

# Studies on Conducting PVP Polymer Composites for AC Conduction

Ritu Tomar<sup>1</sup> and Dr. Chirag R Sharma<sup>2</sup>

<sup>1</sup> Sambhram Institute of Technology,  
Nitte Research and Education Academy  
Bangalore, India.

<sup>2</sup> Department of Electronics, Nitte Research and Education Academy,  
Bangalore, India.

**Abstract**— In this study the polymer composite specimen has been prepared by using polymer polyvinyl- pyrrolidone (PVP) and potassium iodide (KI) using double distilled water as the solvent. The main objective of the present work is to study microstructure, conductivity of the composite specimen for 10 to 40% KI and estimate its responses with AC conductivity to determine dielectric constant, dissipation factor and impedance responses.

**Index Terms**—AC conductivity, dielectric constant, Polymer Composite

## I. INTRODUCTION

Polymer electrolytes represent the newest class of solid state ionic conductors. They contrast sharply with the usual solid ionic materials based on ceramics, glasses, or inorganic compounds with respect to the mode of charge transport (polymer electrolytes only conduct well above their glass transition temperatures) and the value of the ionic conductivity, which is of the order of 100 to 1000 times lower than for the inorganic materials. This drawback is compensated primarily by the greater flexibility of the polymeric materials which allows polymer electrolytes to be made into very thin films of large surface areas to maintain high power levels.

Although conductivity of the order of  $10^{-5}$  S/cm may be obtained for a number of polymer electrolytes at various temperatures, this is not as high as may be desired. Polymer electrolytes therefore have to be configured as very thin, large-area elements, in order to keep the internal resistance of the cell within an acceptable range. A solid state polymer electrolyte (SPE) for dye sensitized solar cell applications must possess the following attributes:

1. It is an ion (usually cation) carrier that can be fabricated as thin films to improve the energy density.

2. It acts as an electrode spacer, which eliminates the need to incorporate an inert porous battery separator.
3. It is a binder, which ensures good electrical contact with the electrodes at all times during charging and discharging.[1-14]

## II. II SELECTION OF MATERIALS

### POTASSIUM IODIDE (KI)

Potassium iodide is ionic KI. It crystallizes in the sodium chloride structure. It is produced industrially by treating KOH with iodine.

A white crystalline solid, with a strong bitter taste, soluble in water, ethanol, and acetone. In fig 4.4 and 4.5 shows the potassium salt and structure of KI. It may be prepared by the reaction of iodine with hot potassium hydroxide solution followed by separation from the iodate by fractional crystallization. In solution it has the interesting property of dissolving iodine to form the tri iodide ion which is brown. Potassium iodide is widely used as an analytical reagent and also as an additive to table salt to prevent disorders due to iodine deficiency.

### POLYVINYLPIRROLIDONE (PVP)

Polyvinylpyrrolidone (PVP) has drawn a special attention amongst the conjugated polymers because of its good environmental stability. PVP is a potential material having a good charge storage capacity and dopant dependent electrical and optical properties. Chemically PVP has been found to be inert, nontoxic and it displays a strong tendency for complex formation with a wide variety of smaller molecules.

Polyvinylpyrrolidone (PVP), also commonly called Polyvidone or Povidone, is a water-soluble polymer made from the monomer N-vinylpyrrolidone. PVP is soluble in water and other polar solvents. When dry it is a light flaky hygroscopic powder, readily absorbing up to 40% of its weight in atmospheric water. In solution, it has excellent wetting properties and readily forms films.

### III. SYNTHESIS BY SOLUTION CASTING METHOD

It is a simple and most commonly used method. By this method polymer thin films of varying thickness can be prepared. Generally, this method includes the following steps:

- (a) Polymer is dissolved in the solvent and allowed to be dissolve,
- (b) Appropriate amount of salt is added to that polymer solution,
- (c) Mixing by means of magnetic-stirrer for complexation,
- (d) Casting the mixture on a glass plate/Petridish/substrate,
- (e) Lastly drying in vacuum or in an inert atmosphere.

0.5 g amount of polymer host, Poly(vinylpyrrolidone) (PVP) was taken in a conical flask and 2 ml Triple distilled water is added to the polymer. After dissolving the polymer in the water medium, appropriate amount of salt, sodium iodide (KI) was added in that solution. Then the solution was stirred for 4 hours by means of magnetic-stirrer. Free standing thin films of solid polymer electrolyte (SPE) were obtained. For casting of Composite Polymer Electrolyte (CPE) films, micro/nano sized filler particles are added to mixed (PVP + KI) solution during Stirring. Then the solution was stirred for 2 hour by means of magnetic-stirrer. The obtained solution was then casted on separate petridish and allowed to evaporate slowly at room temperature.

The process is repeated for different % of potassium iodide. (10%, 20%, 30%, 40%).

### IV. EXPERIMENTAION

#### XRD analysis

##### XRD analysis of PVP

XRD pattern of PVP as shown in fig 1 shows that there are broad peaks which is because of the amorphous nature of PVP. There are no sharp peaks in PVP which implies light intensity diffraction is less. Broad peaks are found at 25 degree & 72 degree respectively.

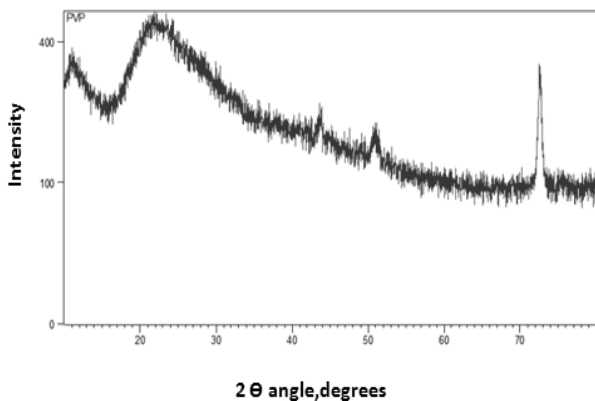


Fig 1 XRD of PVP

##### XRD analysis of KI

XRD pattern of salts shows that there are narrow peaks which is because of the crystalline nature. There are steep increases in salts, for KI the peaks are at regular intervals of 25 degree of 2 theta angle as shown in fig 2

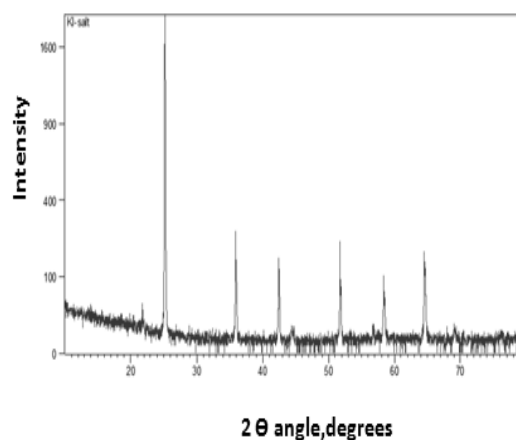


Fig 2 XRD of KI

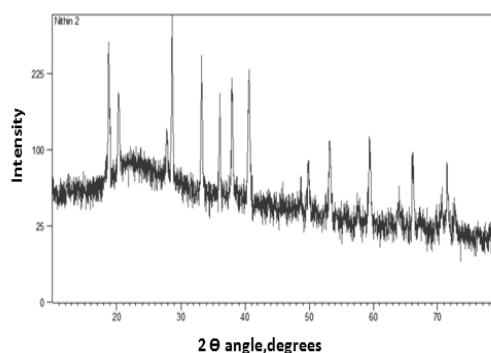


Fig 3 XRD of PVP+KI

#### Conductivity studies

To measure the AC response, samples were prepared by solution cast method and then applying conducting silver paste to form the electrodes in contact with the two circular faces. The AC parameters were measured at room temperature using Hioki (Japan) LCR meter at the selected frequencies in the range from 50 Hz to 5 MHz. The sample was then held between two nominally spring loaded copper plates and experiment is carried out.

Using the values of the equivalent parallel capacitance,  $C_p$ , dissipation factor,  $D$ , and parallel equivalent resistance,  $R_p$ , recorded by the LCR meter at a selected frequency,  $f$ , dielectric and conductivity parameters have been calculated using the equations given below

$$\begin{aligned} \epsilon'' &= \epsilon' / \omega C_p R_p = \epsilon' D & (a) \\ \sigma'(\omega) &= \omega \epsilon_0 \epsilon'' & (b) \\ \sigma''(\omega) &= \omega \epsilon_0 \epsilon' & (c) \\ \epsilon' &= C_p / C_0 & (d) \end{aligned}$$

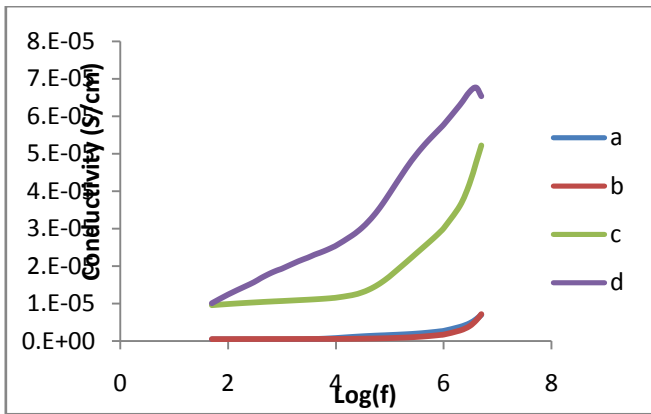


Fig 4 Log(f) versus AC Conductivity

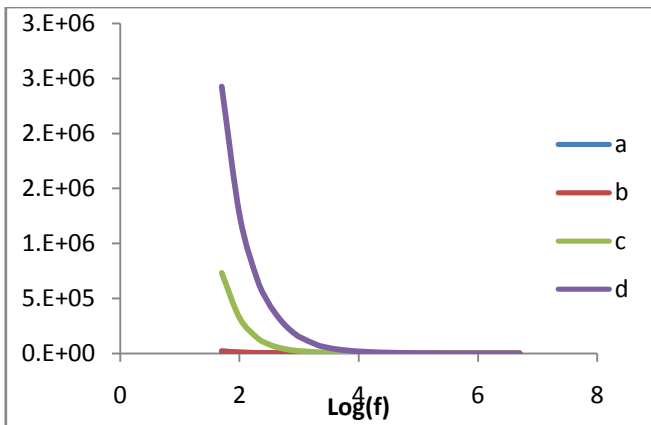


Fig 5 Log(f) versus dielectric constant

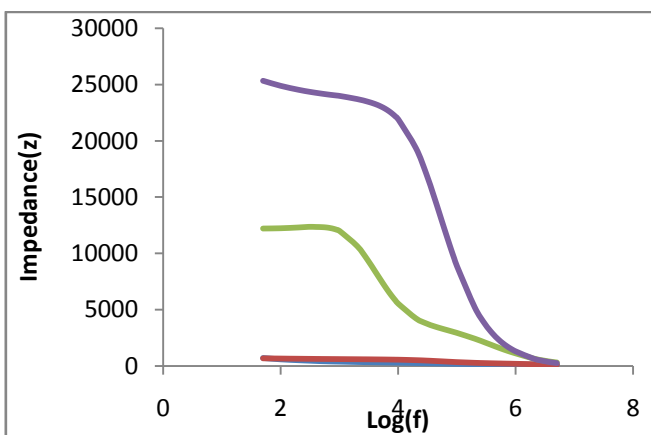


Fig 6 Log(f) versus Impedance

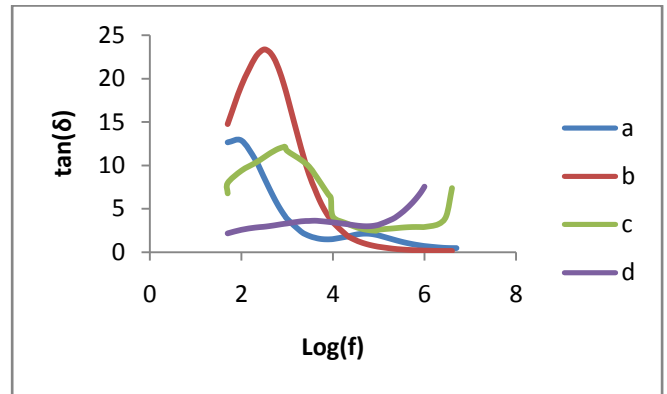


Fig 7 Log(f) versus dissipation factor

The variation of  $\sigma'(f)$  for PVP/KI polymer composites with frequency is shown in Fig.4. The  $\sigma'(f)$  is almost constant over the low frequency range from 50 Hz to critical frequency,  $f_c$  and then, increases with frequency above  $f_c$ , in agreement with Eqs. (e) and (f).

The real part of conductivity,  $\sigma'(f)$ , shows the features of AC conductivity in disordered materials with two regimes separated by a critical frequency,  $f_c = \omega c / 2\pi$ . At low frequency,  $\sigma'(f)$  is nearly constant, corresponding to DC conductivity,  $\sigma(0)$  such that

$$\sigma'(f) \approx \sigma(0), f \leq f_c \tag{e}$$

At higher frequencies,  $\sigma'(\omega)$  increases with frequency and its frequency dependence, according to the hopping model of charge transport in disordered materials, can be approximated by a power law given by

$$\sigma'(f) \text{ is proportional to } f^s, f \geq f_c, \text{ with } 0 < s < 1 \tag{f}$$

$f_c$  is a material parameter, which depends upon many factors such as method of synthesis, microstructure formation, composition.

Fig 5 show the dielectric properties are higher at higher frequencies for 10 to 40 % of KI from a to d curves form fig 6 and fig 7 it observed the impedance and dissipation factor are higher at low frequencies behaving like DC conduction and are lower at higher frequencies for 10 to 40 % of KI from a to d curves.

### V. CONCLUSIONS

PVP is suitable as solid polymer electrolyte with good ionic conductivity AC conductivity studies implied that with increase in frequency electrical conductivity increases to a certain level & then comes to a saturation upto a certain frequency. X-ray diffraction (XRD) studies implied the higher degree of amorphous nature of the polymer electrolytes by reducing the intensity of characteristic peaks.

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**First Author: Mrs Ritu Tomar** is working as Faculty of Engineering Physics in Sambhram Institute of Technology and Research Scholar at Nitte Research and Education Academy, Bangalore. She has published research paper in national and international Journals and Conferences

**Second Author: Dr Chirag R Sharma** had obtained Ph.D and MS degree from University of Utah, USA and Presently working as Professor of Electronics at Nitte Research and Education Academy, Bangalore. Several research papers has been published in national and international Journals and Conferences. He is presently guiding research students and 2 patents.