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Temperature dependent Dielectric studies of Poly(Ethylene Oxide)

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Abstract. Polymers are known to be better materials for dielectric applications. Various polymers with different molecular weights are being studied for dielectric applications. In the present paper, we report the dielectric measurements of Poly(Ethylene Oxide) {PEO} using Impedance spectroscopy studies. The dielectric studies of PEO were carried out on pellets as a function of temperature. It was found that the dielectric constant seems to be negligibly varying with increase in temperature at high frequencies, however, at low frequencies, dielectric constant varies increases with temperature. This may be due to the fact that with the thermal energy provided to the system, more and more dipoles participate and hence the net dielectric constant of the material is also higher at higher temperature. Also at very high frequencies, due to many non-responsive dipoles for fast switching of the applied signal, net dielectric constant of the material also does vary much with temperatures.

1. Introduction

Polymers are being the materials of the era due to their properties like flexible, easy to prepare, chemically stable etc.,. Having their applications spread over various fields including, ion batteries, shielding, electrochromic displays, etc., they are being recently studied for their applications in the field of super-capacitors as dielectrics. It is well known from the literature that the capacitance of a capacitor can be increased using a suitable dielectric material sandwiched between the capacitor plates. However, the dielectric materials are known to vary their dielectric constant with applied frequency as well as temperature [1, 2 & 3]. Literature reports that the dielectric constant of materials increases with temperature due to flexibility achieved by the materials at higher temperatures. Especially in polymers, at higher temperatures, due to larger flexible chains and lesser entangling of the chains, dielectric constant of the polymers is seen to be increasing with temperatures. In the present paper, we report the dielectric studies on Poly(Ethelyne Oxide) {PEO} with varying frequency and temperature.

2. Experimental:

PEO (1 x 10^5 g/mole) was procured from Sigma-Aldrich and used as obtained. Methanol was used as solvent for preparation of PEO pellets. A well known solution cast technique was used for the preparation of PEO pellets where in PEO was dissolved in methanol using continuous stirring for 4 – 6

hours in a magnetic stirrer. The gel formed after stirring was poured onto silver foil for drying of the solvent. The gel was allowed dry in vacuum for 8 – 12 hours for further removal of any solvent from the pellet [4, 5]. Thus a solvent free standing film of PEO was obtained which was used for dielectric measurements. The snap of a sample thus prepared is given in Figure 1.

Figure 1: Snap of a sample after being dried in vacuum chamber

Impedance spectroscopy was used for studying the impedance and hence the dielectric constant of PEO using CH Instruments. The dielectric constant of PEO was measured from 500 Hz to 1MHz at temperatures varying from 225 K to 315 K. The pellet was sandwiched between two blocking silver electrodes for impedance studies. Temperature of the sample was varied using a home built temperature variable cryostat which was controlled by a temperature controller programmed using Lab-View program. The setup used for the measurements is shown in Figure 2.

Figure 2: CH Instruments used for impedance measurements and cryostat setup used for placing the sample

PEO was subjected to powder X-ray diffraction analysis using XRD speectrometer between the 2θ range of 20 to 80 degrees to understand the crystalline nature of the polymer. The XRD spectra of the sample is given in Figure 3.

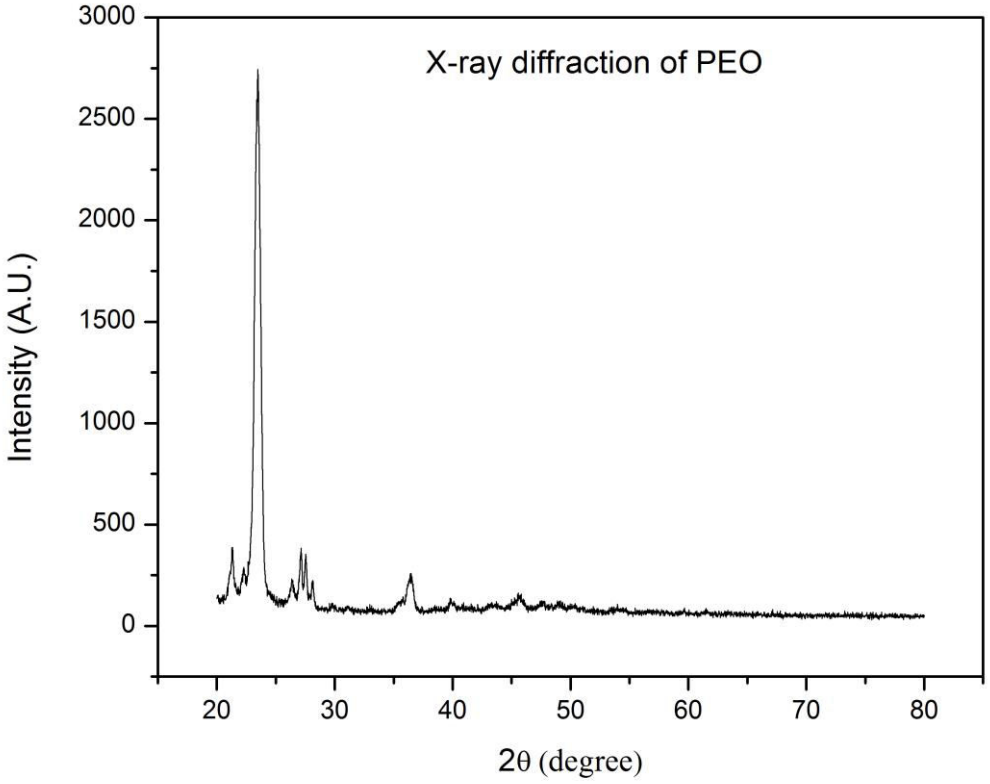

Figure 3: Room temperature X-ray diffraction spectra of PEO sample

3. Results and Discussion:

X-ray diffraction spectra of the polymer shows that the polymer is crystalline. The peaks at 22^o, 24^o 26^o and 36^o are well known peaks of the PEO. The snap of the PEO after drying it in vacuum chamber shows that the samples has good stability and can be used as a solvent free film in capacitors as dielectric material to enhance the capacitance of the capacitor.

It can be observed from Figure 4 that the dielectric constant of PEO varies with both frequency and temperature. A material shows dielectric constant due to the response of the dipoles in the material. Dipoles in the material will not be uniform and hence responds to various frequencies. Also, at different temperatures, due to the provided thermal energy, the dipoles' response to the applied signal will also vary. Dielectric constant of PEO is very low at high frequencies at almost all temperature. This may be due to non-responsive dipoles at high frequencies although thermal energy provided at higher temperatures makes them flexible [6, 7]. If the applied signal switches at a rate faster than the responding rate of a dipole, the dipoles stop responding and thus at very high frequencies, dielectric constant is almost negligibly varying. However at low frequencies, due to the response from various dipoles, the dielectric constant increases with temperature. In the present case of PEO, the dielectric constant increases from 1.4 to 2.4 with increase in temperature from 225K to 315K. This increase may be attributed to the flexibility provided by the thermal energy to the chains and hence increase in dielectric constant at higher temperatures.

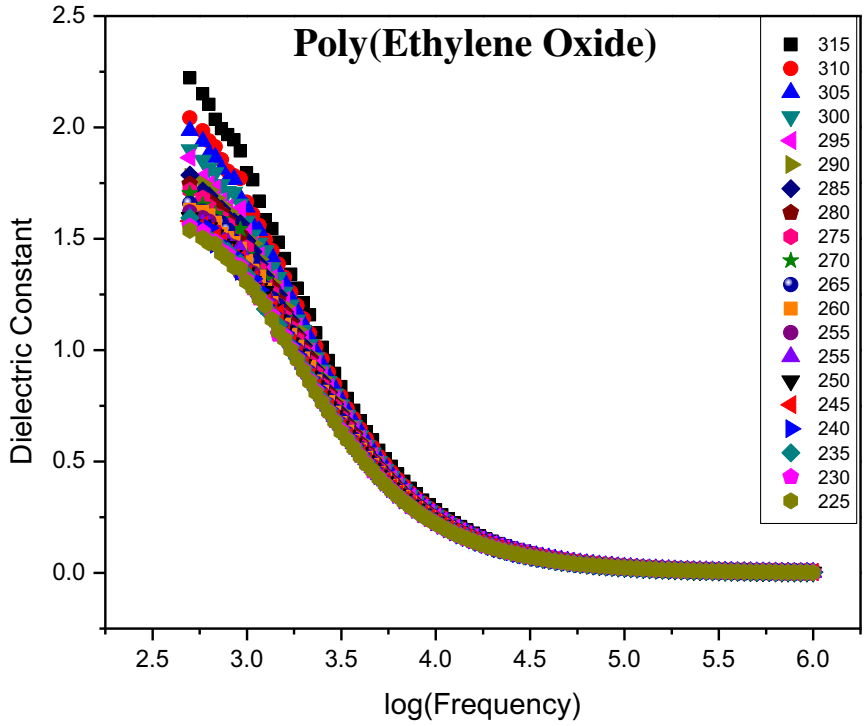

Figure 4. Dielectric constant of PEO with varying temperature and frequency of applied AC signal

4. Conclusion:

A preliminary study of dielectric measurements was carried out on PEO in the form of pellet using solution casting technique. Impedance spectroscopy studies were used to study the dielectric constant of PEO and were found to vary with frequency of the applied signal and temperature at which the sample was maintained. The increased dielectric constant of PEO at low frequencies may due to larger response from the dipoles in the material and much higher at high temperature which may be due to the flexibility provided to the chains of the polymer due to higher thermal energy. The study forms a basis for using the PEO as dielectric material for capacitors in increasing their charge holding capacity.

5. References:

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