Structural, Electrical and Dielectric Study of Polyvinyl Pyrrolidone Polymer (PVP)Blends with PVDF, PVA and $ZnSO_4$Heptahydrate for Optoelectronic Devices

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Abstract

Polyvinyl pyrrolidone polymer (PVP) is an attractive polymer for energy storage devices and optoelectronics devices with its amorphous nature and high molecular weight. In the present paper, we have synthesized (PVP+PVDF+$ZnSO_4$) and (PVP+PVA+$ZnSO_4$). The prepared samples have been characterized by XRD and FESEM for structural and morphology analysis. Impedance spectroscopy has been used for electrical and dielectric study of samples. The frequency dependency of electrical conductivity and dielectric constant of prepared samples have been studied in the range of 1 Hz to 20 MHz by impedance analyser. Step up function properties have been found by the graphical analysis between AC Voltage and AC Current which suggested that these blending of PVP are useful for optoelectronics devices.

Keywords :Polymer, Optoelectronics, Impedance Spectroscopy, Polymer blending, PVP, PVDF

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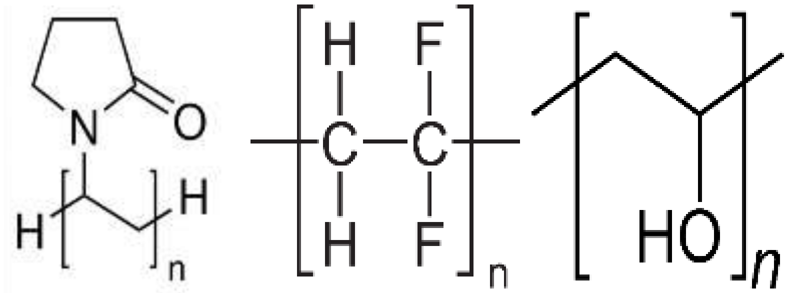
1. Introduction

Nowadays, electroactive polymers are more popular fortheir electrical,dielectric and optoelectrical properties [1-2]. Polymer materials have some attractive features like environmental friendly, flexibility, low cost, thermal stability etc. due to these specific features we found that, electroactive polymers like Polyvinyl Pyrrolidone **(**PVP), poly (vinylidene fluoride) (PVDF), Poly (vinylidene fluoride-Hexafluoropropylene) (PVDF-HFP), Polypyrrole, polyvinyl, polythiophenes etc. have good potential for different applications such as electrochemical devices, energy storage devices as a rechargeable batteries, solar cells, super capacitor, sensor, optoelectronic devices [3-7]. Polymers are long- chain molecules in which a unique or various chemical motives repeat along the chain. Polymers with enhanced conductive properties can be obtained by designing synthesis methods of conjugated structures. A large number of conducting polymers have been synthesized with wide range of specific electrical conductivities[8-10].

In the present study, we have investigated structural, electrical and dielectric properties of PVP with blending of PVDF and PVA. $ZnSO_4$ is used as a salt during preparing the samples. Chemical structures of used polymers are as below



PVP PVDF PVA

2. Experimental Procedure

The Samples have been synthesized by solution casting technique. PVP (Sigma Aldric, M.W.=10000), PVDF (Sigma Aldric, M.W.=53000), PVA (Sigma Aldric, M.W.= 30000) and $ZnSO_4$ heptahydrate have used for material synthesis. DMF has used as a solvent. Two compositions of PVP have prepared one with PVDF and second with PVA. **Table 1** is showing the sample compositions with molecular weight percentage. For sample S-1 and S-2 materials dissolved in DMF and used magnetic stirrer for 20 hours at 500 rpm to get homogeneous solution. Solution poured in the petri dish and put in the microwave oven for dry at 50 ^{0}C for 72 hours.

Table 1: - Sample Compositions of PVP with PVDF and PVA

Sample No.	Polymer-1	Polymer-2	Salt	Sample Composition with weight percentage
S-1	PVP	PVDF	$ZnSo_4$	[(70PVP:30PVDF):30 $ZnSo_4$]
S-2	PVP	PVA	$ZnsO_4$	[(70PVP:30PVA):30 $ZnSo_4$]

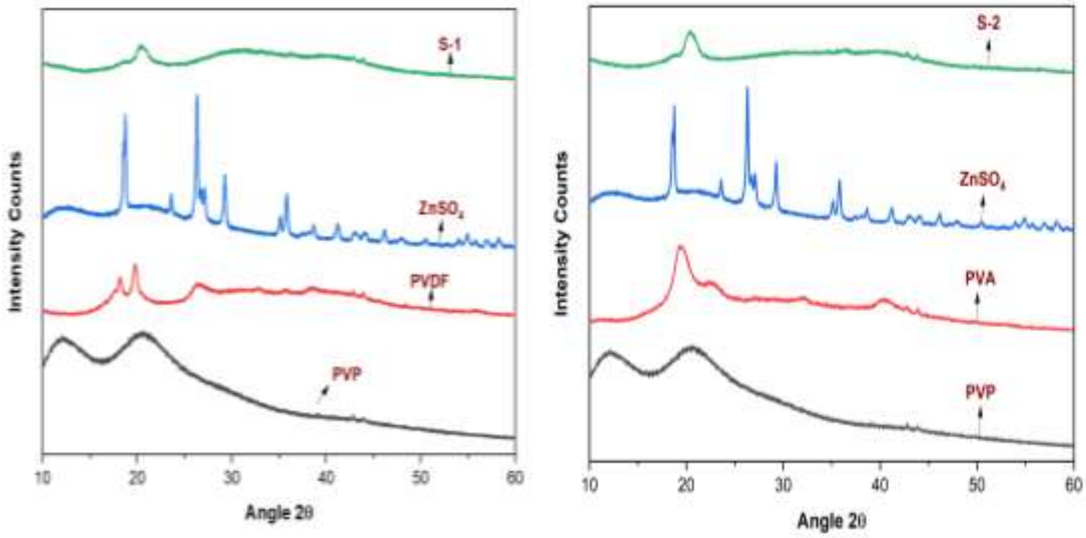
3. Results and Discussion

3.1. XRD Analysis

The X-ray diffraction pattern of the samples S-1and S-2 are shown in **figure 1(a)** and **1(b)** respectively. XRD patterns revealed that the intense peak of sample S-1(PVP+PVDF+$ZnSO_4$) and S-2 (PVP+PVA+$ZnSO_4$) found at 20.5^0 angle. The particle size was determined by Scherrer's formula using strongest peaks [11]

$$t = \frac{0.89\lambda}{\beta\cos\theta} \text{..........} \quad (1)$$

Where β is Full wave half maximum (FWHM) taking into account instrumental broadening λ=1.54 A^0 is the wavelength of X-rays and θ is Bragg's angle. The particle size for sample S-1 was found 26.2nm while particle size for S-2 was found 22.1 nm.

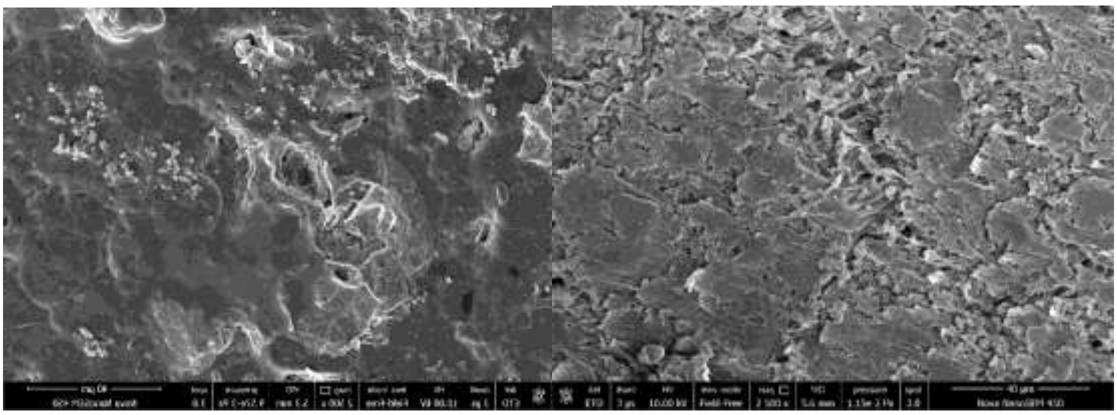


(1a) (1b)

Figure1: XRD patterns (1a) and(1b) for S-1 and S-2 respectively

3.2. FESEM Images

Surface morphology has been investigated by using field emission scanning electron microscopy (FESEM) measurements. The characteristics FESEM images **2(a)** and **2(b**) of sample S-1 ($PVP+PVDF+ZnSO_4$) and Sample S-2($PVP+PVA+ZnSO_4$)respectively have been captured with 40 µm resolution. The blending of PVP with PVA and $ZnSO_4$ is showing good morphological texture in comparison to blending of PVP with PVDF and $ZnSO_4$.



2(a) 2(b)

Figure 2: FESEM Image 2(a) and 2(b) for S-1 and S-2 respectively

3.3. Dielectric Properties

The dielectric properties of sample S-1 and S-2 were studied in the frequency range 40 Hz to 20 MHz

$$\varepsilon r = \frac{Cd}{\varepsilon 0 A} \text{------- (2)}$$

Where $\varepsilon_r$is the dielectric permittivity, Cis the capacitance, d is the thickness of prepared sample pallets, A is the area of cross section of sample pallets and ε_0 = 8.85×10^{-12} F/m is the absolute permittivity [12-13].

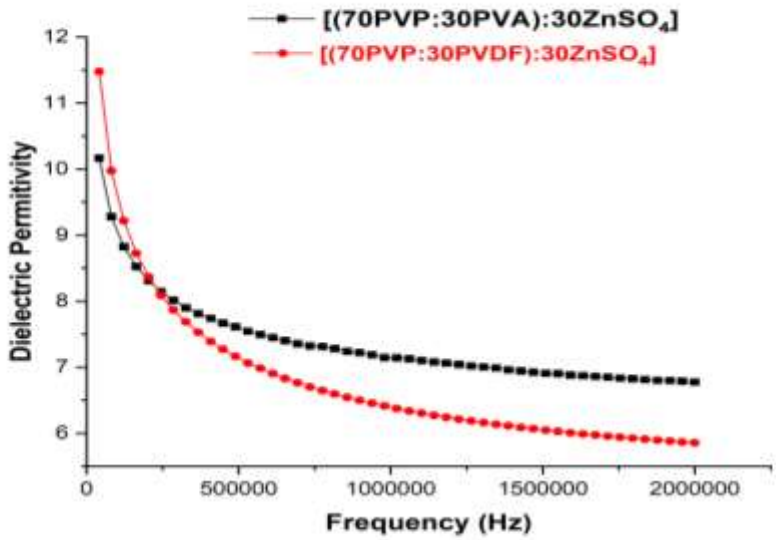


Figure 3: Frequency vsDielectric permittivity of Sample S-1 and S-2

The **figure-3** is showing the variation of dielectric permittivity with frequency. The dielectric permittivity values are higher in lower frequency range for both the samples S-1 and S-2 but dielectric permittivity gradually decreases as frequency goes to higher order up to 20 MHz. It is clear from figure 3 that the samples S-1 (PVP+PVDF+$ZnSO_4$) has higher value of dielectricpermittivity in the low frequency region with compared to sample S-2 (PVP+PVA+$ZnSO_4$) in the higher frequency region dielectric permittivity of PVP with PVDF (sample S-1) decreases much sharply compared to PVP with PVA(sample S-2).

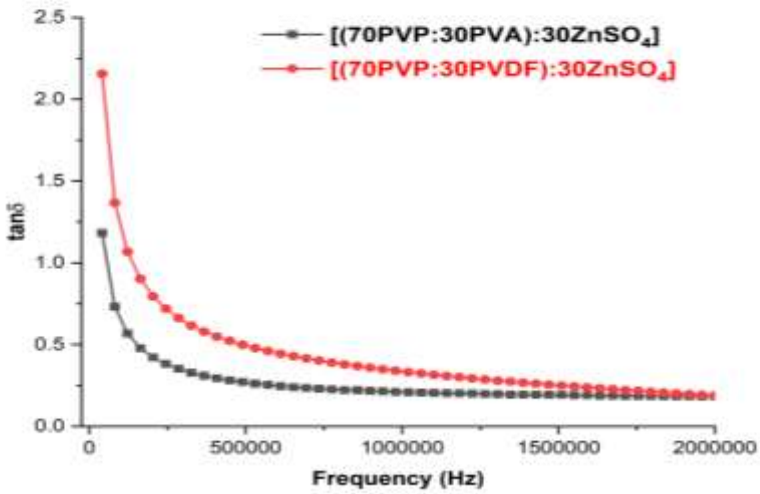


Figure 4: loss tangent (tanδ) as a function of frequency of Samples S-1 and S-2

The loss tangent (tanδ)of PVP with PVDF and PVA have been studied as a function of frequency. The **figure 4** showing that the loss tangent has higher values with low frequency and gradually decreases upto 15 MHz. At 20 MHz frequency loss tangent of both samples S-1 and S-2 reached at same stage.

3.4. Electrical Properties

3.4(a) A.C. Conductivity and Resistance

The a. c. conductivity of the prepared combinations of PVP with PVDF and PVA can be calculated using loss tangent tanδ formula [14]

$\sigma_{a.c.} = 2\pi f \varepsilon_0 \varepsilon_r \tan\delta$ …………. (3)
Where f represents the applied frequency.

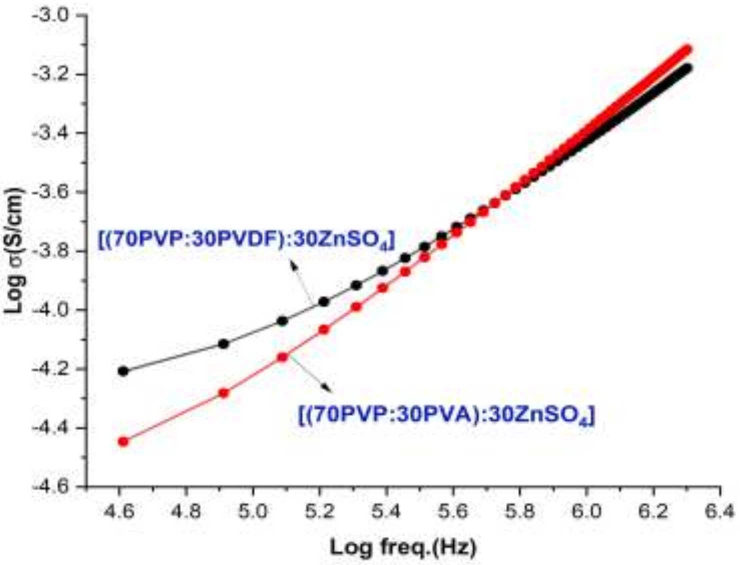
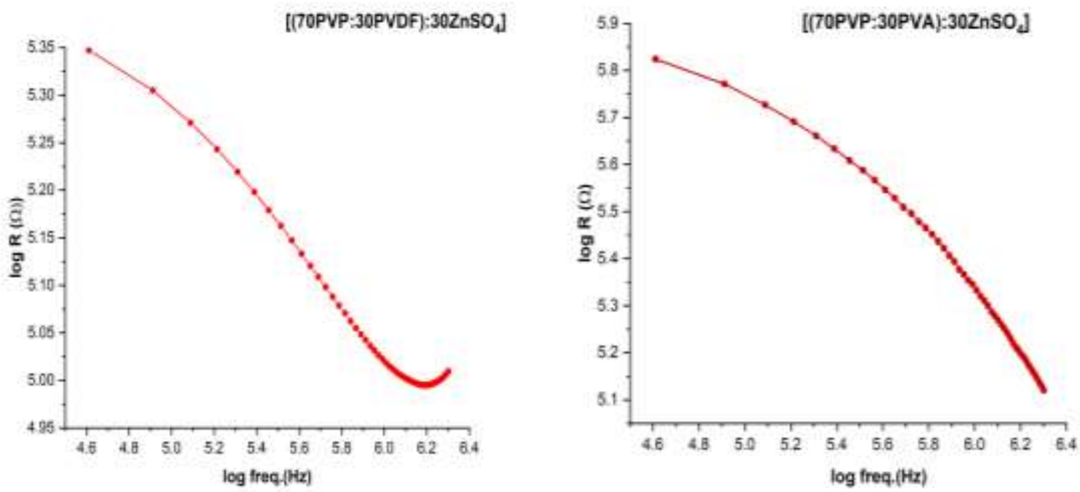


Figure 5:A.C. Conductivity of S-1(PVP+PVDF+$ZnSO_4$) and S-2 (PVP+PVA+$ZnSO_4$) as afunction of log of frequency.

The variation of a.c. conductivity of S-1(PVP+PVDF+$ZnSO_4$) and S-2 (PVP+PVA+$ZnSO_4$) have investigatedwith a log of frequency shown in figure 5. A.C. conductivitiesas a function oflog$_{10}$(frequency) for both of combinations gradually increased as frequency increases. The variations of resistance also studied with frequency as a function of log$_{10}$(frequency);the results are plotted in **figure 6(a)** and **6(b)** which shows that the resistance of sample S-1(PVP+PVDF+$ZnSO_4$)decreased as frequency increased but after a certain value of frequency further increased resistance raise upto 20MHz frequency. But in case of S-2 (PVP+PVA+$ZnSO_4$)the resistance continuously decreased upto 20MHz frequency.



(a) **(b)**

Figure 6(a) and 6(b):A.C. Conductivity of S-1(PVP+PVDF+$ZnSO_4$) and S-2 (PVP+PVA+$ZnSO_4$) as a function of log of frequency.

3.4(b) Step up Function A.C. Voltage vs A.C. Current

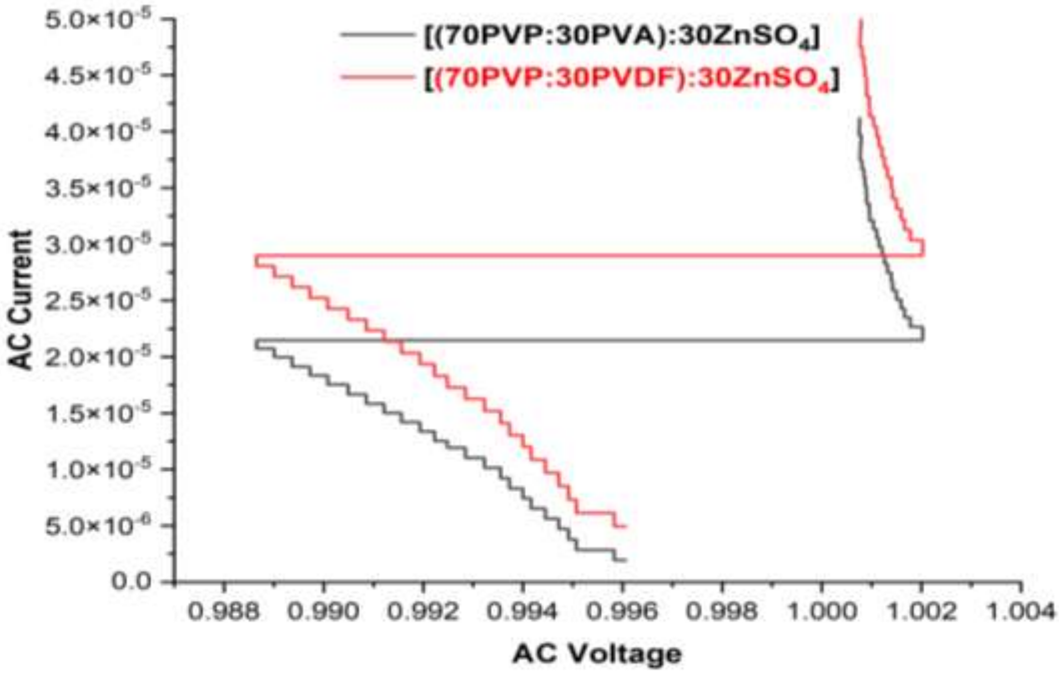


Figure 5:A.C. voltage vs A.C. Current forSample S-1and S-2.

The study of variation between a.c. voltage and a.c. current showing step up function properties for both combination of PVP. The step-up function properties are important for optoelectronic devices [15].The sample of S-1(PVP+PVDF+$ZnSO_4$) is showing little higher values of a.c. currentin the variation with a.c. voltage in **figure 5**.

4: Conclusion

Our results show that the blending of PVP with PVDF and PVA have good potential for optoelectronic devices. The step-up function properties of PVP+PVDF+$ZnSO_4$ shows better results in comparison to PVP+PVA+$ZnSO_4$, similarly dielectric permittivity of PVP+PVDF+$ZnSO_4$ also higher in low frequency range. A.C. conductivity of PVP with PVDF and PVA show frequency dependency, in the low frequency region both combination of PVP show similar decreasing in the a.c. conductivity but at a certain value higherfrequency PVP+PVDF+$ZnSO_4$a.c. conductivity again increased. FESEM results shows that morphology texture of PVP+PVA+$ZnSO_4$is slightly better.

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