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Electrical Conductivity Studies on Polyethylene Terephthalate (PET) Thin Films

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ABSTRACT: The present work was made to study the electrical conductivity of polyethylene terephthalate (PET) thin films. The thickness of the sample thin films of the order of 100-250 microns. The electrical conductivity values of PET thin films dependence on its physical and chemical properties. The main aim of this work is finding the Resistivity values of the PET thin films; from this we can calculate the electrical conductivity of the polymer material (inverse of Resistivity is conductivity). In this study the electrical conducting properties of polymer polyethylene terephthalate has been investigated by using a four-probe apparatus because of its importance in industrial applications. The dependence of DC (direct current) surface resistance on thickness was measured using this method. The surface resistance exhibits the size effect in accordance with the sample (PET) material. The readings are taken with different combination materials such as copper, aluminum carbon strips etc. According to this study suggests that possibility of using PET thin films in electronic components (capacitors, resistors, etc) that operate at temperature dependence applications and this classification not only for polyethylene terephthalate (PET) thin films but also for the other polymer materials

KEYWORDS: Conductivity, Resistivity, Four-probe method, PET thin films.

I. INTRODUCTION

The investigation of the electrical and dielectric properties of polyethylene terephthalate (PET) is interesting both from the fundamental and technological point of view. Several studies have been made of the electrical conductivity of insulating polymer films, [1-3] particularly of polyethylene terephthalate (PET) and polyethylene, but the mechanism of conduction is still ambiguous. Several processes are possible but cannot be distinguished because the morphology, impurity content and electrode-polymer interface of such films cannot be specified. In general, models based on thermal activation of charge carriers over potential barriers whether at trapping sites in the body of the polymer or at the metal electrode-polymer boundary are favored. For example, Amborski (1962) suggested that the current in PET at 130 ^{0}C was due to thermal activation of ions between sites separated by distances of about 69 x10^{-10}m On the other hand, Lengyel(l966) suggested that Richardson- Schottky field-aided electron injection was responsible. Polyethylene terephthalate (PET) is often used as a dielectric in high-performance foil capacitors and as a polymer electrode. Therefore there is much interest in the electrical and dielectric properties of this material from the technological point of view. On the other hand, PET has attracted much interest for fundamental investigations by dielectric relaxation spectroscopy (DRS). In most studies this interest is based on PET being a main chain polymer having dielectrically active primary *and* secondary, relaxation processes and a very useful model for 'low'- crystallinity polymers [9].

II. EXPERIMENTAL PART

The Electrical conductivity of polyethylene terephthalate samples were determined by using Four – probe conducting apparatus. The methods and the material by which using this methods as follows The four-probe unit consists of four pointed pressure contacts which are equally spaced about 1 millimeter apart and positioned on a single straight line. The surface has a flat face but is otherwise of any shape. The four-probe is lowered over the sample so that all the four-probes, which are of equal height, make contact with the sample. A four-probe unit along with a constant current supply source voltmeter and milli Ammeter. Before starting the experiment, it is ensured that the sample surface is clean. The sample is placed on a piece of mica and the two are placed in the holder. The probe is lowered and it is checked that there is good contact between the point-probe and the sample. The voltage is applied to the sample through probes 1 and 4. It is adjusted to give a desired current and its value measured (I_x). The voltage across probes 2 and 3 is measured (V_x). The value of the inter-probe spacing b is noted from the supplier's manual or is, otherwise, measured. Resistivity for the sample between probes 2 and 4 is obtained from Equation (6) and (7). The four-probe method gives an average value of the Resistivity. If specimen having irregular shape, Resistivity determination becomes difficult due to the difficulty in measurement of cross-sectional area. The four-probe method avoids the necessity of measurement of cross-sectional area and is thus suitable for arbitrarily shaped samples. It is also an accurate method for determination of (ρ).

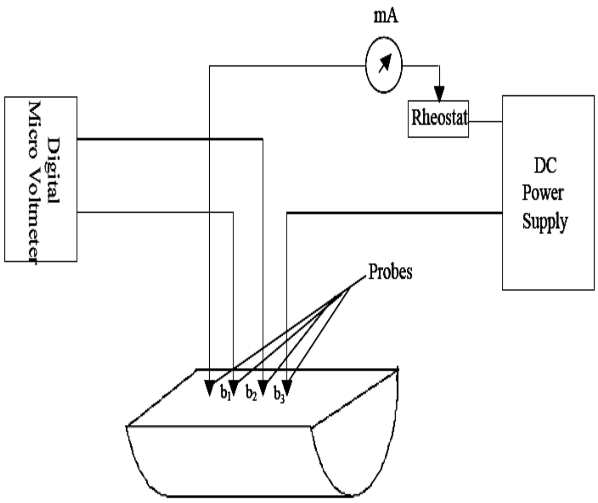

Figure1: Four – probe Apparatus

Calculation of Specific Resistivity (ρ):

The Block diagram of the four probe setup as shown in the Figure1, Where b_1,b_2,b_3, represent the four-probes. Voltage is applied at probes 1 and 4 and the Voltage (V_X) between probes 2 and 3 is measured.

Also, the current (I_X) is measured. The Resistivity (ρ) is given by

$$R \alpha \frac{L}{A} \quad (1)$$

Where L is the Length of the specimen, A is the Area and the R is the Resistance, from the equation (1)

$$R = \frac{\rho L}{A} \quad (2)$$

Where ρ is the Resistivty

$$\rho = \frac{RA}{L} \quad (3)$$

From the equation (3) the Area of the specimen is the product of the Length (L) and Breath (b) and the equation (3) can be written as

$$\rho = Rb \quad (4)$$

According to ohm's Law R=V / I i.e., Resistance = (Voltage / Current), So the equation(4) becomes

$$\rho = \frac{Vb}{I} \quad (5)$$

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apply the probe values in the equation (5),we get $\rho = \left[\frac{V_x}{I_x}\right]\left[\frac{2}{\frac{1}{b_1}+\frac{1}{b_3}-\frac{1}{b_1+b_2}-\frac{1}{b_2+b_3}}\right]$ (6)

if $b_1 = b_2 = b_3 = 8mm$

$$\rho = \left[\frac{V_x}{I_x}\right]2b \quad (7)$$

If the bottom surface is non-conducting, the factor 2b is replaced by a more complicated correction factor f. This correction factor is supplied by the manufacturer of the probe. And the list of samples used in this study as follows Copper Strip, Aluminum Strip, Carbon Strip, Carbon – Carbon Strip combination, Carbon - Polyethylene terephthalate (250 μm) – Carbon, Carbon - Polyethylene terephthalate (175μm) – Carbon.

III. RESULTS AND DISCUSSION

Results obtained by using Four – Probe apparatus are graphically represented in Figs 2- 7 From this we understood that voltage more are less linearly increases with applied current.[4-8] The ratio V_x / I_x shows some variation initially and reaches constant value beyond 200mA current for copper and beyond 250 mA for Aluminum. For carbon constant value is reached beyond 250 mA. In order to keep electric field within dielectric limit, the experiments were repeated for PET samples up to 150 mA current only. So the Resistivity (ρ) value becomes stable beyond 100mA even with sample. Therefore it is understood that thin polymer films of thickness 100- 200 μm can be studied by using Four-Probe method and it is possible to measure their specific resistance (ρ) using Four – Probe Apparatus.

Sample	Carbon-PET(175μm)-Carbon	Carbon-PET(250μm)-Carbon	Carbon	Carbon - Carbon	Aluminium	Copper
Resistivity (ρ) $x10^{-6}\,\Omega$ m	331	311	290	280	1.30	0.45
Conductivity (G) x 10^{6} Ω^{-1} m^{-1}	0.0032114	0.0032154	0.0034448	0.0035710	0.7692100	.2060001

Table1. Calculated Values of Specific Resistance (ρ) and Conductivity (G)

From the experimental values it is observed that higher the value of the Resistivity(ρ) and the lower the value of the conductivity (G), where inverse of Resistivity is conducvity

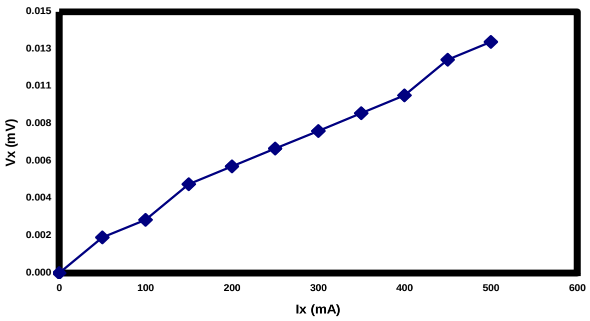

Fig : 2 V-I Characteristics of Copper Strip

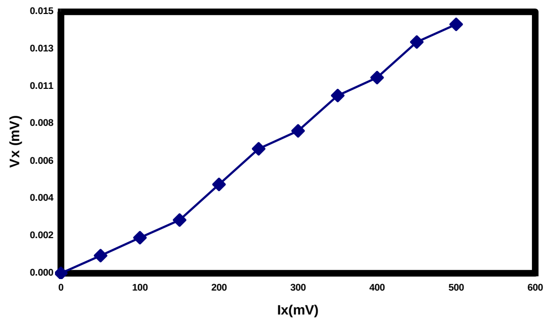

Fig : 3 V-I Characteristics of Aluminum Strip

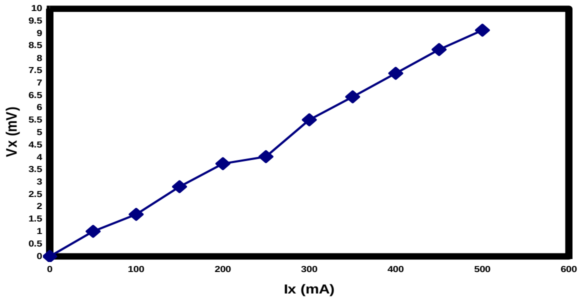

Fig :4 V-I Characteristics of Carbon Strip

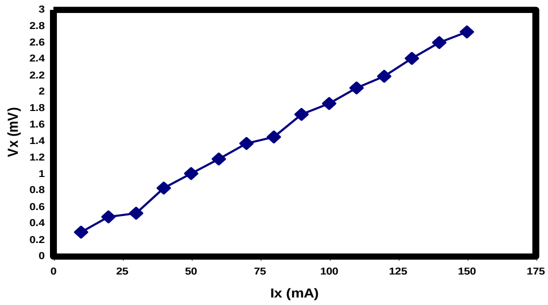

Fig :5 V-I Characteristics of Carbon- Carbon Strip

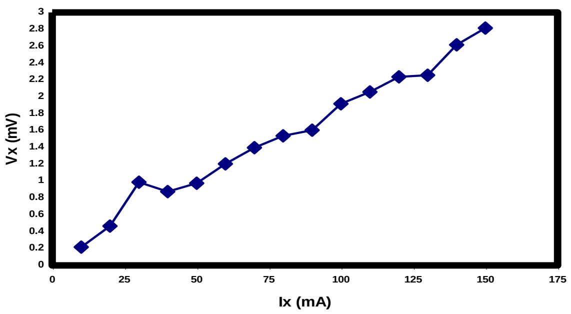

Fig :6 V-I Characteristics of Carbon-PET 250µm

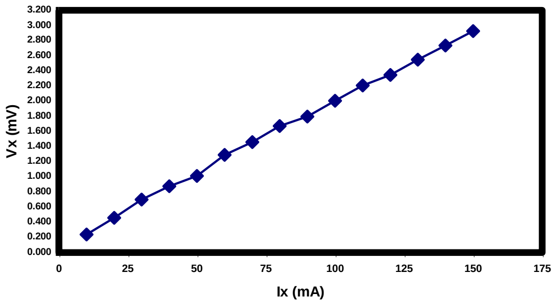

Fig :7: V-I Characteristics of Carbon-PET 175µm

IV. V- I CHARACTERISTICS

Fig 2, 3, and 4 give the V- I Characteristics of copper, Aluminum and Carbon specimens. Copper specimens show linear characteristics only between 200- 400 mA . Aluminum specimen shows linear characteristic only if $I_x <$ 200mA.[10] Carbon specimen show constant slope beyond 300mA. Fig 5 shows even after introducing thin film constant slope is reached even at 100mA. Fig 6 and 7 shows that the thin films of thickness 175 µm is more linear than thick film of 250 µm.

V. CONCLUSION

The results show that polymer materials behave as insulators. However they have specific Resistance and Conductivity more are less in the range of carbon samples. These results agree with the results of established research reviews. In their opinion, Conductivity of PET may be due to the presence of CH_2 groups.

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