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Dielectric Properties of Cellulose with EC-PVP Polymer Blends

KEYWORDS: Dielectric permittivity, Polymer blends, dielectric loss, A C conductivity

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ABSTRACT *Polymer blends of Cellulose with EC and PVP for different thickness and for different weight percents have been used for measurement of dielectric constant, dielectric loss and A C conductivity as a function of frequency over the range 50 Hz – 5 MHz at room temperature. The values of dielectric constant and the dielectric loss of the polymer blend increases as thickness increases. The Dielectric constant as well as the dielectric loss values of the blends increases as weight percent of PVP decrease with increase of Cellulose substance. In case of different weight percent, it has been observed that the dielectric constant also decreases exponentially over the frequency 200 Hz -3 kHz and after that it is independent of frequency. The A C conductivity of the polymer blends after 100 kHz increases as a different weight percent, the A C conductivity increases as weight percent of PVP increases with Cellulose.*

Introduction

Polymers can be made that are electrically insulating, semi-conducting and conducting [1]. The polymer blends are combination of different polymer-matrix composites, a material important to the electronic industry for its dielectric properties in the use of capacitors [2]. The study of dielectric constant, dielectric loss and a. c. conductivity, as function of frequency is one of the most convenient and sensitive methods of studying the polymeric structure [3, 4]. However, the possibilities of tunneling and space charge limited conduction So that it motivates us to study the dielectric properties of polymer blends [5]. One of the largest areas of application for polymers, polymer blends and composites on their basis are electronic and electrical industries. Pure polymers are generally electrical insulators in their nature, so they are applied as electrically insulating materials. Polymers contain a very low concentration of free charge carriers, they can be easily shaped with low cost technologies; they have light weight; they provide corrosion resistance and they can offer a wide range of electrical conductivities [6-8].

Experimental Mesurements

The sample of polymer blend is prepared by using polymers **viz**., Ethyl Cellulose (EC), Polyvinyl Pyrrolidone (PVP) and Cellulose powder (C). These polymers were obtained from S.d. Fine Chem Ltd, Mumbai, India. The different quantities of substances such as EC, PVP and C in the form of powders have weighed using the single pan balance with accuracy ± 0.0001 gm. These substances have been mixed and grinded properly. The circular shape of pellets have been made by applying 2-3 tons of pressure using the pellet making machine with Die of 10 mm. The surfaces of pellets of EC and its blends were coated with silver paint for Ohmic contacts to provide electrical connections. The prepared polymer blends were used to study the capacitance and dielectric properties such as dielectric constant, and a. c. conductivity as a function of frequency ranging from 50 Hz - 5 MHz at room temperature using PC based LCR meter (Model: HIOKI 3552-50-LCR Hitester).

3. Results and discussion

The dielectric properties of polymer blends of Ethyl Cellulose (EC), Polyvinyl Pyrrolidone (PVP) and Cellulose powder (C) as single entity are obtained from the experimental measured values of capacitances. The A C conductivity is obtained by Equations (1)-(3) using the estimated values of dielectric constant and dielectric loss with the frequencies for different compositions.

Dielectric Properties

The dielectric permittivity of the polymer blend has been calculated from the experimentally measured values of the capacitance using a relation given below.

$\varepsilon' = C d / \varepsilon_o A$ (1) Where C is capacitance of the dielectric material, d is thickness of the polymer blend, A is area of the blend and ε_o is the permittivity of free space. The dielectric permittivity was obtained using Equation (1) from the measured values of capacitance as function of frequency. The values of dielectric permittivity of the polymer blends of thickness 5.12 mm at different weight percentage are given in Fig 1.

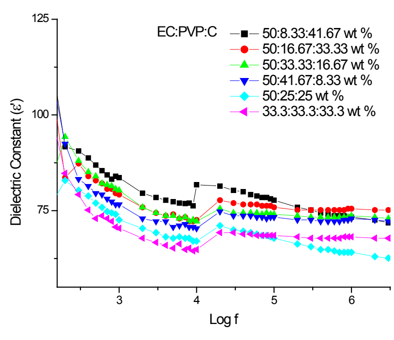

Fig. 1. Variation of dielectric values as function of frequency of polymer blend at different thickness.

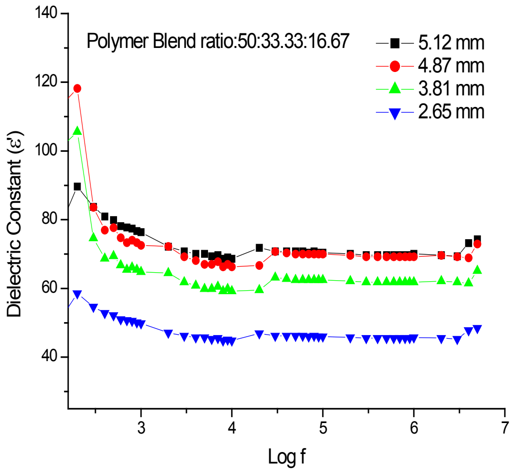

Fig. 2. Dielectric values as function of frequency of the polymer blend at different weight percentage.

From Fig 1, it is observed that the values of dielectric permittivity of the polymer blend decreased exponentially as the frequency increases up to around 1 KHz and gradually decreases up to 10 KHz and at 10 KHz sudden increase in dielectric permittivity is observed for all the polymer blends and after wards gradually decreased. In case of higher frequency the dielectric constant remains same and is independent of the frequency. It is also observed that as weight percentage of PVP increased, with decreasing weight percent of cellulose powder, the dielectric permittivity also decreased. Further, it is observed from the same figure that, in case of 50:25:25 wt% the dielectric permittivity decreased exponentially at lower frequency up to around 10 K Hz. The values of dielectric permittivity decreased as compared to its blends of higher doping concentration of PVP with cellulose powder. But in case of polymer blend of each at equal wt%, i.e. of ratio 33.3:33.3:33.3 the dielectric permittivity is lowered than that of the other compositions. This implies that for a given wt% of EC, as wt % of PVP with cellulose increased, the values of dielectric constant also increased. Hence we observed the modifications in dielectric properties of the blends rather than those in an individual case [10]. The dielectric permittivity of the polymer blends at different thicknesses is given in Fig 2. It is observed from Fig 2, that as frequency increased the dielectric permittivity of the polymer blend decreased exponentially at lower frequency ranging from 100 Hz to 10 K Hz. At 10 KHz slight increase in permittivity is observed and afterwards it decreases gradually and remains constant at higher frequencies for all the thicknesses.

Dielectric loss

The dielectric loss as a function of frequency for the polymer blends at different thickness and weight percentage are obtained using Equation (2).

$\varepsilon'' = \varepsilon' \tan \delta$ (2) The plots of dielectric loss versus frequency for different thicknesses and for weight percentages are given in Fig 3 - 4. We observed that as thickness of the polymer blend increased in the ratio of 50:33.33:16.67, the dielectric loss also increased. It is also observed that the dielectric loss decreased exponentially over the frequency range 300 Hz – 3 KHz and afterwards it remains constant as frequency increased for all the thickness. In case of the polymer blends of thickness 5.12 mm at different weight percentages is observed that as frequency increased the dielectric loss of the polymer blend decreased exponentially at lower frequency range, that is, from 200 Hz to 10 K Hz and afterwards it decreases gradually and remains constant at higher frequencies. The same trend has been observed for all the blends of different weight percentages as frequency increased. Further, from Fig 4 it is observed that the dielectric loss increased as weight percentage of PVP increased with decreasing weight percent of cellulose of the polymer blends. In case of 50:25:25 wt% of EC:PVP:C the dielectric loss decreased exponentially at lower frequency up to around 10 K Hz, where as in case of each 50 wt%, the dielectric loss is lowered than that of the blend at ratio of 50:25:25 wt%.

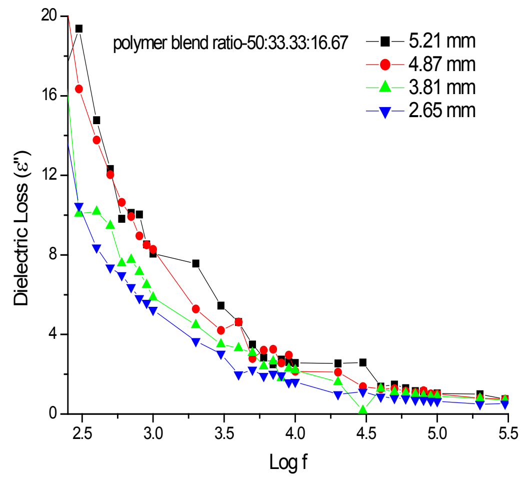

Fig. 3. Dielectric loss as function of frequency of the polymer blend at different thickness.

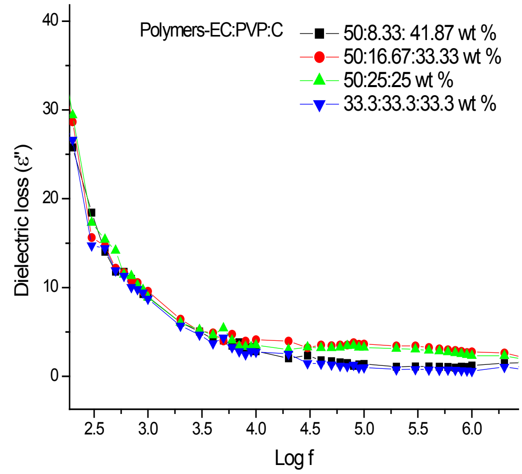

Fig.4. Dielectric loss as function of frequency of the polymer blend at different weigh percentage.

The blends are heterogeneous, hence dielectric constant may arise due to interfacial and space charge polarization at frequency from 50 Hz to 5 M Hz. At lower frequency the dipole can respond rapidly to follow the field and dipole polarization has its maximum value, so highest dielectric constant and dielectric loss. At higher frequencies dipole polarizability will be minimum, as the field cannot induce the dipole moment, so dielectric values attain minimum [8]. This may lead to large values of dielectric constant at low frequencies. Due to the application of an electric field the space charges are moved and dipole moments are created. This is called as space charge polarization. The dielectric loss is strongly reliant on the frequency of the applied field.

Conductivity Measurements

The A C conductivity of the polymer blends is measured as a function of frequency using Equations (1)-(3), for different weight percentages, at room temperature.

$\sigma_{ac} = \varepsilon' \varepsilon_o \omega \tan \delta$ (3)

The plot of A C conductivity versus frequency of the polymer blends at different weight percentages are given in Fig 5.

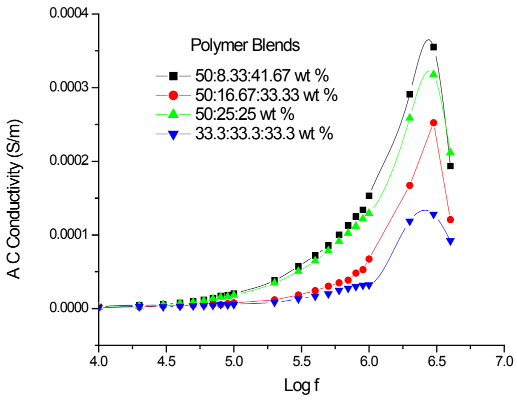

Fig. 5. A C conductivity as function of frequency of the polymer blend at different weight percentage.

From Fig 5 it is observed that as weight percentage of PVP increased with decreasing weight percent of cellulose, A C conductivity also decreased. In case of 50:25:25 wt% of the blend the A C conductivity remains same over the frequency range 100 Hz to 10 KHz and it increased non linearly over the frequency range 1-5 MHz. The values of A C conductivity increased as compared to its blends of 50:16.67:33.33 wt %. But in case of each 50 wt%, the values of A C conductivity changed appreciable. This implies that for a given wt% of EC, as wt % of PVP with cellulose increased the values A C conductivity also increased. Hence we observed the modifications in A C conductivity of the blends rather than those in case of their individuals [9]. On the other hand, as the frequency is increased further, conductivity goes on increasing and the conductivities of all the samples merge together indicating the formation of excess charge carriers such as polaron and bipolaron at higher frequencies [10]. The total conductivity of the composite may depend on the microscopic and macroscopic conductivities. The microscopic conductivity depends upon the doping level, conjugation length or chain length etc, Whereas the macroscopic conductivity depends on the inhomogeneities in the composites, compactness of pellets, orientation of micro particles etc [11].

CONCLUSIONS

We conclude that as the frequency increases the dielectric constant of the polymer blend decreases exponentially at lower frequency range, afterwards it decreases gradually and remains constant and shows independent of the frequency for all thicknesses of the blends. It is also observed that as thickness of the blend of polymer increases the values of dielectric constant increases. In case of dielectric loss as thickness of the polymer blend increases the dielectric loss also increases. Further, the dielectric loss decrease exponentially over the frequency range 300 Hz – 3 KHz and afterwards it remains constant as frequency increased for all the thickness. The measurement of A C conductivity shows nonlinearity at higher frequency range and as weight percentage of the PVP and cellulose in polymer blend increases the A C conductivity also increases.

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