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Influence Of Gamma Irradiation On The Dielectric Properties Of PVA- PS Polymer Blends

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Abstract
Pure Polyvinyl alcohol (PVA), Polystyrene (PS) and $PVA_{0.5}PS_{0.5}$ films were prepared by simple cost effective solution casting techniques. The as prepared films were subjected to gamma irradiation upto 1.5 kGy at room temperature. The irradiated and unradiated films were subjected to XRD and electrical analysis. The results revealed that gamma irradiation improves the crystallinity as well as electrical conduction of the films. Moreover, the $PVA_{0.5}PS_{0.5}$ polymer blend film showed enhanced behavior than pure PVA and PS in both the structural and electrical properties.

I. Introduction

Developments in science and technology, especially over the last two decades, Polymers play a huge important role [1]. The significance of these materials is often taken for granted, yet polymers are fundamental to most aspects of modern life such as building, communication, transportation, clothing and packaging due to their features like low cost, high environmental stability, ease of handling, electrical, optical and mechanical properties and hence the researchers interested to study the mechanical and physical properties of the polymers [2]. The role of polymer electronics is not primarily a replacement for existing silicon devices, but opens up the prospect of completing new applications that combine the features of transistor, LED, detector and interconnect devices with the freedom of design, flexibility and low cost of plastics. In view of these new findings, it seems possible that polymers may solve present and forthcoming problems and add new functionality to microelectronic circuits and systems. Polytronics creates a new and very promising technological area with new applications and products [3]. Many types of additives are added to the polymers to improve and modify its properties [4-7]. The doping of transition metals to polymeric network is of great interest for scientific and technological point of view [8-10]. In recent years, radiation is used for polymer processing and modification. Irradiation with X-rays, alpha, beta and gamma radiation also have a significant effect on polymer properties and some physical properties are usually modified [11-12]. The irradiation of polymeric materials with ionizing radiation (e.g. Gamma rays, X-rays, accelerated electrons and ion beams) lead to the formation of very reactive intermediates, free radicals, ions and excited states. These intermediates can follow several reaction paths that results in disproportion, hydrogen abstraction, arrangements and/or the formation of new bonds. The main interaction of ionizing radiation with polymers concerns its molecular weight and its ability to induce crosslinking or scission which may result in the formation of a wide range of materials without introducing any chemical initiators and without dissolving the sample [13]. Many industries are based on polymer radiation crosslinking technologies such as wire and cable insulation, applications in rubber tires and radiation vulcanization of rubber latex etc. [12]. Even small amounts of radiation can induce significant changes in the physical or mechanical properties of a polymer, with the extent of these changes being dependent upon the chemical structure of a particular polymer.

Polyvinyl alcohol (PVA) is the world’s largest volume, synthetic, water soluble polymer. It has excellent film forming, emulsifying, and adhesive properties [14-18]. Polystyrene is a vinyl polymer. Structurally, it is a long hydrocarbon chain, with a phenyl group attached to every other carbon atom [19]. Polystyrene (PS) is an amorphous polymer with bulky side groups. A blend is a mixture of two or more polymers. Blending opens up a root for a combination of different properties. Some recent results indicate that conducting polymer composite materials may have significantly improved electronic and mechanical properties as compared to pure conducting polymer films, making the composite more suitable for microelectronic applications.

In our present study, we made an attempt to prepare polyvinyl alcohol/polystyrene blends .Blends were prepared by simple solution casting technique and were then exposed to gamma rays. Variation in the electrical conductance of blends has been investigated by changing temperature from 27 to 150 °C at constant γ irradiation dose (1.5 kGy). The change in conductivity was monitored by a two-probe measurement technique and corresponding structural changes in PVA, PS and $PVA_{0.5}PS_{0.5}$ blends were followed by X-ray diffraction (XRD studies. Also, the dielectric constant and loss of the prepared pure and blend films have been determined.

II. Experimental

2.1 Materials

Polyvinyl alcohol (PVA) and polystyrene (PS) monomers were obtained from Sigma Aldrich and used without any purification. The dimethyl sulphoxide (DMSO) and double distilled water (DDW) were used as a solvent and purchased from central drug house (P) Ltd.

2.2 Preparation of PVA-PS blend

For the casting of the $PVA_{0.5}PS_{0.5}$ blend film, 10 wt. % of pure PVA and PS were dissolved in a DDW-DMSO mixture individually and stirred for 1 h at 60 ºC, and then the two solutions were mixed. After subsequent stirring, homogeneous solutions of these hydrogel was transferred into a petri dish at room temperature to obtain smooth film under ambient conditions in a fume hood over a week. Polymer film was then dried under vacuum to remove the residual solvent. A similar method was used to prepare pure PVA and PS films.

2.3 Characterization

The prepared films were cut into the size of 5 x 2 cm^2 used for irradiation studies. These films were irradiated using cobalt-60 source at Ceter for Applications of Radioisotopes and Radiation Technology(CARRT), Mangalore University, Karnataka, India. Films were exposed to 1.5 kGy dose of γ-iiradiation at room temperature. The thickness of the films were measured at 5 randomly selected places with Mprobe reflectrometer. Irradiated and uniradiated films were subjected to XRD and dielectric measurement. Dielectric measurements was made on circular pieces of the samples with diameter 13 mm using Agilent 4284A LCR precision meter at room temperature for fixed frequency of 1 kHz.

III. Results and Discussion

The influence of low-dosage γ-irradiation (1.5 kGy) on the PVA, $PVA_{0.5}PS_{0.5}$ and PS films was analyzed by X-ray diffraction. Fig. 1(a) shows the diffractograms of the unirradiated and irradiated films. From the spectra, it is also noted that there are two broad peaks appeared at 19.77º and around 40.63º. The broadening and intensity of the first strong peak was slightly increased when irradiated with γ-radiation (1.5 kGy) which indicates the films are improved in crystallinity nature. Also the intensity of the diffraction peak is resulted from the number of PVA/PS chains packing together. Additionally it was noted that there are no new peaks appeared in PVA-PS blend and PS films when irradiated with γ-radiation. However, in the case of γ-irradiated PVA film a new peak was appeared in 28.72º. The second broad shape, low intensity peak slightly shifted towards higher angle side when irradiated with γ-radiation, which correspond to noncrystalline zones within the crystalline polymeric matrix [20]. In order to make the picture explicit to readers, the high intensity broad peak appeared at 19.77º is fitted with Gaussian function and shown in Fig. 1(b). The observed data from the Gaussian fitted curve is given in Table 1. From the observed data there is a significant effect of gamma irradiation on either the intensity of the diffraction peak or on its full width at half maximum (FWHM). The semicrystalline nature of PVA is resulted from the strong intermolecular interaction among PVA chains through hydrogen bonding. In the case of $PVA_{0.5}PS_{0.5}$ blend film, the addition of PS to PVA leads to an increase in the intermolecular interaction between chains and thus an increase in the degree of crystallinity [21]. The fact that the intensity and broadening of these peaks increased reveals that the structural rearrangement takes place.

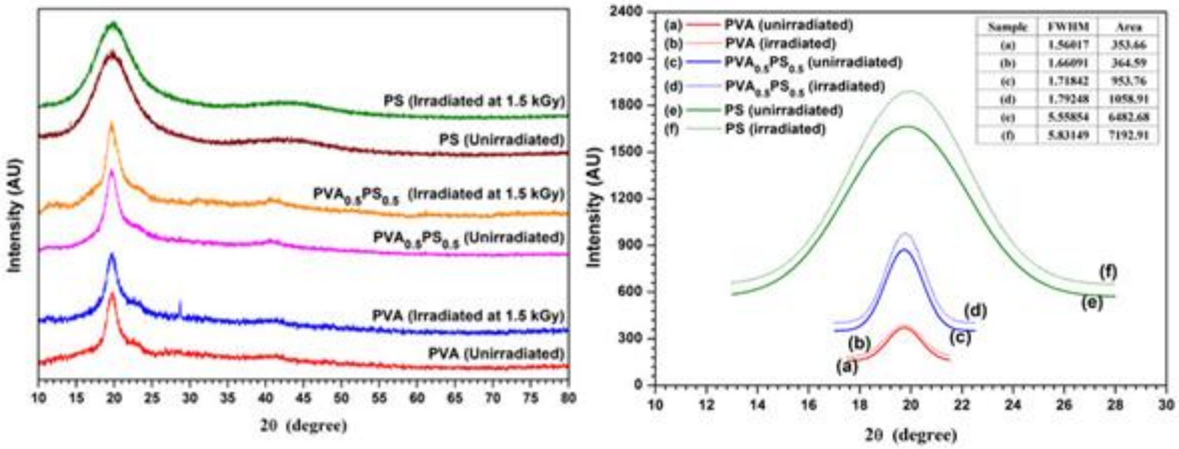

Fig. 1: (a) X-ray diffraction patterns of unirradiated and irradiated PVA, $PVA_{0.5}PS_{0.5}$ and PS films (b) Gaussian function fitted curves for high intensity broad peak

Table 1: Arez under the peak and FWHM data observed form Gaussian fitted curve for PVA, $PVA_{0.5}PS_{0.5}$ and PS films

Sample	Peak intensity	Area of the peak (° AU)		FWHM (°)	
	(AU)	Value	Standard error	Value	Standard error
PVA (Unirradiated)	213	353.66	8.78	1.5602	0.0634
PVA (Irradiated at 1.5 kGy)	206	364.59	12.48	1.6609	0.0728
$PVA_{0.5}PS_{0.5}$ (Unirradiated)	521	953.75	18.13	1.7184	0.0937
$PVA_{0.5}PS_{0.5}$ (Irradiated at 1.5 kGy)	574	1058.91	17.17	1.7925	0.0846
PS (Unirradiated)	1095	6482.68	40.43	5.5585	0.2437
PS (Irradiated at 1.5 kGy)	1244	7192.91	53.83	5.8315	0.2691

The results of dielectric constants (ε_r), dielectric loss (tanδ) and AC conductivity (σ_{ac}) for PVA, $PVA_{0.5}PS_{0.5}$ and PS films in the temperature range from 27 to 138° at 1 kHz are shown in Figs. 2-4. From the figures it reveals that for all the samples the ε_r, tanδ and σ_{ac} slowly increases with increasing temperature as well as increases when irradiated with γ-radiation. At lower temperatures, the thermal energy that is absorbed by the PVA, $PVA_{0.5}PS_{0.5}$ and PS films, at a certain fixed frequency, is small and a small number of dipoles can rotate with small angles. The increase of ε_r is determined by the number of orienting dipoles per unit volume and their dipole moments [22-23]. As the temperature increased, the viscosity of polymeric films is decreasing and the dipoles have sufficient energy and can orient themselves easily in the direction of the applied electric field. Also, the chain segments get sufficient thermal energy to speed up its rotational motion and consequently the increase in polarization occurs [22-23].

The temperature dependence of σ_{ac} can also be explained by the crosslinking predominant effect. When temperature increases, the mobility of polymer chains increased and the fraction of free volume inside the polymer matrix also increased. This facilitates the segmental motion of the polymer blend chains and leads to an enhancement in σ_{ac} at high temperatures. The electrical conductivity of PVA-PS blend ($PVA_{0.5}PS_{0.5}$) films has been enhanced by about two orders of magnitude by comparing pure PVA. The gamma irradiation with a dose of 1.5 kGy increases the conductivity of PS films about 3 times.

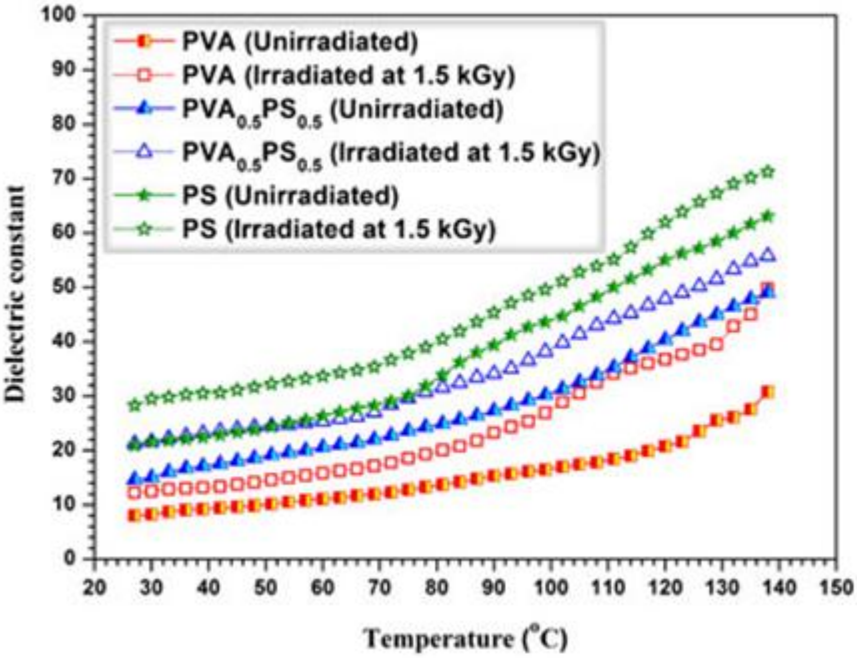

Fig. 2: Variation of the dielectric constants for PVA, $PVA_{0.5}PS_{0.5}$ and PS films as a function of temperature at constant 1 kHz frequency.

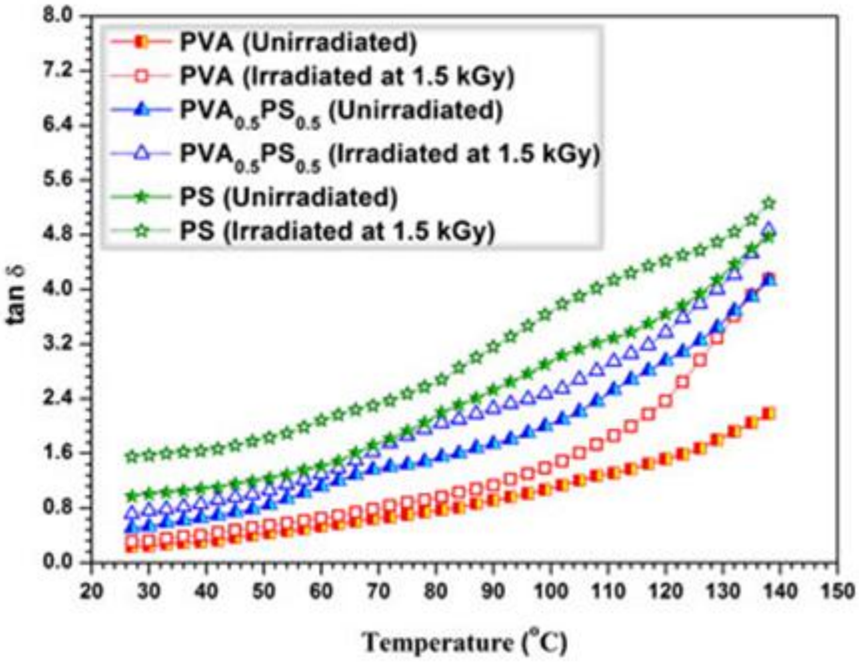

Fig. 3: Variation of the dielectric loss (tanδ) for PVA, $PVA_{0.5}PS_{0.5}$ and PS films as a function of temperature at constant 1 kHz frequency.

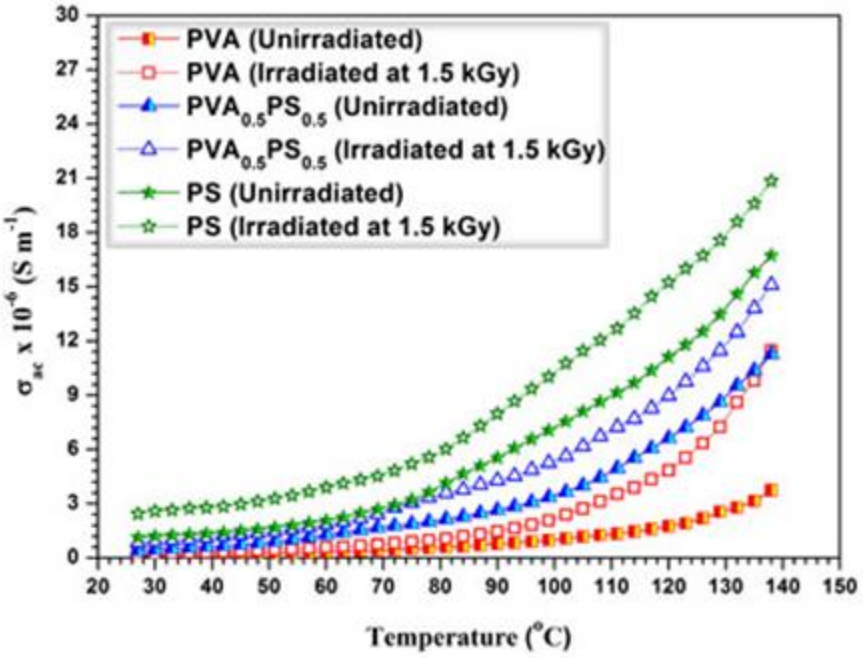

Fig. 4: Variation of the AC conductivity (σ_{ac}) for PVA, $PVA_{0.5}PS_{0.5}$ and PS films as a function of temperature at constant 1 kHz frequency.

IV. Conclusion

PVA-PS polymer blends were prepared by simple casting techniques. The effects of γ irradiation on the structural and electrical properties were analyzed. From the explicit picture of XRD, it was clear that when the films were irradiated with γ rays (1.5 kGy) the roughness's of the films were decreased and the crystallinity of the samples was increased. From the observed data there is a significant effect of gamma irradiation on either the intensity of the diffraction peak or on its full width at half maximum (FWHM).The temperature dependence of σ_{ac} can also be explained by the crosslinking predominant effect. The electrical conductivity of $PVA_{0.5}PS_{0.5}$ blend film has been enhanced by about two orders of magnitude when compared with pure PVA. Also, σ_{ac} is increased by the order of 2 for γ-irradiated films. The enhanced conductivity at higher dosage rate makes use of these films for electronic applications.

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