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Parallel Plate Technique Determination of Dielectric Constant and Strength of Plastic

Sunday David Najoji, Muhammad Abubakar

Abstract – A dielectric is an electrically insulating material or non-conducting material which can be polarized in the presence of an electric field. The problem of this research work is determination of some dielectric properties of plastic (polyvinyl chloride) with the sole aim to determining the dielectric constant and dielectric strength. The method used is the parallel plate technique where parallel plate capacitor was constructed from two parallel aluminum plates with a plastic dielectric material in between them. The capacitance measurements were carried out with a multimeter across the parallel plate arrangement. A battery was then connected across the arrangement and the potential difference measurements were also taken using multimeter. The data was analyzed graphically and the result that were obtained shows that the dielectric constant is 4.7 and dielectric strength (breakdown voltage) is 100V/m which are within the range of standard values. It is recommended that further research work should be carried out using other methods for the sake of comparism.

Index Terms: polarization, electric field, dielectric material, breakdown voltage, dielectric properties, capacitor and parallel

1 INTRODUCTION

A dielectric material is an electrical insulator that can be polarized by an applied electric field. When a dielectric is placed in an electric field, electric charges do not flow through the material as they do in electric conductor but only slightly shift from their average equilibrium position causing dielectric polarization, positive charges shift in the opposite direction. This creates an internal electric field that reduces the overall field within the dielectric itself [1]. The problem posed by dielectric properties of plastic material is necessary because of the numerous uses of plastic in the electronic industry. The aim of this research work is to determine the dielectric constant and dielectric strength of plastic. A frequent purpose of these experiments is to verify the relation between the capacitance and the plate separation based on the parallel plate capacitance equation [2]:

$$C_d = \frac{k\varepsilon_o A}{D} \quad [1]$$

where C_d is the capacitance of the dielectric material, k is the dielectric constant, ε_o is the permittivity of free space ($8.85 \times 10^{-12}\ Fm^{-1}$), A is the area of the plates, and D is the dielectric thickness. The dielectric constant of a dielectric material is defined as the ratio of the capacitance using that material as the dielectric in a capacitor to the capacitance using a vacuum as the dielectric.

Dielectric strength is the ability of a dielectric material to resist the maximum voltage applied on it for a long period without failure, the potential difference at which failure occurs is known as Breakdown Voltage [3]. The failure of a dielectric material is the loss of the material to its electric insulation property and its transformation into conductor, the maximum electric field applied on the material at which failure occurs is called dielectric strength E, [4], applying high voltage on the material higher than a specific critical value causes relatively high electric current flow, and so the material loses its insulating property and transforms into conductor. Dielectric strength is measured by electric field according to the equation [5]:

$$E = \frac{V}{D} \quad [2]$$

where E is the electric field across the dielectric material, V is the maximum potential difference applied and D is the thickness of the dielectric material.

Several studies have been carried out on dielectric materials, among which is the work of Mark et al [6] on dealing with the dielectric constant of paper and different cellulosic materials. Sirvio and Omari [7] carried out a research on the measurement of different types of paper for a number of new applications. Also, Vanja [8] carried out the research on measuring the dielectric constant of paper using a parallel plate capacitor. Worth mentioning too is the work of Riddle et al., [9] on complex permittivity measurements of common plastics over variable temperatures. Among these studies above none of them carried out the research on dielectric constant and strength of plastic using a parallel plate technique as such this research become necessary.

Plastics are used in many areas of manufacturing and have naturally found application in the construction of electronic devices [9]. The performance of dielectric material is characterized by their complex permittivity (ε) for the dielectric used under week electric field by their polarization of electric field relationship and their breakdown field (i.e. dielectric strength) for dielectric used under a high electric field [10]. A parallel plate technique can be used to store a finite amount of energy before dielectric breakdown occur. The maximum energy is used as a function of dielectric volume, permittivity and dielectric strength changing the plate area and the separation between the plate while maintaining the same volume causes no change of the maximum of energy that the parallel plate technique can store so long as the distance between the plate, length and width of the plate remain the same [11]. The dielectric properties of the load materials are also important in the design of the radio-frequency (RF) or microwave power equipment needed for the heating process. Since dielectric properties of materials are highly correlated with the amount of water in materials such as agricultural products and food materials, sensing the dielectric properties can be used for rapid measurement of their moisture content [12].

2 MATERIALS AND METHODS

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Seven (7) parallel plate capacitors of size eight centimeters (8 cm) by eight centimeters (8 cm) each from two parallel aluminum plates, with the plastic dielectric material placed in between them for each arrangement were constructed. The thickness of the dielectric material (plastic) was varied from 2mm to 14mm at 2mm intervals for the capacitive arrangements. The length and thickness measurements were carried out using a ruler and micrometer screw gauge respectively. The surface areas of the capacitors were kept constant for each arrangement. The circuit diagram of the arrangement is shown in fig1.

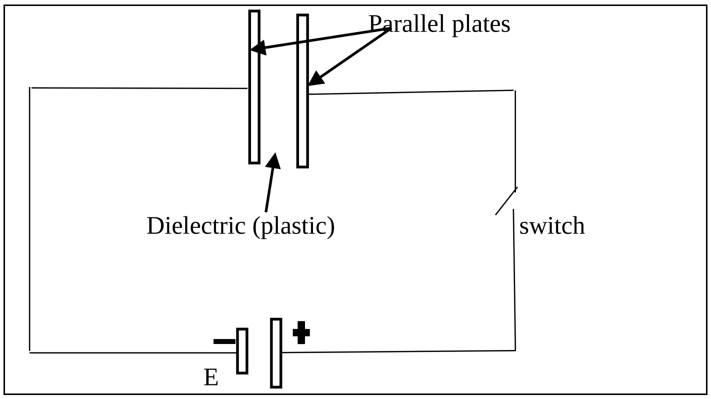

Fig. 1. Circuit for determination of dielectric constant and strength

The capacitances and potential differences of each arrangement was determined using a multimeter across them. A source of an electric field (battery) was connected across each arrangement and switch closed (fig1) before the potential difference across them were taken while capacitance measurement were taken when the switch was opened (fig1) and all the data obtained was recorded against each corresponding thickness. The data obtained was then processed graphically where a graph of capacitance versus the reciprocal of the thickness and electric potential difference versus thickness were plotted respectively to determine the dielectric constant and the dielectric strength.

3 RESULTS AND DISCUSSION

The capacitance equation [1] suggests that the variation of capacitance (C) against the thickness inverse $\left(\frac{1}{D}\right)$ of the dielectric material is linear as obtained in the curve (fig2). The equation [2] of dielectric strength (E) also suggest that the variation of the potential difference (V) against the thickness of the dielectric

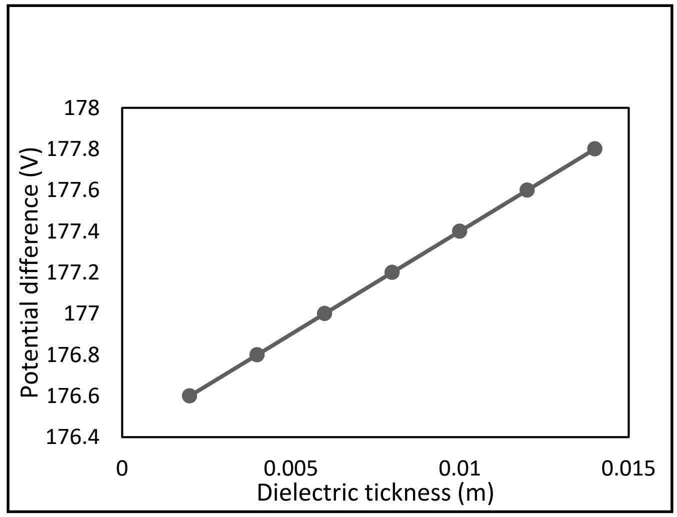

Fig. 3. Graph of potential difference against thickness of the dielectric material.

material is linear as obtained in the curve (fig3). The slope of the graph (fig2) was determined and the result was divided by the constant area and permittivity of free space and the result was found to be 4.7 which represents the value of the dielectric constant of the dielectric material (plastic), which agrees well with standard value range of dielectric constant of plastic which is between 2 and 5. This is the strength of the force one charged particles exerts on another at a distance or an expression of the extent to which a plastic material concentrates electric flux. From the Graph of potential difference (V) against thickness (D) of the dielectric material (fig 3). The slope of the graph (fig 3) was determined to be 100 V/m which represents the breakdown voltage of plastic which agrees well with the standard value of dielectric strength of plastic which ranges between 100 to 300 V/m. This breakdown voltage that is the voltage at which the dielectric material ceases to be an insulator rather begins to conduct like a conductor. It is also the point at which the dielectric material begins to experience failure of its insulation properties.

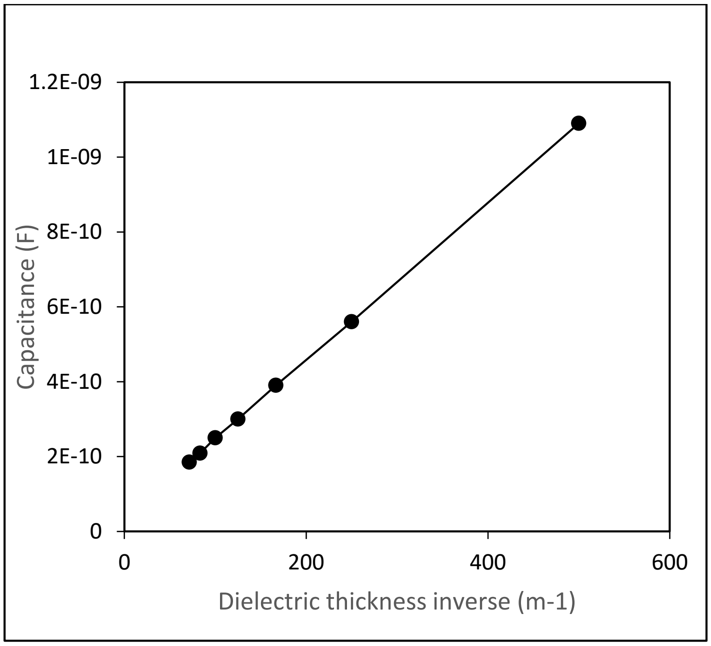

Fig. 2. Graph of capacitance against dielectric thickness inverse.

4 CONCLUSION

From equation [1] and [2], suggest linear variation of capacitance versus thickness inverse of dielectric material, potential difference versus dielectric thickness respectively as obtained in both curves that is plastic has a linear characteristics for both. Both dielectric constant and dielectric strength were obtained as a consequence of the slopes of their curves. The dielectric constant was obtained as 4.7 while the dielectric strength was 100 V/m. Other methods should be used to determine both the dielectric constant and dielectric strength for the sake of result comparism.

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