Effect of EVA Content upon the Dielectric Properties in LDPE-EVA Films

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Abstract: Low density polyethylene (LDPE) blends with different percentages of ethylene vinyl acetate polymer membranes were prepared by a hot press casting method. The effects of EVA content on the electrical properties of LDPE were studied. The results on the electrical properties revealed that the surface resistance, volume resistivity, and breakdown voltage of the LDPE decrease with EVA content and reach a minimum at a 30 wt% of EVA. Dielectric constant and dielectric loss factor were increased with increasing EVA content up to 30 wt% of EVA. It can be deduced that the electrical properties of LDPE are improved by blending with EVA.

Keywords: **Low density polyethylene, Ethylene vinyl acetate, Dielectric properties, Breakdown voltage.**

I. Introduction

Polymers are in general insulated materials, with low values of electrical conductivity and a low value of dielectric constant. One of the ways to increase electrical conductivity is to introduce high electrical conductivity fillers such as metal powders or carbon black in the polymer matrix. Then, the value of the electrical conductivity of the compound can be increased several orders of magnitude depending on the volume fraction and the dispersion of this second phase in the matrix [1]. Blending of different polymers offers and economically viable and versatile way to the development of new polymers. The polyolefin blends like ethylene vinyl acetate copolymers (EVA) with semi-crystalline polymers like polyethylene (PE) or polypropylene (PP) give rise to materials with different structures and viscoelastic properties.

Low cost, easy availability and good process ability of various grades of low density polyethylene (LDPE) has made it most versatile polymer for various applications such as cable and wire insulation, food packaging, medical components and many more [2]. Ethylene Vinyl Acetate (EVA) is widely used as a insulating and sheath material for high voltage cables and also in the footwear and toy industries due to its high flexibility and chemical inertness [3-6].

The rationale of this work is to implement the effect of EVA loading on the electrical behaviours of LDPE/EVA blends. In addition, to supplement the dielectric results, volume resistivity and breakdown voltage measurements have also been performed.

II. Material and Methodology

This study was carried out using granules of low density polyethylene (LDPE) supplied by Bandar Imam Petrochemical Company (Iran) were used as the polymer matrix (density= 0.92 g/cm^3, melt index= 0.75 g/10 min under loading of 2.16 kg at 190 °C). Ethylene vinyl acetate (EVA 18%, MFI = 2.2 g/10 min), grade 8430 supplied by Hyundai Company, Korea, with density of 0.9 g/cm^3.

The melt compounding of the blends of LDPE with 10, 20 and 30 wt % ethylene–vinyl–acetate (EVA) was carried out in Twin Screw Extruder with 30 cycle/min, at 150 °C – 165 °C, then moulded to flat sheets (2 ± 0.05 mm thickness) using DR Collin laboratory hot press at 165 °C for 5.0 min under 20 MPa pressure. Then, the sheet samples were cooled to room temperature.

Surface and volume resistance of blends were measured at room temperature by a Tera-ohm-meter, made by CEAST Company, Italy. A dielectric loss measurement system, model TRS-10T (ANDO Electric Co., Japan) was used for determining the dielectric constant and the dielectric loss tangent of the samples. Frequency was tuned at 1 MHz in the experiments. The breakdown voltage of the samples was measured by a Dielectric Rigidity system P/N 6135.053, CEAST Company, Italy.

The samples in the form of sheet were studied by attenuated total reflectance, FTIR using Equinox55 FTIR spectrometer, in the standard wave number range 400 - 4000 cm^{-1} fed with film-sheet samples, keeping air as a reference.

III. Results and Discussion

Resistivity studies are very important for insulating materials, because the most desirable characteristic of an insulator is its ability to resist the leakage of electrical current. Fig. 1 compares the surface resistance and volume resistivity of LDPE/EVA blends as a function of content of EVA. It is clear that the surface resistance and volume resistivity of the unblended LDPE samples is substantially higher than LDPE/EVA blends. As can be observed from Fig. 1, the surface resistance and volume resistivity of the blends decrease with the content of EVA. High cross-linking density causes to increase the average molecular weight of polymer. The electrical resistivity depends on the charge carrier concentration and on the mobility of charge carriers [7]. It is indicated that the EVA can increase charge carrier mobility in the LDPE matrix. In LDPE/EVA blends, the huge area of the polymer-polymer interface may impulses the movement of the charges in the materials, which may cause the increment of the electrical conductivity and consequently the volume resistivity. On the other hand, in insulators, charge carrier concentration depends on position of acceptors. Due to the presence of polar groups of the vinyl acetate co-monomer in EVA, increasing EVA, expand the position of positron traps and increase mobility of charge

carriers that increases electrical conductance. So, we can state that the highest surface conductance and volume conductivity of the blends with 30 wt% of EVA may be related to the highest cross-inking density [7].
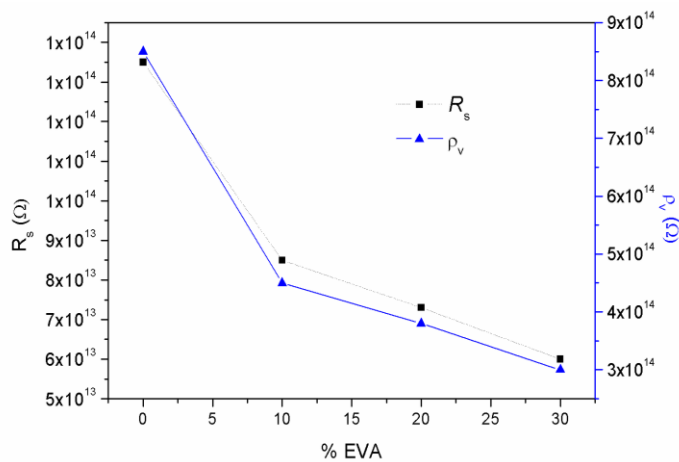

Fig. 1 *Variation of* (■) *surface resistance,* (▲) *volume resistivity of LDPE/EVA blends as a function of EVA content.*

Dielectric constant refers to the ability of any material to store electric charge. Dielectric strength or breakdown voltage define the voltage at which current begins to flow through the insulating dielectric film. For thin films, avalanche breakdown ultimately determines the breakdown strength of the polymer [8].

Fig. 2 shows the variations of breakdown voltage and dielectric constant of LDPE/EVA blends, as a function of EVA content. It was observed that the breakdown voltage of LDPE/EVA is lower than LDPE which may be attributed to the presence of polar groups on the EVA back bone [9-11]. The dielectric constant of a materials arises due to polarisation of molecules and usually the dielectric constant increases with increase in polarisability. The different type of polarisations possible in a material are the polarisation arising from (i) electric polarisation (ii) atomic polarisation and (iii) orientation polarisation due to the orientation of dipoles parallel to the applied field [12].

Obviously polar polymers (EVA) have a higher dielectric constants than non-polar polymer (LDPE). From Fig. 2, it is obvious that addition of EVA increases the dielectric constant value of blend. Upon the addition of EVA the crystallinity of the blend decreases. As the crystallinity decreases dipoles can orient more easily. A correlation between the dielectric constant and resistivity at 298 K is [13]:

$$\log R = 23 - 2\varepsilon \qquad (1)$$

This equation shows that the electrical resistant of polymers decreases exponentially with increasing dielectric constant. In LDPE/EVA blends as shows in Fig. 2, the dielectric constant increases with increase in flexible content (EVA), the volume resistivity decreases (Fig. 1). The increase in dielectric constant is more pronounced from 30 wt % of EVA composition wherein EVA forms continuous phase. The continuous nature of the

EVA phase leads to better orientation of dipoles and results in high dielectric constant.

The permittivity of the polymer is representative of the various polarization phenomena that come into play when the polymer is composited. The overall polarization of a polymer, like the LDPE, is the sum of four terms: electronic, atomic, orientation and space charge polarization, among them the first two are intrinsic in nature and for non-polar polymer are important [14].

For polar polymers, both the atomic and electronic polarization are often negligible compared to orientation and space charge polarization [14]. So, it is the orientation polarization that has a major contribution to the permittivity of a polar polymer like the EVA. This arises owing to the presence of permanent dipoles on the back bone of the macromolecular chain. Since, LDPE is a non-polar polymer with smaller permittivity than EVA; its blends would show permittivity which is held between the permittivity of the LDPE and EVA depending on the content of EVA component in the blends. It is desirable to keep the capacitance of the insulating material as minimal as possible when they are used as cables in industries.

Furthermore, from Fig. 2 it can be seen that although the permittivity of the blends is smaller than that of EVA and larger than that of LDPE. An important observation is that dielectric constant increases considerably with the addition of EVA up to 30 wt % EVA content, and then with increasing EVA more than 30 wt %, it have negligible influence on the permittivity of the LDPE samples. The increase is due to orientation polarisation of polar EVA followed by oscilation under electric field. Morever due to lesser crystallinity of EVA the movement of the dipole become easier and hence heat lose is more.
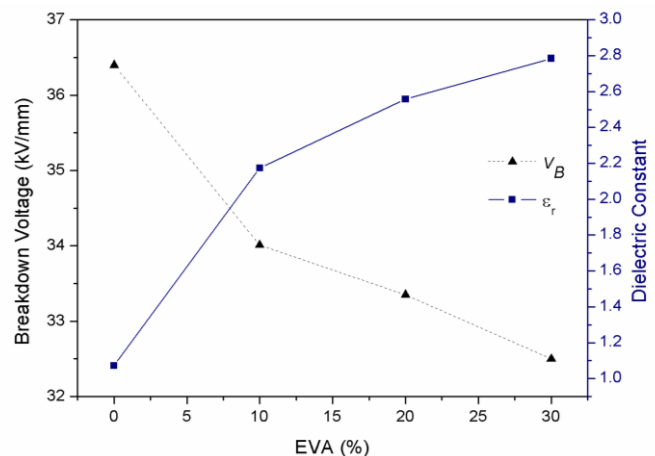

Fig. 2 *Variation of* (■) *dielectric constant,* (▲) *breakdown voltage of LDPE/EVA blends as a function of EVA content.*

Fig. 3 reveals that the loss factor of the LDPE polymer is smaller than that of LDPE/EVA blends and EVA which can be related to the presence of polar groups and heterogeneity nature of the blend samples [15]. For non-polar polymers, the loss factor may, however, increase sharply due to the presence of additives, impurity concentrations and physical heterogeneity [16]. This means that mixing of a polar polymer at low amount level can affect the electrical properties of the non-polar polymer.
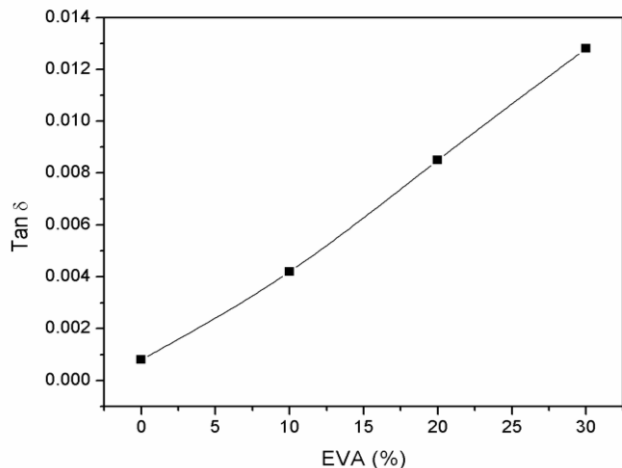
Fig. 3 *Variation of dielectric loss factor of LDPE/EVA blends as a function of EVA content*

The presence of EVA content may affect the degree of crystallinity (a factor that can influence the dielectric constant results). Two infrared bands corresponding to the CH_2 bending mode, one at 1474 cm^{-1} due to the crystalline phase and the other at 1464 cm^{-1} due to the amorphous phase, are usually used to calculate the crystalline fraction in polyethylene samples. In particular, the empirical formula given below has been used to obtain the amorphous content [17]:

$$X_c = \frac{1 - \dfrac{(I_a/I_c)}{1.233}}{1 + (I_a/I_c)} \qquad (2)$$

where I_c and I_a are the intensities of the bands at 1474 and 1464 cm^{-1}, respectively. The constant 1.233 represents the intensity ratios of these bands in the spectrum of a 100% crystalline polyethylene, and was derived using the factor group splitting applied to a single polyethylene crystal [18] (this phenomenon can be predicted using group theory and is used to calculate crystallinity content in polyethylene because it causes certain fundamental vibrational modes of the chain to split only in the crystals).
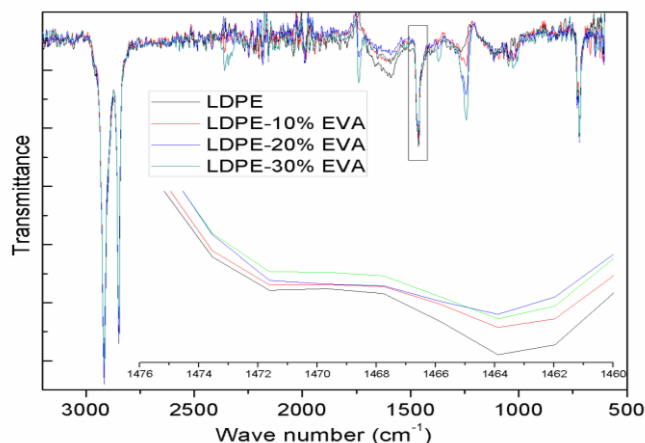

Fig. 4 *FTIR spectra of the LDPE and LDPE/EVA blends. The inset shows the region in which the bands used to estimate the crystalline fraction.*

The FTIR spectra of the neat LDPE and LDPE/EVA blends are shown in Fig. 4. The relative values of crystallinity fraction, obtained from the analysis of FTIR spectra using (2). These results show that the incorporation of EVA does not modify the LDPE crystallinity and it will be constant on 12±1 % for all blends of LDPE/EVA. On the other hand, no extra IR bands were found in the blends compared to those of the neat LDPE (Fig. 4), which indicates the absence of degradation and, hence, chemical changes in the matrix during processing which could influence electrical properties such as the dielectric breakdown strength (e.g., oxidation of the polymer).

IV. Conclusion

Some important properties of LDPE modified by EVA blend have been studied. During the modification of LDPE, the EVA content found to cause considerable effect of the electrical properties of LDPE. Results on the surface resistance and volume resistivity revealed that the higher content of EVA in LDPE/EVA blends causes lower than pure LDPE. The maximum values for surface and volume conductivity were observed at 30 wt% of the EVA. Also the breakdown voltage of the blends prepared by mixing of various amounts of EVA with LDPE decrease compared to the purred LDPE, while the permittivity and loss factor increase. Significant changes in dielectric properties of the blends are due to the reinforcement of EVA and strong interaction between EVA and LDPE. The results obtained by FTIR, indicate that the presence of EVA does not exert any influence on the crystallinity of the LDPE.

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