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To study the effect of electron beam and chemical crosslink on electrical properties of pp: epdm: ldpe ternary blends

Chandan A. Fuke, Prakash A. Mahanwar*

Department of Polymer & Surface Engineering, Institute of Chemical Technology, Nathalal Parekh Marg, Matunga, Mumbai- 400019, India

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chandanfuke009@gmail.com
Phone: +91-7709459134

Abstract

Electron beam curing is the growing field of technology for ecofriendly high rate of crosslinking of polymer. Thermoplastic vulcanizates are one of the leading polymers and blends used in varied industries. The chemical crosslinked polyolefins are used as insulating coatings for high voltage transmitters. The present paper exploits the possibilities of developments of alternative material to conventional PVC so as to have green cable. Present paper presents the effect of polymer component concentration, electron beam dosage and chemical crosslinking on electrical and mechanical properties of neat polymers as well as ternary blends. It is found the PP: EPDM: LDPE ternary blend with electron beam crosslinked with 100 kGy shows superior electrical, mechanical properties as compared to conventional PVC coating.

1. Introduction

Blending polymers has become a remarkable way for producing new materials with tailor made properties. To focus to make them applicable for application such as wire and cable insulation, E-devices, and automotive application. Among them mostly thermoplastic elastomer blend has been used for such kind of application [1–4] e.g. LDPE/EPDM, PP/EPDM, LLDPE/EPDM and Silicone based blends [5–8]. However, this approach is complicated by the fact that polymer blends are generally thermodynamically immiscible. Thus, achieving compatibilization of immiscible polymer blends has been a long-standing academic and technological challenge. In the last decades, in spite of the large number of studies on the compatibilization of binary polymer blends, few studies have considered ternary or multi-component polymer blends. In order to distinguish with the vocabulary used in literature, a 'ternary polymer blend' in this work consists of three immiscible components, which are non-reactive or chemical affinity towards each other. Many ternary blends reported in literature contain at least two miscible phases and/or one of the components is a compatibilizer. They received less consideration on ternary or multi-component blends may arise from the difficulty of compatibilization in such systems, especially the preparation of an effective compatibilizer for such blends. There are some researchers reports concerned with mixtures of three or more polymer (not including the compatibilizers), some have treated mixtures where some of the polymers are either miscible or have an affinity for others in the blend. An example is acrylonitrile-butadiene-styrene /poly (phenylene ether)/polystyrene (ABS/PPE/PS). Polyphenylene ether(poly(2,6-dimethyl-l,4-phenylene ox-ide)) is miscible with polystyrene in all proportions, and if the acrylonitrile content of the ABS is limited, no compatibilizer at all is needed. The same is true for the ternary blend, PPE/PS/SAN (styrene-acrylonitrile), polycarbonate/poly (ethylene terephthalate)/poly (butylene terephthalate) (PC/PET/PBT) [9–11]. Polycarbonate is partially miscible with poly (butylene terephthalate), polycarbonate/poly (vinylidene fluoride)/ poly (methyl methacrylate) [12,13]. Poly (vinylidene fluoride) and poly (methyl methacrylate) are miscible, and poly (m-ethyl methacrylate) is sufficiently compatible with polycarbonate that further compatibilization was unnecessary. Mixtures of polyolefins also have kinship with this group. At the other extreme are mixtures that are so complex as to obscure compatibilizer interaction [14–16].

This project deals with the development of polymeric material based on PP/LDPE/EPDM blends. Mechanical and electrical properties are an important property which deciding factor for materials selection. The continuing growth in the use of plastics for engineering and other applications is due in no small measure to the development, during the past five decades, of new and tougher plastics materials. The problem facing the raw materials manufacturer is not simply to increase properties. Improvements in fracture resistance must be achieved without undue impairment of other properties; nor must costs be neglected. For many applications, the requirement is for a moderately priced polymer which can be molded easily, and which exhibits adequate properties over a wide range of temperatures. Most of the major plastics manufacturers have dedicated a significant part of their research and effort to the search for materials with these features. Extensive research and progress work have therefore been carried out to formulate polymers with higher properties.

2. **Material and Methods**

2.1. Material

Ethylene-propylene diene elastomer (EPDM, NORDEL IP 3722P grade) with 71% ethylene content, 0.5% ENB, Mooney Viscosity, ML 1 + 4 at 125 ^{0}C (ASTM D1646) 18 and density of 0.87 g/mL has been supplied by Dow chemical. LDPE (MFI 1.85 gm/10min, density of 0.922 gm/cc) in form of pellets has been supplied by Reliance Petrochemicals. PP (MFI 4.16 gm/10min, density of 0.90 gm/cc) in form of pellets has been supplied by Reliance Petrochemicals. Dicumyl Peroxide (DCP) having purity 98% and Vinyl trimethoxysilane (VTMO) from S D Fine Chemical Limited, Mumbai.

2.2. Blend preparation

The based polymers EPDM, PP, LDPE are preheated at 80^{0}c for 4 hr. in air circulating oven. As shown in table no. 1 LDPE, PP and EPDM in different weight proportions with DCP These polymers were crosslinked by melt blend using APV baker twin screw extruder with RPM 60 and temp. 210°C. For further study, dumble-shaped specimens are prepared by compression molding at 210°C and pressure 120kg/cm^2 in a hydraulic compression molding machine. The sample thickness of 2 mm was controlled using the frames of different standard thickness.

Table 1: Different composition of LDPE/PP/EPDM blends with DCP

	LPE	**LPE 0.2**	**LPE 0.4**	**LPE 0.6**
LDPE (gm)	40	40	40	40
PP (gm)	40	40	40	40
EPDM (gm)	20	20	20	20
DCP (phr)	-	0.2	0.4	0.6
VTMO (phr)	-	0.2	0.2	0.2

In this study, sample codes for LDPE, PP and EPDM are considered as “L,” “P,” and “E.” The blends of LDPE, PP and EPDM are written as LPE. The base polymer keeps constant and DCP percentage varying like 0.2, 0.4 and 0.6 represented as LPE 0.2, LPE 0.4 and LPE 0.6 respectively. For irradiation codes are LPE 50kGy, LPE 100kGy and LPE150kGy for dose 50, 100, 150 kGy respectively.

2.3. Electron Beam Irradiation

The compression molded dumble-shaped specimens of 2 mm thickness are irradiated by high energy electron beam in an inert environment using 5MeV electron beam accelerator at a radiation dose of 50,100, and 150 kGy (kilo Grey) at dose rate of 2.5 kGy/pass. The distance of the sample from the scan horn is 20 cm and the conveyer speed are set at 10 Hz.

3. Characterization

3.1. Gel Content

Gel content of control blends and composites are measured by Solvent extraction technique using xylene as solvent. The samples are extracted in hot Xylene for 48 hrs. at 110 ^{0}C. Extracted samples are dried in a vacuum oven at 80 0C till constant weight. The gel content (% gel fraction) is determined using the following formula:

$$(\%) Gel\ Content\ \frac{Weight\ after\ extraction}{Weight\ before\ extraction}\ X\ 100$$

3.2. Mechanical Properties

3.2.1. ***Tensile Properties***

Tensile testing was carried out by using a universal testing machine (LLOYD Instrument LR 50 K) following ASTM D 638 standard. The cross-head speed was maintained at 50 mm/min. Sample dimension is LO (length overall) × We (width narrow section) × T (thickness) = 115 mm × 5mm× 2 mm. The average tensile properties of four replicas are reported here.

3.2.2. ***Hardness.***

Hardness of polymer blends is measured using Shore "A" Durometer following ASTM D 2240. The specimen was first placed on a hard-flat surface. The indenter for the instrument was then pressed into the specimen making sure that it was parallel to the surface. The hardness was read within 1 sec of firm contact with the specimen.

3.3. Dielectric Strengths

The dielectric strength for test specimens was determined as per IEC-60243-1 (ASTM D 149) standard at 250 V and 50 Hz. The voltage at which dielectric breakdown occurs is read as dielectric breakdown voltage. Dielectric breakdown strength (kV/mm) is calculated from the ratio of dielectric breakdown voltage (kV) to the thickness of the specimen (mm).

$$Dielectric\ Strength\ \left(\frac{kV}{mm}\right) = \frac{Breakdown\ Voltage}{Thickness}$$

3.4. Volume and Surface Resistivity

The volume and surface resistivity for test specimens are measured as per ASTM D257 using a test cell along with mega ohm meter (Make Prestige Electronics, Mumbai, India). A sample of circular-type specimen is used for measurement. The surface resistivity is measured by applying 500 V DC between main and guard electrode. The similar procedure is adopted for the volume resistivity. Volume resistivity was calculated using the following formula and measured as per ASTM D-257-66.

$$Volume\ Resistivity\ (ohm\ cm) = \frac{AR}{t}$$

Where A is the area of upper electrode, R is the resistance (in ohm) between upper and lower electrode, and t is the thickness (in cm) of the test specimen

Surface resistivity measurements assume the applicability of Ohm's law

$$Surface\ Resistivity = \frac{PR}{d}$$

where, R the resistance, P the effective perimeter of the guarded electrode, d the width of the gap.

4. Results and discussion

4.1. Gel Content

Gel content is the measurement of the degree of crosslinking in cross-linked polymers. The crosslinking capability of chemical and radiation crosslinking blend i.e. LPE 0.2, LPE 0.4, LPE 0.6, LPE 50kGy, LPE 100kGy, and LPE 150kGy are determined from the gel fraction analysis represented in figure no 1. Higher the gel content higher will be the crosslinking, as the gel content is measure of degree of crosslinking. from over all observation it can be believed that the blend having the higher percentage of peroxide i.e. dicumyl peroxide shows higher degree of crosslinking (gel content). As the crosslinking increase because of formation three-dimensional crosslinked network structure. While in case of radiation crosslinking the as irradiation doses increase the gel content increase means crosslinking increase[17]. There is significant change in both radiation and chemical crosslinking. Radiation crosslinking comparatively higher than that of chemical crosslinking.

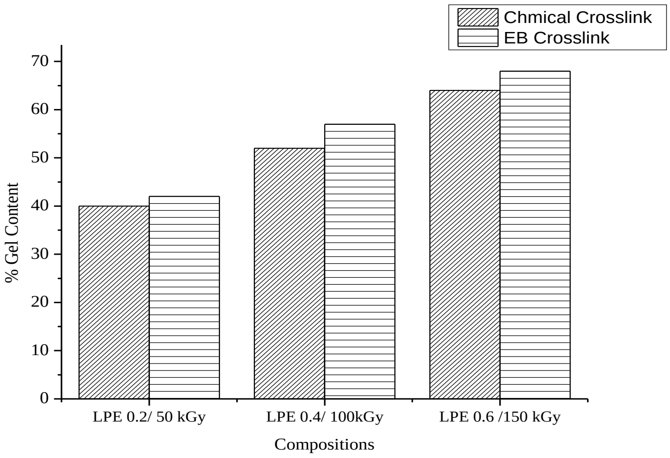

Figure 1: *Gel content of LPE blends*

4.2. Mechanical properties

4.2.1. Tensile Properties

The mechanical properties such as tensile strength, elongation at break, modulus and hardness of blends i.e. LPE, LPE 0.2, LPE 0.4, LPE 0.6, LPE 50kGy, LPE 100kGy, and LPE 150kGy. It indicates that with an increase the peroxide content into the blends the tensile strength, modulus and hardness increase, and there has been gradually decrease in elongation. By the addition of DCP the mechanical properties have been improved, due to the crosslinking and formation of crosslinked structure. DCP proved crosslinking sides, so its improved immiscibility. Durometer hardness test does not serve well as a predictor of other properties such as strength or resistance to scratches, abrasion, or wear, and should not be used alone for product design specifications. Electron beam irradiation increase the all mechanical properties because irradiation gives better properties than that of chemical crosslinking. Because of radiation crosslinking gives more crosslinking structure which is proved from gel content results.

Table 2: mechanical properties of LPE blend system

	Tensile Strength (Mpa)	**Young's Modulus**	**% Elongation**	**Hardness Shore D**
LPE	4.58	3.49	184	61
LPE 0.2	5.74	4.27	176	68
LPE 0.4	7.27	4.71	131	70
LPE 0.6	8.63	5.62	93	74
LPE 50 kGy	5.92	4.83	172	63
LPE 100 kGy	8.17	5.34	143	70
LPE 150 kGy	9.25	6.31	87	78

4.2.2. ***Hardness***

Hardness values of crosslinked and un-crosslinked blends are rep-resented in histogram (Figure 2). Similar trends in hardness have been observed as in tensile strength and modulus. The pure LEP shows hardness of 67. In the blend composition as the percent-age of crosslinking increases the hardness increases. But after EB crosslinking, hardness value for all blends goes up marginally.

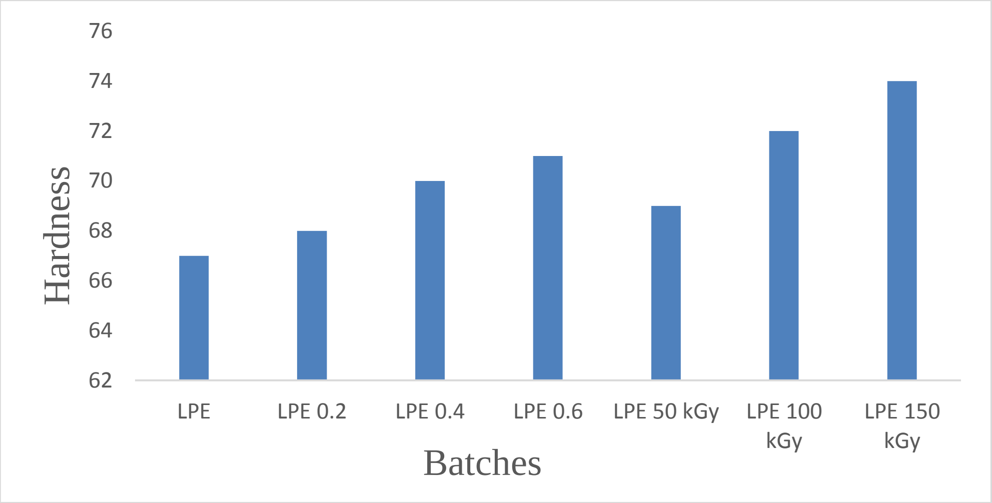

Figure 2: Hardness of LPE blends

4.3. Electrical Properties

The dielectric properties describe the electrical insulation behaviour of polymeric material. The electrical properties i.e. dielectric constant, dielectric strength, volume and surface resistivity for LPE, LPE 0.2, LPE 0.4, LPE 0.6, LPE 50kGy, LPE 100kGy, and LPE 150kGy are represented in table no 3. from over all observation it can be believed that dielectric strength increases as the DCP content increases, but up to 0.4 % then there was slight decrease in the properties because of higher crosslinking there might be the degradation start. This same trend observed in irradiation crosslinking also. LDPE and PP has poor radiation resistivity generally this polymer can withstand up to 100 kGy. In volume and surface resistivity the increase in the both properties as the crosslinking increases[18]. After irradiation chain crosslink network is formed so there might be no chance of formation of charge carrier under applied electric field and polymer become insulating material.

Table 3: Electrical properties of LPE blend systems

	Dielectric Constant	**Dielectric Strength (kv/mm)**	**Volume Resistivity (Ω-m)**	**Surface Resistivity (Ω)**
LPE	2.115	22	2.14 *10^3	4.75 *10^3
LPE 0.2	2.241	24	4.61*10^3	7.94*10^4
LPE 0.4	2.537	27	1.84*10^4	2.47*10^5
LPE 0.6	2.496	26	8.62*10^4	1.07*10^5
LPE 50 kGy	2.307	23	5.73*10^3	6.67*10^4
LPE 100 kGy	2.628	28	3.94*10^4	3.64*10^5
LPE 150 kGy	2.359	25	8.97*10^4	9.02*10^4

Conclusion

The overall study deals with the investigation of Effect of chemical and electron beam crosslinking on LDPE/PP/EPDM blend system. The gel contents progressively increase with the increase in electron beam irradiation dose and percentage of DCP. Electron beam enhance the crosslinking as compared to chemical crosslinking because of higher crosslinking efficiency of EB irradiation. Same trend observed in mechanical properties, tensile strength, and modulus increases. While the elongation decreases with an increase the crosslinking percentage. Electrical properties of LPE 100 kGy and LPE 0.4 shows higher dielectric properties, while increase DCP and irradiation dose the slight decreases the dielectric properties. Surface and volume resistivity of LPE system has been gradually increases as the crosslinking percentage increases, because of no charge formation after crosslinking.

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