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# Study on the Compatibility and Mechanical Properties of BR-LDPE-PVC Blends

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**Abstract.** A series of ternary polymer blends of polybutadiene rubber (BR), low density polyethylene (LDPE) and poly (vinyl chloride) (PVC) were prepared and characterized. Our aim of the work is to study the compatibility and mechanical properties of dicumyl peroxide (DCP) and sulfur (S) cured blends. The scanning electron microscopic (SEM) study supports the morphology of the blends. Tensile test results for all blends samples are compared. From tensile strengths data, it was found that the tensile strength (TS) BR-LDPE-PVC ternary blends are higher than BR-LDPE blends. Result also indicated that the DCP is better curing agent than sulfur for these ternary blends.

**Keywords:** Polymer blends**,** polybutadiene rubber, compatibility, LDPE, PVC

## 1. Introduction

In recent years, economic, technological, and other regulatory pressures have gradually narrowed the further development of new chemical varieties of polymers.

A blend can offer a set of properties that may give it the potential of entering application areas not possible with either of the polymer comprising the blends [1]-[3].

The use of polymer blends for industrial applications has become more prevalent over the past few decades. Today, polymer blends are widely used in the tire, mechanical goods, and adhesive industries. The main reason for the wide acceptance of elastomer blends is the fact that it is possible to obtain the right compromise of finished product properties by blending two or more elastomers at a certain optimum composition. Many elastomers that are dissimilar in chemical structure are blended to improve processibility, performance, durability, physical properties, and to achieve an economic advantage. Elastomers with similar polarities and solubility characteristics can be easily combined to produce a miscible polyblend [4]. The miscibility may be achieved through specific interaction, for example, (i) repulsive, (ii) dipole–dipole, (iii) ion–dipole, (iv) ion–ion, hydrogen bonding, and (v) chemical reaction between the reactive blend constituents [5]. The commercially useful polymer–polymer combination is linked by intermolecular forces such as van der Waal's forces or dipole moments and exhibits sufficient thermodynamic compatibility to prevent the polymer phases from separating during melt processing [6].

In this paper, our aim is to investigate the compatibility and mechanical properties of BR-LDPE-PVC blends by melt mixing using DCP and sulfur as curing agents

## 2. Experimental

### 2.1. Materials

Polybutadiene Rubber (BR), Low Density Polyethylene (LDPE), Plasticized Poly (Vinyl Chloride) (PVC) are obtained from Qingdao, P.R. China. The technical specifications of these polymers are as follows: LDPE: General purpose grade, weight-average molecular weight $1.0x10^5$, MFR = 25 g/min, density = 0.90 g/cc.

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PVC: plasticized with 25% (by volume) of DOP (dioctylphthalate), general purpose grade, weight average molecular weight = $1.2x10^5$, MFR = 1.5 g/min, density = 1.27 g/c.c., Zinc Oxide, Steric acid, Dicumyl peroxide (DCP), N-Cyclohexyl-2-benzothizazole sulfonamide (CBS), Sulfur (S) were all commercial grade.

## 2.2. Preparation of BR-LDPE blends

Blends of polybutadiene rubber (BR) and low density polyethylene (LDPE) were prepared by melt mixing of polymers on a Haake Rheocoder model RHEOCORD 90 at a rotor speed 60 rpm at 135±2 $^{O}$C. LDPE was added and 1 minute was given for its melting, then BR in the form of small sheet was added, and three more minutes were given for blending.

BR-LDPE-PVC blends were prepared on a Haake Rheocoder employing a rotor speed of 60 rpm and a temperature of 140±2 $^{O}$C. LDPE and PVC was first melted and homogenized for 1 minute and then masticated BR was added, then mixed for 3 minutes. The formulation of BR-LDPE and BR-LDPE-PVC blends (both sulfur curing and DCP curing) are presented in Table 1 and Table 2 The preshaped sheets of the compounded polymers were prepared in the two roll laboratory size open mill followed by molding at 150 $^{O}$C under a pressure 40±2 kg/cm$^2$ for the respective cure time ($t_{90}$) as obtained by moving die rheometer

Table 1: The formulation of sulfur cured BR-LDPE-PVC blends

| Ingredients (phr) | Mix Number | | | | |
|---|---|---|---|---|---|
| | A1 A2 A3 | B1 B2 B3 | C1 C2 C3 | D1 D2 D3 | E1 E2 E3 |
| BR | 100 | 75 | 50 | 25 | 0 |
| LDPE | 0 | 25 | 50 | 75 | 100 |
| PVC | 0, 15, 20 | 0, 15, 20 | 0, 15, 20 | 0, 15, 20 | 0, 15, 20 |
| ZnO | 5 | 5 | 5 | 5 | 5 |
| Stearic acid | 2 | 2 | 2 | 2 | 2 |
| CBS | 1 | 1 | 1 | 1 | 1 |
| Sulfur | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |

Table 2: The formulation of DCP cured BR-LDPE-PVC blends

| Ingredients (Phr) | Mix Number | | | | |
|---|---|---|---|---|---|
| | A1 A2 A3 | B1 B2 B3 | C1 C2 C3 | D1 D2 D3 | E1 E2 E3 |
| BR | 100 | 75 | 50 | 25 | 0 |
| LDPE | 0 | 25 | 50 | 75 | 100 |
| PVC | 0, 15, 20 | 0, 15, 20 | 0, 15, 20 | 0, 15, 20 | 0, 15, 20 |
| ZnO | 5 | 5 | 5 | 5 | 5 |
| Stearic acid | 2 | 2 | 2 | 2 | 2 |
| DCP | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |

## 2.3. Test methods for different properties

The surface morphology of BR-LDPE and BR-LDPE-PVC blends were studied by using SEM of JEOL JSM-6700 scanning microscope.

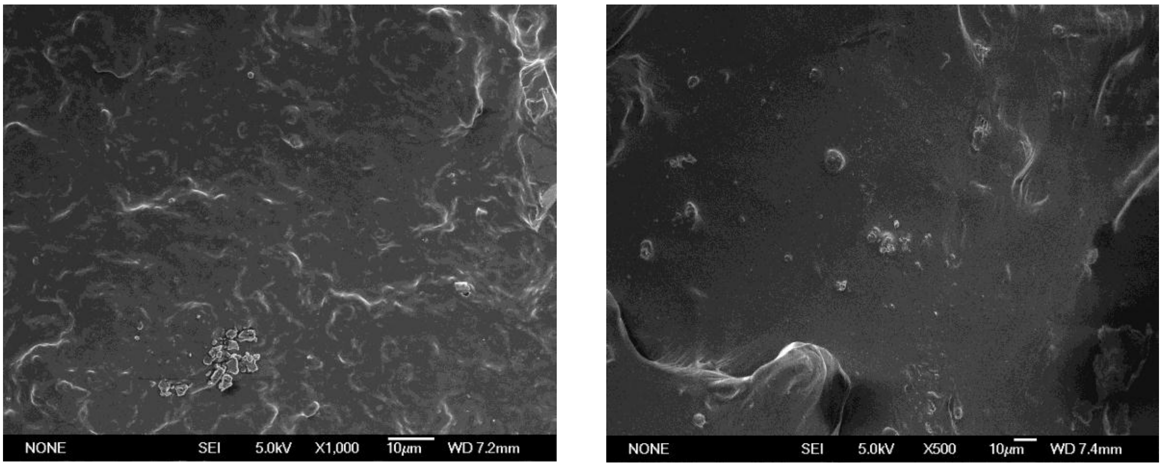
The mechanical properties like tensile strength (TS) and elongation at break (EB) were carried out according to the standard ASTM D 412-51 T procedure using dumbbell-shaped specimens at room temperature by Gotech AI 7000M Universal Tensile Machine (UTM), Japan with jaw separation speed of 60 mm/min. The hardness was measured using a Shore D Durometer. At least four specimens per sample were tested for each property and the mean values are reported.

# 3. Results and Discussion

## 3.1. Morphological study

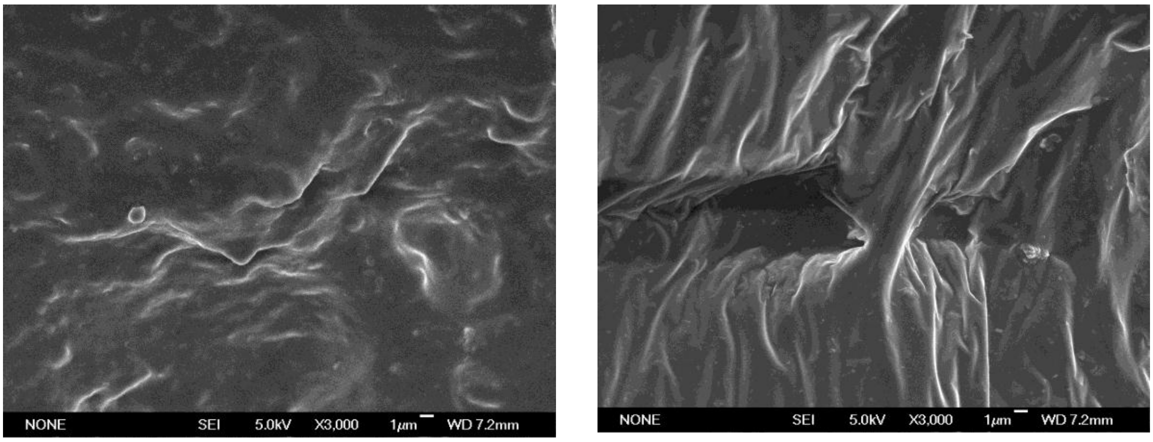
The morphology as observed from the fracture surface of the BR-LDPE and BR-LDPE-PVC blends exhibit a homogenous distribution of polymers in presence of 15 phr PVC (Figs. 1 & 2). The homogenous distribution of NR-BR-LDPE blends was also observed by Joseph *et al* [6]. These results indicate that PVC has better capability to compatibilize with LDPE and BR. It has also been observed that morphology of DCP cured blends much better than sulfur cured blends.

The scanning electron micrographs (SEM) of DCP cured blends suggested that the minor phase domain size decreases on increase of the concentration of PVC. This type of morphology is likely to improve the mechanical properties of the blends as the dose level increases, which may be due to uniform distribution of the blend components as well as the compatibilization at the polymer/polymer interface.




(a) (b)

Fig. 1: (a) 75BR/25LDPE sulfur cured blend; (b) 75BR/25LDPE/15PVC sulfur cured blend




(a) (b)

Fig. 2: (a) 75BR/25LDPE DCP cured blend; (b) 75BR/25LDPE/15PVC DCP cured blend

## 3.2. Mechanical properties

The changes of mechanical properties of the blends can be explained from the compatibility point of view. Better compatibility of blends in presence of PVC reflects in higher improvement of mechanical properties (Table 3 and Table 4). From Table 3 and Table 4 it has been observed that the mechanical properties of DCP cured BR-LDPE-PVC blends are better than sulfur cured blends having same composition. The mechanical property such as TS was found to be best for composition of 75BR/25LDPC/15PVC sulphur cured blend (Table 3). The decrease of mechanical properties at high dose of LDPE may be due to the presence of uncured LDPE phase, since LDPE phase does not get cured in presence of sulfur. The hardness of both sulfur and DCP cured blends increases with the increase of the amount of LDPE. This may be due to thermoplastic character of LDPE. When compared to BR-LDPE blends the tensile strength and hardness of these ternary blends are marginally superior.

Table 4 shows that mechanical properties of DCP cured blends. Results indicate that tensile properties and hardness DCP cured BR-LDPE-PVC blends are comparatively higher compared to same blends prepared with sulfur as curing agent. This may be due to the curing of LDPE phase in presence of DCP as curing agent.

Table 3: Mechanical properties sulfur cured BR-LDPE-PVC blends

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| BR | 100 | 75 | 50 | 25 | 75 | 50 | 25 | 75 | 50 | 25 |
| LDPE | - | 25 | 50 | 75 | 25 | 50 | 75 | 25 | 50 | 75 |
| PVC | - | - | - | - | 15 | 15 | 15 | 20 | 20 | 20 |
| Tensile strength ($N/mm^2$) | 1.38 | 6.41 | 5.83 | 5.16 | 7.50 | 6.03 | 5.16 | 5.48 | 5.30 | 3.60 |
| Elongation at break (%) | 270.0 | 363.10 | 462.37 | 331.62 | 215.62 | 285.18 | 273.65 | 350.75 | 360.50 | 205.12 |
| Hardness | 52 | 55 | 66 | 82 | 69 | 82 | 89 | 67 | 79 | 88 |

Table 4: Mechanical properties DCP cured BR-LDPE-PVC blends

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| BR | 100 | 75 | 50 | 25 | 75 | 50 | 25 | 75 | 50 | 25 |
| LDPE | - | 25 | 50 | 75 | 25 | 50 | 75 | 25 | 50 | 75 |
| PVC | - | - | - | - | 15 | 15 | 15 | 20 | 20 | 20 |
| Tensile strength ($N/mm^2$) | 2.55 | 6.88 | 6.14 | 5.58 | 8.30 | 6.40 | 5.96 | 7.03 | 5.92 | 4.32 |
| Elongation at break(%) | 347.81 | 359.56 | 371.83 | 462.37 | 352.00 | 346.87 | 248.96 | 273.00 | 255.58 | 291.62 |
| Hardness | 55 | 66 | 70 | 86 | 70 | 84 | 88 | 65 | 73 | 87 |

## 4. Conclusion

From this study it have been concluded that:

1. Homogenous compatible blends can be obtained from BR-LDPE-PVC by using sulfur and DCP curing agents with good mechanical properties.
2. DCP cured blends posses higher tensile strength and hardness compared to sulfur cured blends.
3. 75/25 BR-LDPE and 75/25/15 BR-LDPE-PVC blends are found to be suitable for best composition.

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