COMPLEX IMPEDANCE SPECTROSCOPY OF EPOXY & POLYCARBONATES

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Abstract

Impedance spectroscopy is a powerful method for characterizing the electrical properties of materials and their interfaces. In this study impedance measurements were made over a wide range of frequencies to investigate the bulk resistance of the samples. An attempt is made here to study the conductivity of epoxy+7.5%polycarbonate, epoxy+10% polycarbonate, epoxy+12.5% polycarbonate using complex impedance spectroscopy.

1. Introduction

Complex impedance spectroscopy was first applied by Bauerle[1] to analyse the response of yttria doped zirconia to sinusoidal perturbations. Since then, this technique has been used for characterizing a wide range of materials which include polymers, oxides, glasses, fluorides etc. This technique has been instrumental in the development of both electrode and electrolyte materials for solid-state electrochemical devices. Several theories have been proposed to describe the complex impedance spectroscopy techniques [(2-7)]. Electrical characterization of any material was done by measuring ac conductivity at a frequency of 1 kHz. But his method was useful and effective only when the system was purely resistive. However, material electrode systems represent a cell assembly of complex impedance involving both resistance and capacitance in an unknown configuration. Not only the function between the electrode-electolyte, but also the interfaces between the grain boundaries within the electrolyte are more complex. Therefore, recent trends are emerging towards the study of frequency related phenomena through the impedance spectroscopy. As far as polymers are concerned; CIS studies have been reported for different polymer samples [8-12]. It was observed that in the crystalline phase, the polymer chains are rigid and thus the ion mobility is almost negligible and the overall conductivity is very low.

2. Sample preparation

The epoxy resin Araldite LY-556 and Hardener LY 051 and polycarbonate were used as the matrix components in the preparation of epoxyresin+polycarbonate (blend).The main feature of this epoxy system is its excellent mechanical and dynamic strength. Araldite LY 556 is a clear liquid with a viscosity in the range of 9000 to 12000mPa^2 at 25^{0}C. The epoxy in the resin varies between 5.2 and 5.45 equil/kg. It has a shelf life of 3 years if the product is stored in a dry place at a temperature range of 18-2525^{0}C.The polycarbonate has a self flow rate of 15 g/min. In order to make the blend the epoxy resin was added with poly carbonate dissolved in dichloro methane. The solvent was removed by degassing in vacuum for about one hour. To this, the harder was added in stoichiometric ratio. The thoroughly mixed mixtures with varying poly carbonate content was used as the matrix. The blend sheets were made by room temperature curing. To ensure complete curing, the blend sheets were post cured at 100^{0}C per 5 hours.

3. Experimental Procedure

The sample under study was placed in an electrically shielded conductivity cell which was connected to the inverting input of current to voltage converter. Measurements were made at room temperature. The sinusoidal signal V_i sin (ωt) from 8038-based signal generator was fed to sample via the voltage follower. The other end of the sample was connected to CVC. The voltage at the output of CVC becomes V_0 Sin (ωt + ø) where ø is the phase introduced by the sample. By measuring voltages at the output of CVC, gain was calculated. Here the phase angle (ø) was calibrated in terms of frequency at the output of VCO. By measuring gain and phase angle, impedance of the sample was calculated which was resolved into real and imaginary parts as $Z' = |Z| \cos ø$ & $Z'' = |Z| \sin ø$ Where $|Z| = R_f / A$. The real and imaginary impedances were evaluated as a function of frequency (10Hz – 100 KHz). The data collected was analyzed in the form of impedance plots. From the complex impedance plots, bulk resistances of the sample were obtained from the intercept on X-axis .

Finally ac conductivity was calculated using the relation

$\sigma = t/R^{*} a$

where'‘t’ is the sample thickness, ‘a’ is the area of cross-section of the sample and ‘R’ is the bulk resistance obtained from impedance plot.

4. Results

The real and imaginary parts of impedances were evaluated for epoxy, epoxy + 2.5% polycarbonate as a function of frequency. From the impedance plots shown in Fig.1, Fig.2 and Fig.3, conductivities measured for these samples are 1.27×10^{-11} $(\Omega\ Cm)^{-1}$, 2.65×10^{-11} $(\Omega\ Cm)^{-1}$, and $5.0010^{-11} (\Omega\ Cm)^{-1}$ respectively.

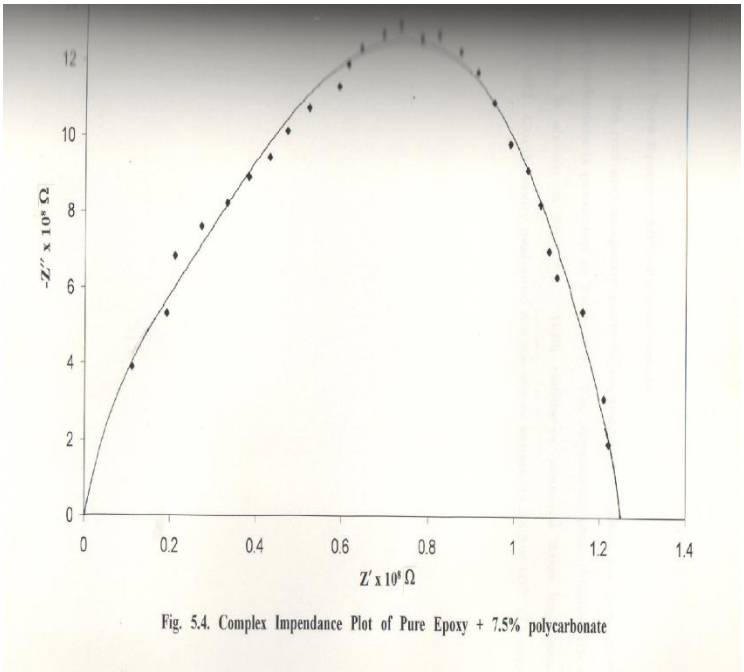

Fig. 5.4. Complex Impendance Plot of Pure Epoxy + 7.5% polycarbonate

Fig. 1

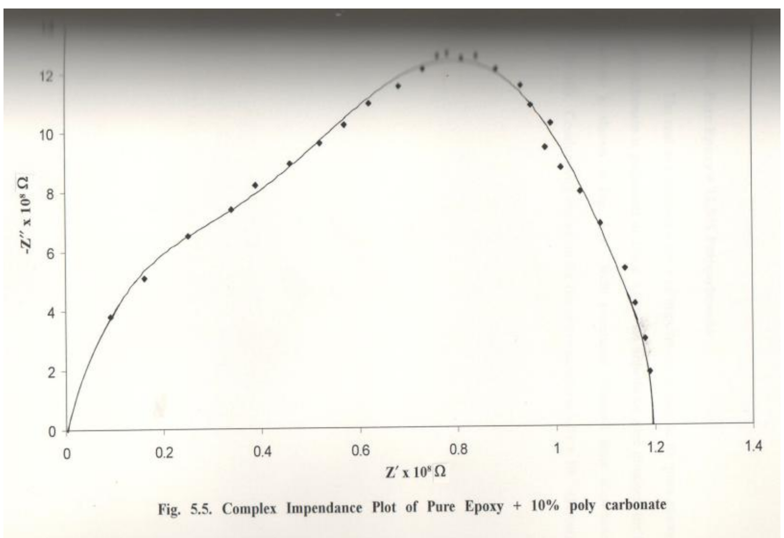

Fig. 5.5. Complex Impendance Plot of Pure Epoxy + 10% poly carbonate

Fig.2

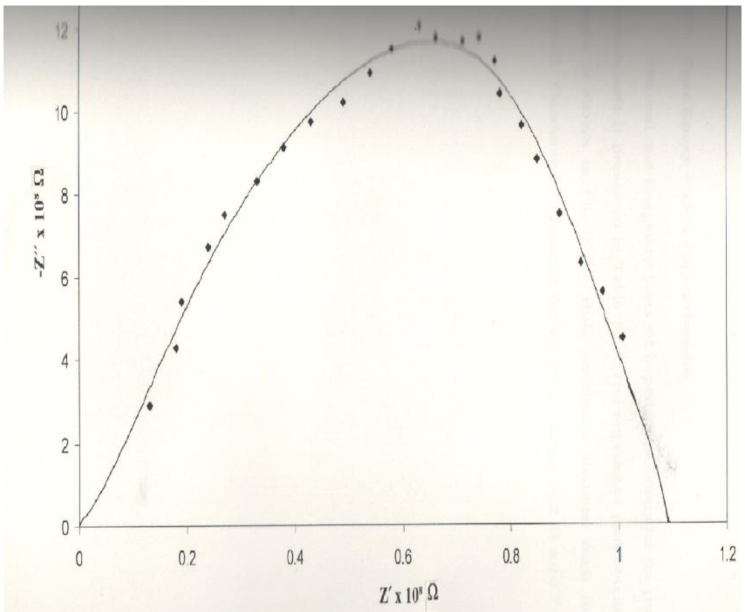

Fig. 5.6. Complex Impendance Plot of Pure Epoxy + 12.5% polycarbonate

Fig.3

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