International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Study of Microwave Dielectric Properties of $FeCl_3$-doped Polyvinyl Acetate Based Thin Films

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Doi: https://doi.org/10.55248/gengpi.4.1223.123449

A B S T R A C T

Polyvinyl acetate films doped with Ferric chloride (FeCl3) have been prepared by sudden quenching technique from their aqueous solutions. In this paper, dielectric constant, dielectric loss and loss tangent of undoped and FeCl3 - doped poly vinyl acetate films of different thicknesses have been studied at 9.1 GHz microware frequency. The change in the dielectric constant and loss was observed with doping % of FeCl3. The maximum dielectric constant, dielectric loss and loss tangent was found at 1.96, 0.53, 0.27 FeCl3 mol.% resp. The variation of dielectric constant, dielectric loss and loss tangent showed an increasing trend with increasing dopant concentration. It has been concluded that, the dielectric constant, dielectric loss and loss tangent depend on dopant concentration.

Keywords: Microwave bench; Poly vinyl acetate; Fe – doping effect; Dielectric response.

1. Introduction

In the recent years, conjugated polymers have been the main focus of research throughout the world [1,2]. They have very diverse structure and applications ranging from domestic articles to sophisticated scientific and medical instruments. The modern era can definitely be called a polymer era as we wear these manmade materials sleep between them, build houses, pull switches, with their help. We can see and hear the sights remote from us. This polymers made revolutionary advancement in the field of medicine, with their help cripples could walk heart valves can be repaired and damage human organs could be replaced.

Now a day through proper selection of monomers and their combinations, catalysts and other additives and adopting appropriate polymerization conditions and techniques, experts are able to construct polymers molecules of almost any desired size, shape, complexity and of any desired chemical structure suited to almost any contemplated end use.

Polymers like Poly vinyl acetate is easily available in market. It has low cost and is easily soluble in organic solvents such as methanol. Poly vinyl acetate is mainly used for the manufacture of PVA, especially in the form of thin films. Poly vinyl acetate with other polymers and compounds, it is used in adhesives and for the large scale manufacture of gramophone records. The aim of present work is to prepare thin films of undoped and $FeCl_3$ doped Poly vinyl acetate having different thickness and to determine the dielectric constant and dielectric loss at microwave frequency.

2. Experimental

2.1 Preparation of Films

$FeCl_3$ – doped polyvinyl acetate thin films of varying thicknesses of different concentration, the size of rectangular waveguide in X-band microwave bench, were prepared in the laboratory by sudden quenching technique [3]. Powdered form of poly vinyl acetate and methanol were taken in test tube and then added $FeCl_3$ in proper proportion to this mixture by calculating weight percent formula. Weighing was done on monopan balance. This mixture was finely mixed for 1 hour to form a homogeneous mixture. Cleaned glass plate with acetone and poured some mixture on glass plate to form film of 0.1 concentration. The second film was prepared by adding some methanol to remaining mixture and poured on glass. Using the aforementioned method, five types films of different concentration 0.1, 0.2, 0.3, 0.4 and 0.5 were prepared. For each type of film concentration, five samples of varying thicknesses were also prepared.

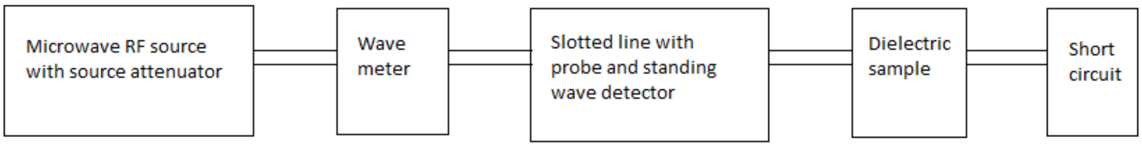

Fig.1: Experimental set up for measurement of the dielectric constant.

Dielectric constant measurement at microwave frequency

For accurate measurement of dielectric constant width at twice minima method was used [4]. Following steps were followed in this method.

1. The frequency of source was determined by taking micrometer reading of cavity resonator.
2. The guide wavelength λg, was measured by short circuiting waveguide section.
3. The distance, ΔX shown in Fig.2 was measured by width at twice minima method.
4. The position of minima without sample A was recorded Fig. 2.
5. Dielectric sample (film) was then introduced in the waveguide touching the short – circuit end.
6. The distance ΔXs, was measured.
7. The position of minimum 'B' of standing wave pattern occurring with sample was recorded Fig. 2.
8. Shift in minima Δl was calculated.

The dielectric constant was calculated by using the formula (1). The reading were noted at which beam voltage near about 150V and beam current at 25 mA and at room temperature.

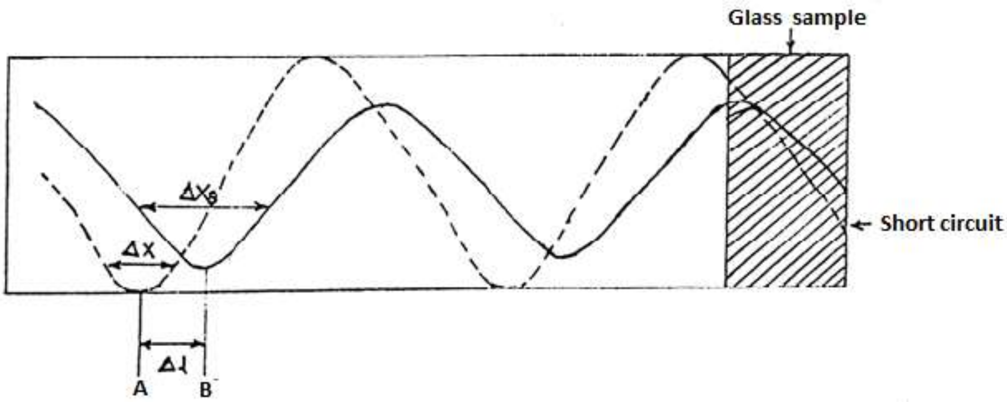

Fig. 2: Standing waves in the waveguide with and without sample.

3. Results and discussion

The dielectric constant, dielectric loss and loss tangent and $FeCl_3$ - doped polyvinyl acetate films of different thicknesses are studied at 9.1 GHz microwave frequency and at room temperature. The values of dielectric constant (ϵ') and dielectric loss (ϵ'') depicted in Table 1 are found to be reasonable to the films.

Table 1: Values of dielectric constant (ε'), dielectric loss (ε'') and loss tangent (tanδ) for different concentration at microwave frequency (9.1 GHz).

% of $FeCl_3$ doping	Dielectric constant (ε')	Dielectric loss (ε'')	Loss tangent (tanδ)
0.1	1.7670	0.1457	0.0824
0.2	1.8126	0.2370	0.1307
0.3	1.8159	0.2435	0.1340
0.4	1.8432	0.2980	0.1616
0.5	1.9602	0.5320	0.2714

Dielectric constant (ϵ') is given by the following formula [5]:

$$\epsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_o}{\lambda_d}\right)^2 \left\{1 + \frac{\alpha_d \lambda_d}{2}\right\} \quad (1)$$

where, λ_0 - free space wavelength(= 3.29 cm); λ_c - cut off wavelength(= 4.5828cm); λ_d - wavelength of wave(= 3.03 cm).

α_d can be determined by following formula:

$$\alpha_d = \frac{\Delta x . 2\pi}{\lambda^2 g} \quad (2)$$

where, Δx - width at twice minima; λ_g - guide wavelength(= 4.72 cm).

Dielectric loss (ε'') is determined from the following formula:

$$\varepsilon'' = 1/\pi \, (\lambda_0/\lambda_d)^2 \alpha_d \lambda_d \quad (3)$$

Loss tangent (tanδ) was calculated using the formula [4]:

$$\tan\delta = \varepsilon''/\varepsilon' \quad (4)$$

Thickness, width (Δx) all values for different concentrations are included in Table 2. Fig. 3 shows the plot of dielectric constant (ϵ') versus % of $FeCl_3$ doping for different concentration of Fe - doped polyvinyl acetate films. The variation of dielectric constant increases with increasing dopant concentrations. The maximum dielectric constant was observed at 1.96 $FeCl_3$ mol%. It showed that for different composition of material, we get different dielectric constant.

Table 2: Values of width (Δx) for different concentrations and thicknesses at room temperature.

Sample concentration	Thicknesses (cm)	Position of twice minimum T.R. with sample Δx_1(cm)	Position of twice minimum T.R. without sample Δx_0 (cm)	Δx_1- Δx_0 (cm)	Mean Δx (cm)
0.1	0.0256	1.865	1.73	0.135	0.455
	0.0044	1.855		0.125	
	0.0055	1.800		0.070	
	0.0018	1.800		0.070	
	0.0032	1.785		0.055	
0.2	0.0047	1.860	1.73	0.130	0.740
	0.0038	1.920		0.190	
	0.0029	1.865		0.135	
	0.0023	1.905		0.175	
	0.0133	1.840		0.110	
0.3	0.0033	1.940	1.73	0.210	0.760
	0.0046	1.830		0.100	
	0.0327	1.940		0.210	
	0.0077	1.810		0.080	
	0.0025	1.890		0.160	
0.4	0.0346	1.840	1.73	0.110	0.930
	0.0047	1.960		0.230	
	0.0234	1.980		0.250	
	0.0070	1.905		0.175	
	0.0512	1.895		0.165	
0.5	0.0029	2.160	1.73	0.430	1.660
	0.0035	2.175		0.445	
	0.0073	2.195		0.465	
	0.0464	1.930		0.200	
	0.0858	1.850		0.120	

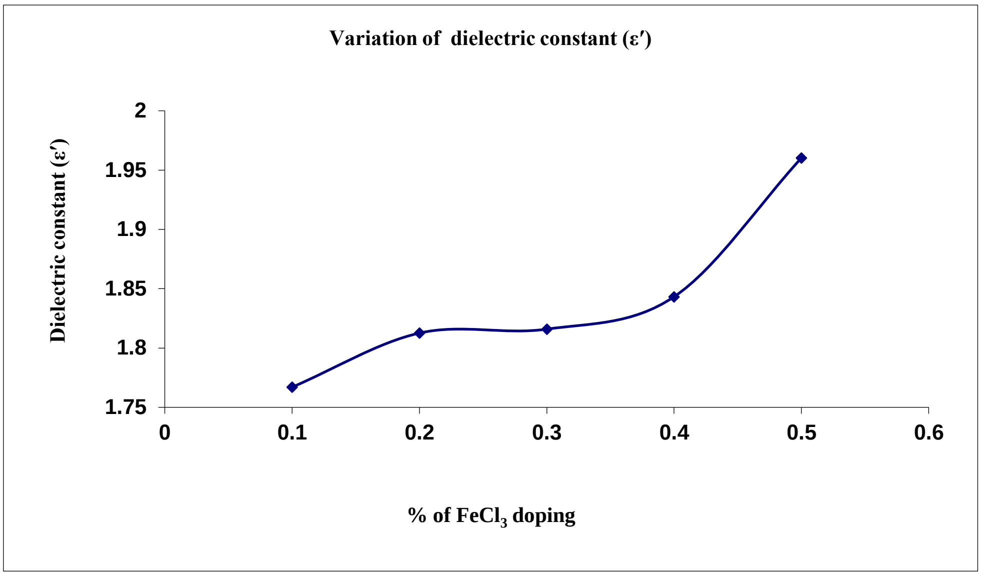

Fig. 3: Variation of dielectric constant (∈') with % of $FeCl_3$ doping at room temperature.

The variation of dielectric loss (∈'') versus % of $FeCl_3$ doping at room temperature as shown in Fig. 4. From figure, it can be seen that, dielectric loss increases with increasing doping % of $FeCl_3$. The maximum dielectric loss is found to be 0.53. The variation of tangent loss (tan δ) with % of $FeCl_3$ doping as shown in Fig. 5. From figure, it is clear that, loss tangent for different concentration is different. The loss tangent increases with increasing doping % of $FeCl_3$. The maximum loss tangent is found to be 0.27.

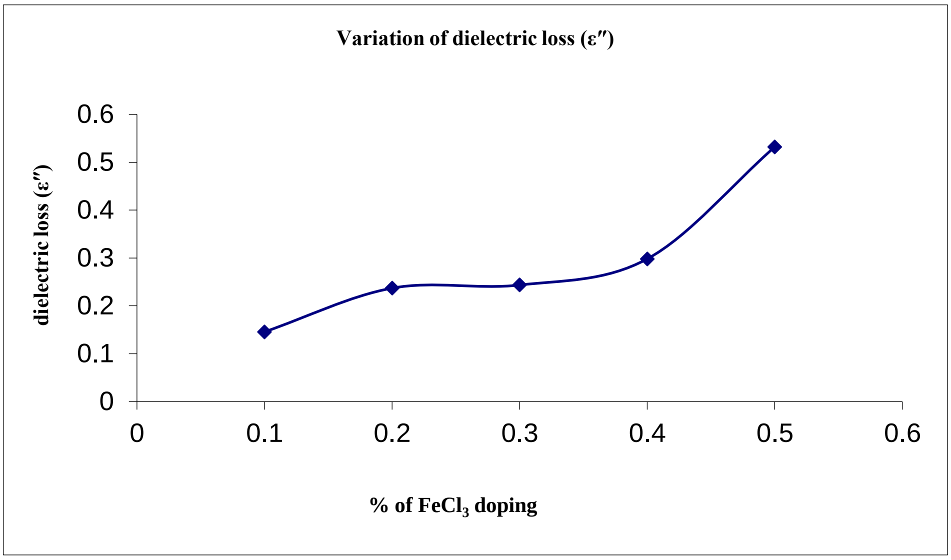

Fig. 4: Variation of Dielectric loss (∈'') with % of $FeCl_3$ doping at room temperature.

The origin of microwave dielectric loss in polymers are categorized as: (a) dipolar absorption dispersions in both crystalline and amorphous polymers; (b) dipolar losses due to impurities, additives or fillers in a polymer material; (c) microwave absorption in conducting polymers (poly acetylene and poly (sulphur nitride)) for which the current carriers are electrons; and (d) photon-phonon absorption spectra corresponding to the density of states in amorphous regions of a polymer material [6].

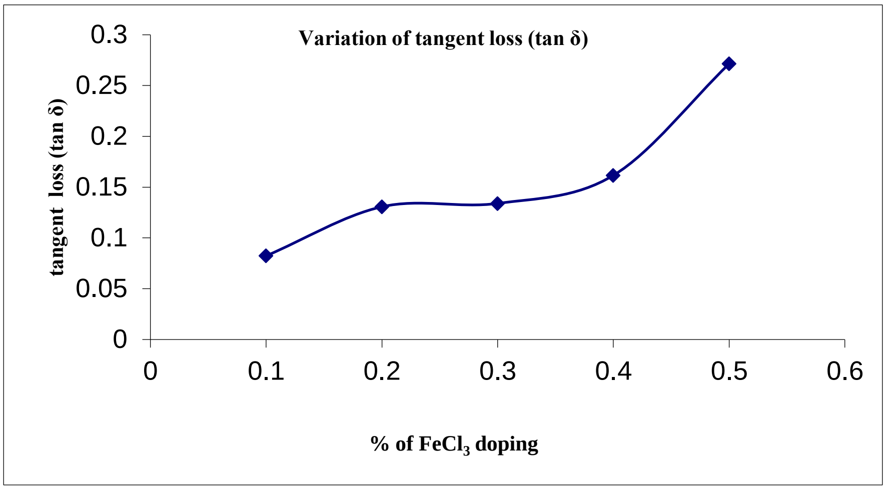

Fig. 5: Variation of tangent loss with % of $FeCl_3$ doping at room temperature.

When $FeCl_3$ doped in polyvinyl acetate, in this reaction the splitting of a chloride anion occurs forming the negatively charged macrocation, which is then transferred to the positively charged. The principal mechanics of microwave absorption in poly vinyl acetate and $FeCl_3$ is the reorientation of dipoles. Microwave processing is suitable to these materials, because it form strong dipoles. Permittivity and dielectric loss with increasing concentration and increase in temperature. The materials tend to be efficient absorbers of microwave radiation.

Polymer dielectric constant can vary during a processing cycle or if a phase change occurs as temperature varies, solvents is removed and the reaction proceeds changing the type and concentration of dipoles. The properties of amorphous region suggest the existence of many localized state and release the excited charge carriers in these states. Therefore, the dopant present in low concentration does not significantly affect the dielectric constant. But, when the dopant is present in large concentration it creates additional sites for trapping and thereby enhancing the dielectric constant.

4. Conclusions

In summary, the dielectric properties of $FeCl_3$ - doped polyvinyl acetate films of different thicknesses have been investigated at 9.1 GHz microwave frequency and at room temperature. The dielectric constant, dielectric loss and loss tangent are observed to depend on doping concentration of $FeCl_3$. A little variation in the dielectric constant is observed with doping % of $FeCl_3$ and also, dopant present in low concentration does not significantly affect the dielectric constant. But, when dopant is present in large concentration, it creates additional sites for trapping and thereby, enhancing the dielectric constants. In general, at microwave frequency the movement of network and modifying ions are held responsible for relative dielectric constant and the oscillations between them for losses.

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