of the resistivity obtained.

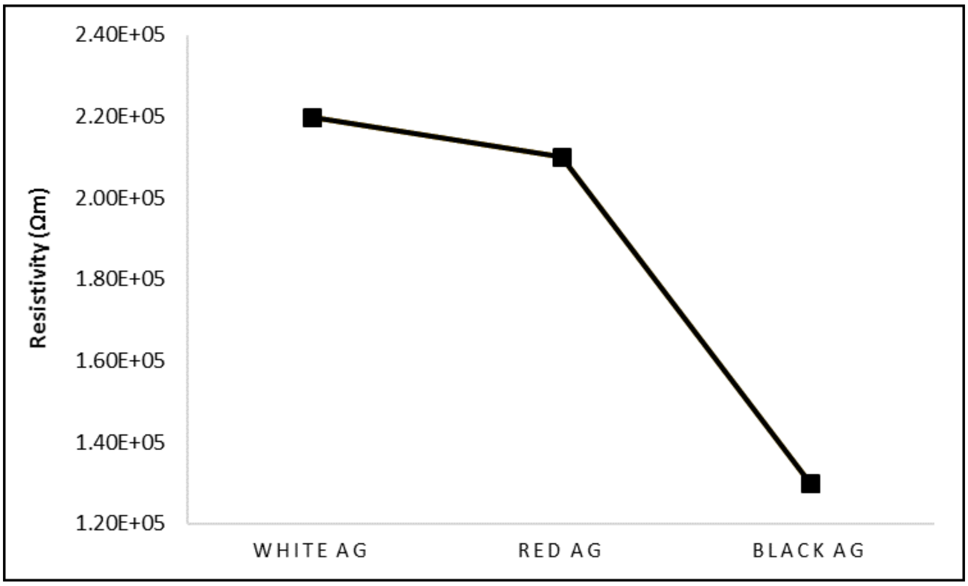

Fig. 3: Resistivity of AG Samples

Figure 3, shows the resistivity with respect to color at the room temperature. The resistivity found for AG white is higher (2.2×10^5) Ωm compared to both AG red and black, respectively. This result is in agreement with work reported in (Adam *et al.*, 2014). The reasons for this behavior are attributed to concentration of AG.

Table 2, is the summary of results obtained for the electrical conductivity and resistivity of the Arabic gum samples.

Table 2: Summary of Values obtained for Electrical Conductivity and Resistivity

Sample	Electrical Conductivity (μS/m)	Electrical Resistivity (Ωm)
White	4.55	2.2×10^5
Red	4.81	2.1×10^5
Black	7.56	1.3×10^5

Based on the values shown in Table 2, it is inferred that color variation is a significant factor when determining the suitability of AG for electronic and other applications.

As mentioned earlier, that AG is a natural biopolymer which possessed electrical properties like conducting polymers. As such AG Black can be used for semiconductor applications.

VI. CONCLUSION

This work deals with the measurement of electrical conductivity and resistivity of AG sample when incorporated with colors. It was shown that color plays a significant role in the value of conductivity for polymeric materials. In this study, the black colored AG sample had the highest value of conductivity (7.56 μS/m) while white colored AG sample had the lowest value of conductivity. For the resistivity, however, white AG had the highest resistivity while black AG had the lowest resistivity. It is thus postulated that conductivity of a material strongly depends on color variations. For possible fabrication of communication devices with AG, the black colored AG is most suitable especially for semi-conductor devices under careful controlled conditions by introducing impurities which will contribute either an excess or a deficit of electrons.

- **Competing Interest:** The authors declare that they have no competing interests.

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- **Consent for publication:** Not applicable

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