

Research Article

Influence of TiO₂ Nanofiller on Dielectric Studies of (1-X) PVP: X (CH₃COOK) Polymer Electrolyte Films

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Abstract

Nanocomposite solid polymer electrolyte films were prepared by doping TiO₂ nanofiller with different wt% compositions of PVP-CH₃COOK by solution cast technique. Dielectric studies were performed on the nanocomposite polymer films at room temperature by using HIOKI 3532-50 LCR Heister in the frequency ranging between 5000 Hz and 50000 KHz to find the best optimum conductivity and electric relaxation process of the samples.

Keywords: Polymer electrolytes, TiO₂ Nanofiller, Solution cast technique and Dielectric studies

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Introduction

Over a past few decades an attractive attention has been made towards nanocomposite materials due to their low production cost and excellent structural, electrical, thermal and magnetic properties [1-3]. Nanocomposite polymer films are expected to exhibit a major change in wide range of technological applications and industrial fields such as conductive coating, sensors, microwave absorbing and energy storage devices etc. The first report on polymer electrolyte material has been given by Wright and Armand in 1970s which has taken a growth step towards new area of research called polymer electrolytes and focus has been made on the non-volatile memory applications due to its potential behavior [4, 5]. Nanocomposite polymer films are prepared by compounding the polymer with conductive nanoparticles like SiO₂, TiO₂, ZrO₂, Al₂O₃ and also some plasticizers like ethylene carbonate (EC) and propylene carbonate (PC) [6, 7]. The content of conductive nanoparticle reaches to a critical value a continuous electrical conductive network is formed rendering the polymer composite electrically conductive [8, 9].

Polyvinyl pyrrolidone (PVP) polymer has shown a drastic change in both the academic and industrial world ever since it comes to experimental existence [10, 11]. Polyvinyl pyrrolidone has excellent physical and mechanical properties such as high thermal conductivity, good mechanical strength, high specific surface area and high mobility of charge carriers [12]. Polyvinyl pyrrolidone is also used in many applications such as batteries, solar cells, fuel cells and super capacitors [13, 14]. Inorganic salt like potassium acetate is used as dopant material to the host polymer in order to enhance the ionic conductivity. TiO₂ is used as nanofiller in the preparation of films to improve the mechanical integrity and softness of the films. Rao et al. presented their results in their earlier studies [15-51]. In the present investigation, nanocomposite polymer films were prepared by dispersing TiO₂ nanoparticles with [PVP: CH₃COOK] polymers to improve the dielectric properties of the prepared nanocomposite films.

Experimental

PVP with average molecular weight (M.W: 36,000), potassium acetate (CH₃COOK) 98% pure and titanium oxide (TiO₂) were purchased from Sigma Aldrich chemicals, India. All the samples were taken in different wt% ratios. The triple distilled water was used as a solvent. The above mentioned chemicals were placed in a conical flask and kept at continuous stirring for 24 Hrs for complete dissolution. Later TiO₂ (x = 1%) was added to get a fine dispersion in the composite polymer solution. The solution was poured in polypropylene petridishes and kept in hot air oven at 60 °C for 48 hrs to remove the moisture traces on the prepared films. The obtained nanocomposite films were placed in a desiccator until further characterization. A set of nanocomposite polymer electrolyte films were prepared with different wt% ratios visually [PVP: CH₃COOK:TiO₂]- (90:10:1%), (80:20:1%), (70:30:1%) and (60:40:1%).

Results and Discussion

Dielectric Properties

Figure 1 shows that the value of ϵ' is continuously decreasing with increasing frequency for a particular time of interval and becomes stabilized due to polarization phenomenon [52]. From the Figure 1 it is clearly observed that as increasing the frequency the dielectric constant values gradually decrease, but the dielectric constant value is found to be high for the sample 60PVP:40CH₃COOK:TiO₂ (1 wt %), due to the formation of space charge region at the electrode -electrolyte interfaces. This also concludes that the salt is completely soluble in the polymer matrix and the doped nanofiller are completely dispersed in the polymer chains giving raise to mobilization of ions in the polymer matrix. This could be due to the enhancement of electric conductivity.

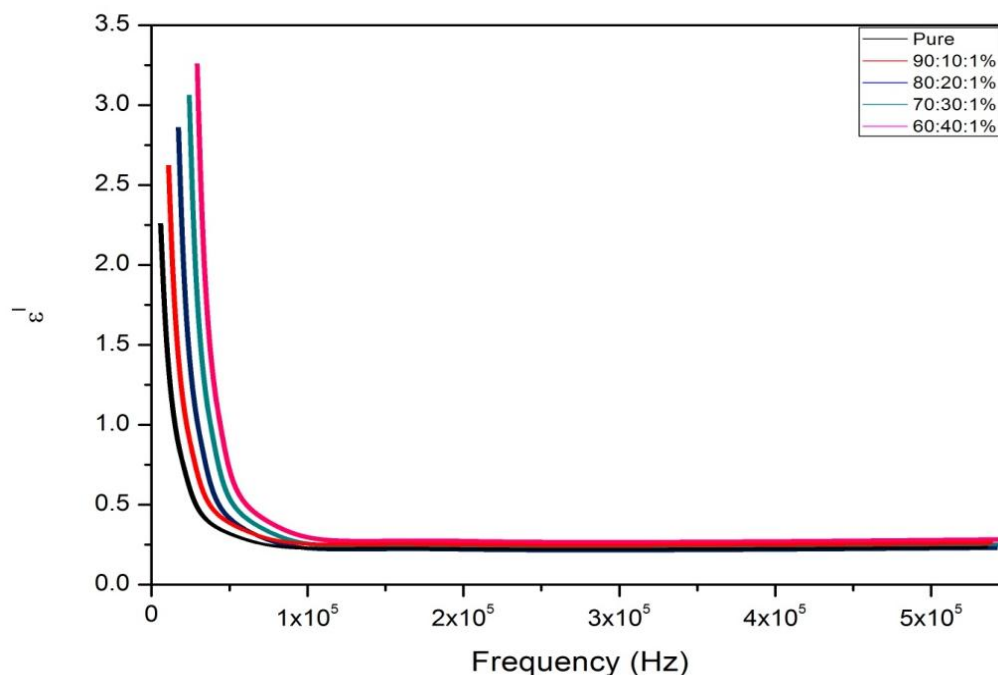


Figure 1 Variation of the real part of dielectric constant with frequency for different wt% ratios

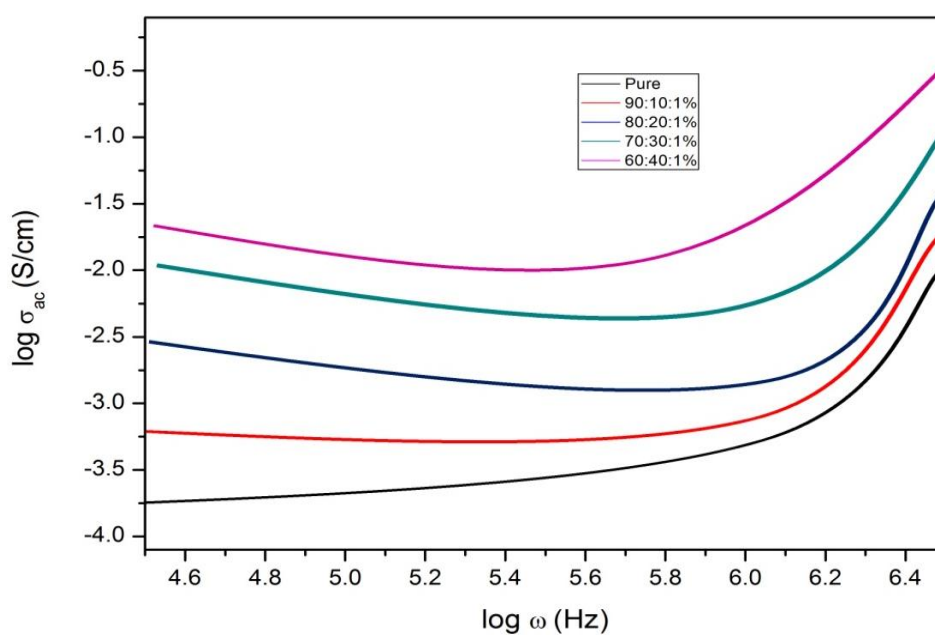


Figure 2 Variation of $\log \omega$ with logarithmic conductivity for different wt% ratios

A graph has been drawn between the logarithmic angular frequency with respect to the logarithmic conductivity is shown in **Figure 2**. From the Figure 2 it is clearly observed that oriental source of polarizability increased, when

the logarithmic angular frequency is increased and also observed that the effective polarization is high for the sample 60PVP:40 CH₃COOK: TiO₂ (1 wt %). This may be due to the transfer of mobile ions which cause a constant value of dielectric constant [53].

The variation of tangent loss (δ) with respect to logarithmic angular frequency (ω) for different wt% ratios of the polymer electrolyte samples have shown in **Figure 3**. The decrease in the tangent loss results with increase in the log frequency. This may be due to the reduced proportion of amorphous material leading to reduction in the magnitude of dispersion. The appearance of peaks suggests the presence of relaxing dipoles in the samples and also with electrical relaxation process or inability of dipoles [54].

Variation of temperature with $\tan \delta$ for different wt% ratios of polymer electrolytes is shown in **Figure 4**. The dielectric constant of composite electrolytes increases apparently with the increase of temperature. The increment in dielectric constant peak is observed as increasing the temperature. This change may cause due to the ionic jump orientation, space charge polarization and electronic contribution of K⁺ ions [55-57].

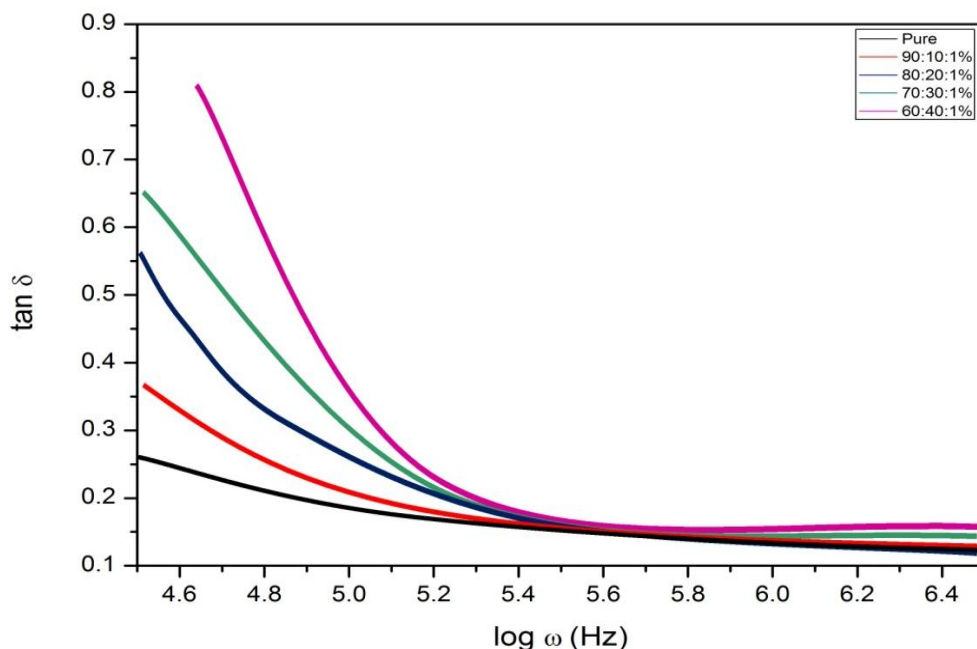


Figure 3 Variation of tangent loss vs logarithmic angular frequency for various wt% ratios

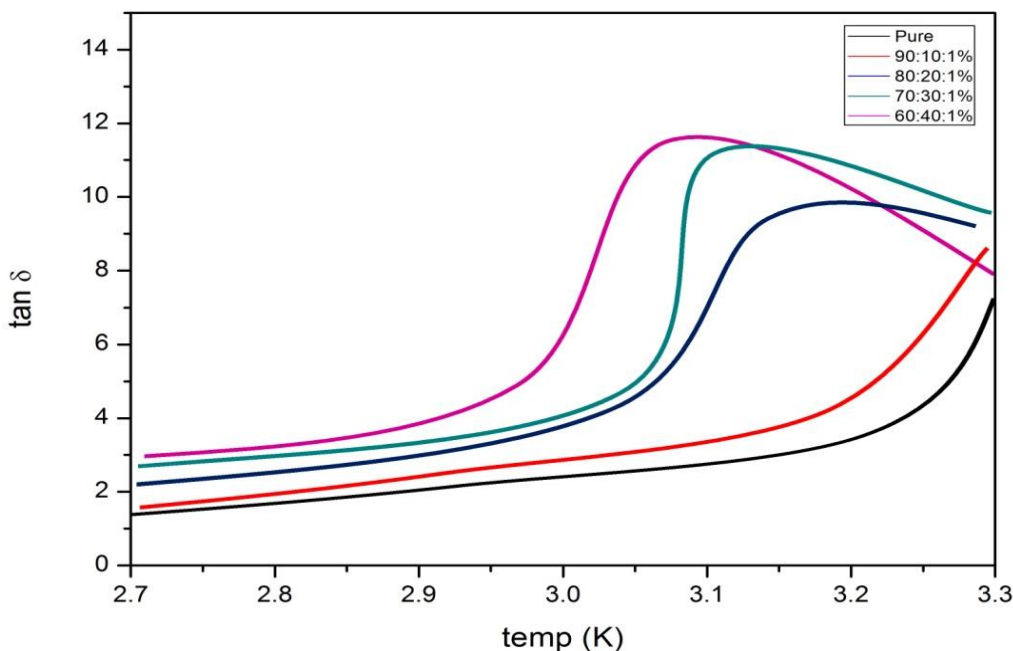


Figure 4 Variation of temperature with $\tan \delta$ for different wt% ratios at 303 K

Conclusion

Nanocomposite polymer films have been prepared with different wt% ratios by doping TiO₂ nanofiller to PVP: CH₃COOK by solution cast technique. Dielectric studies were performed on the prepared nanocomposite polymer films at room temperature and found that the best optimum conductivity and electric relaxation process exist for the composition 60PVP:40 CH₃COOK: TiO₂ (1 wt %).

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