MICROWAVE DIELECTRIC STUDIES ON PSF/PMMA POLYMER BLENDS

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Abstract: The development of polymers with increasingly lower dielectric constants and losses has been the focus of several investigators. Accurate measurement of complex permittivity is needed for circuit design, minimization of cross talks, and characterization of signal-propagation speed. We have made PSF/PMMA blends and evaluated the dielectric parameters at 8.92 GHz frequency and at 35^0 C temperature. Dielectric measurements of blends show reduced dielectric constant than that of pure PSF. Decrease in dielectric constant in the blends may be attributed to enhanced free volume. Relaxation time for PSF/PMMA blends come out to be of the order of 10^{-13}s. It comes out to be a bit higher in magnitude in the blends as compared to that of pure PSF. The increased relaxation time (τ)values in blends may be due to the intermolecular interactions between PSF and PMMA molecules. Optical constants, absorption index 'K' and refractive index 'n' have also been evaluated.

Keywords: Dielectric constant; Relaxation time; Blends; Absorption index ;

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DOI: - 10.48047/ecb/2023.12.si5a.098

INTRODUCTION

The dielectric properties are utilised in material characterization for the purpose of device fabrication and are helpful in the evaluation of useful parameters viz. conductivity and relaxation time. As electrical components are miniaturized, the need for well characterized dielectric measurements on thin materials is in great demand [1–5].

There is much interest in the development of inexpensive composite polymers with an appropriate weight, appropriate electric conductivity and/or appropriate impact value for use with practical articles. Polymer blends / composites have steadily gained growing importance during the past decade. A vigorous development of polymer blends /composite and extensive utilization of polymer materials in technology has led to the quest for new polymer blends/composites. The importance of polymers is mainly because polymers are still regarded as a cheap alternative material that is manufactured easily. The intensive use of polymer in broad use has led to the development of materials for specific applications .

Polymers are typically utilized in electrical and electronic applications as insulators where advantage is taken of their high resistivities. Polymers and the atoms that make them up have their electrons tightly bound to the central long chain and side groups through 'covalent' bonding. Covalent bonding makes it much more difficult for most conventional polymers to support the movement of electrons and therefore they act as insulators. The effectiveness of a material as an insulator is usually measured by quantities like dielectric constant $\in_r$ and dissipation factor (*tan* δ). A significant body of data has been reported for how these parameters vary in polymers and polymer blends in the megahertz range [6–9]. Relatively little data currently exists for polymers' and blends' dielectric behaviour at frequencies above 1 GHz.

In the present study, blends of PSF and PMMA have been prepared and investigations in the form of thin films have been taken at microwave frequencies. The experimental data have been used to evaluate various dielectric parameters.

Experimental

Polysulphone (PSF) supplied by Gharda Chemicals Ltd. Bharuch, Gujarat (India) and poly (methyl methacrylate) or (PMMA) supplied by HiMedia Laboratories Pvt. Ltd., Mumbai (India) were used for the study.

Thin films of PMMA and PSF were prepared by solution cast method. For preparing blends of polysulphone and PMMA in variable proportions, the granules of PMMA and PSF were dissolved in common solvent i.e. dichloromethane, and stirred thoroughly for a few hours to ensure mixing. The mixed solution was used to prepare blend membrane by solution cast method. Blends of PSF/PMMA in the ratio 30:70 and 10:90 were prepared.

For microwave measurements of dielectric parameters of thin films, we have used the technique developed by Dube [10] .The sample mounted along the axis of the waveguide . With this configuration, the electric field acts in the plane of the film. The advantage of this method is that the thin specimen is placed longitudinally at the centre of the broad side of a hollow rectangular waveguide excited in the TE_{10} mode so that the whole specimen remains in maximum electric field. Standing waves are produced in the rectangular waveguide by short-circuiting the system.

Being electrode less technique, measurements at microwave frequencies are free from electrode polarization and associated problems and thus yield real material parameters.

RESULTS AND DISCUSSION

In table 1(a) dielectric constant ($\in_r$), dielectric loss ($\in_i$),loss tangent (tanδ) and relaxation time(τ) have been reported for PMMA and PSF and their blends at 8.92 GHz frequency and at 35^0 C temperature for 100 μm thick films.

In table 1(b) a.c. conductivity (σ), absorption index (K) and refractive index (n) have been reported for PSF/PMMA blends of thickness 100 μm of various doping percentages at 8.92 GHz frequency and at 35^0 C temperature.

Table 1 (a): Dielectric parameters and relaxation time for PSF/PMMA blends at 8.92 GHz. frequency and at 35^0C temperature

Composition of PSF/PMMA Blend	Dielectric Constant $\in_r$	Dielectric Loss $\in_i$	Loss Tangent *tan* δ	Relaxation Time $\tau \times 10^{13}$Sec.
PSF / PMMA Blend (Film thickness=100μm)				
100%+0%	2.99	0.213	7.11×10^{-2}	12.7
30%+70%	2.63	0.282	10.71×10^{-2}	19.1
10%+90%	2.58	0.257	9.96×10^{-2}	17.8
0%+100%	2.52	0.057	2.25×10^{-2}	4.0

Table 1 (b): *A.C. Conductivity, absorption index and refractive index for PSF/PMMA blends at 8.92 GHz. frequency and at* 35^0C *temperature*

Composition of PSF/PMMA Blend	Conductivity σ(mho/m)	Absorption Index *K*	Refractive Index *n*
PSF / PMMA Blend (Film thickness=100μm)			
100%+0%	10.5×10^{-2}	3.55×10^{-2}	1.73
30%+70%	13.9×10^{-2}	5.34×10^{-2}	1.63
10%+90%	12.7×10^{-2}	4.97×10^{-2}	1.61
0%+100%	2.8×10^{-3}	1.13×10^{-2}	1.58

Dielectric constant and loss

Dielectric constant ($\in_r$), for PMMA at 8.92 GHz and at 35^0 C temperature has been obtained as 2.52 and loss tangent (tanδ) has been obtained as 2.25×10^{-2} for film thickness 100μm, respectively. These results are in agreement with the values of dielectric constant and loss tangent reported by Riddle and Baker–Jarvis [11].

Dielectric constant ($\in_r$), for polysulphone at 8.92 GHz and at 35^0 C temperature has been obtained as 2.99 and loss tangent (tanδ) has been obtained as 7.11×10^{-2} for films of thickness 100μm. These results are in agreement with the values of dielectric constant and loss tangent reported by Riddle and Baker–Jarvis[11] .

As we see from table1(a), for the PSF/PMMA blend of various compositions, reduced values of dielectric constant $\in_r$ than pure polysulphone are obtained. To our knowledge dielectric constant values of PSF/PMMA blends for these compositions at microwave frequencies are not reported in literature.

In polymers holes or voids are present which is called free volume. Reduced dielectric constant in the blends may has resulted due to the enhanced free volume.. It seems that more voids have been created at the phase boundaries, enhancing free volume. Enhanced free volume lowers polarization by decreasing the number of polarization groups per unit volume. A correlation of high free volume and low dielectric constant has been previously reported for polyimides [12]. Formation of blend may have resulted in increased free volume.

Loss tangent for PSF/PMMA blends of 30:70, and 10:90 has been obtained as 10.71×10^{-2} and 9.96×10^{-2}. The origins of microwave dielectric loss in polymers are attributed to dipolar absorption dispersions in both crystalline and amorphous polymers, dipolar losses due to impurities and photon-phonon absorption spectra corresponding to the density of states in amorphous regions of polymer .

Relaxation time and conductivity

The relaxation time is calculated by using the relation, $\tau = \varepsilon_i / \omega\varepsilon_r$. Relaxation time for PMMA has been obtained in the order of 10^{-13}s. The values are in agreement with the τ values obtained by Khare *et al* [13], in case of PSF films the order remains same. Relaxation time for PSF/PMMA blends also come out to be of the order of 10^{-13}s. However, it comes out to be a bit higher in magnitude in the blends as compared to that of pure PSF. The increased τ values in blends may be due to the intermolecular interactions between PSF and PMMA molecules.

The a.c. conductivity is obtained by using the relation, $\sigma_{ac} = \omega\varepsilon_0\varepsilon_i$. The conductivity of PSF/PMMA blends is obtained in the range 12.7×10^{-2} and 13.9×10^{-2} for different compositions of PMMA in blends.

The observations show that addition of PMMA to PSF increases the conductivity over that of PSF. This may perhaps be due to the modification of trap structure introduced by the addition of PMMA. The PMMA molecules in the blend might be producing additional traps of shallow as well as deeper depths, thus providing conducting pathways for the charge carriers.

Absorption index and refractive index

Using the relations

$$tan\,\delta = \frac{2\ K}{1 - K^2} \text{ and } \in_i = 2n^2 K$$

The optical constants *viz.* refracting index (n) and absorption index (K) have been calculated by using the dielectric data .In the PSF/PMMA blends where the thickness for all compositions is 100 μm, an increase in absorption index values is noted. For blends under investigation 'K' comes out to be in the range 5.34×10^{-2} and 4.97×10^{-2}.

The values of refractive index (n) are found to be in the range 1.61-1.63 for PSF/PMMA blends . the values are lower than that of pure PSF.

CONCLUSIONS

The dielectric investigations at microwave frequency show that the dielectric constant of PSF changes appreciably due to inclusion of PMMA in the blends. Not only dielectric constant $\in_r$ but change in the dissipation factor i. e. loss tangent (tanδ) has been noticed. These blends can be used in various applications as they show reduced dielectric constant values. Optical constants determined from dielectric data will also help in selecting the blend for use in microelectronic industry.

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