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**Thermal Conductivity and Thermal Diffusivity of  
Thermoplastic Elastomeric Blends of  
Styrene Butadiene Rubber/High Density Polyethylene:  
Effect of Blend Ratio and Dynamic Crosslinking**

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**Abstract:** The thermal conductivity and thermal diffusivity of the blends of HDPE and SBR of different compositions were simultaneously measured at room temperature and normal pressure by Transient Plane Source (TPS) method. It has been found that the addition of SBR to the HDPE decreases its thermal conductivity and thermal diffusivity. Various theoretical models such as Parallel, Series, Geometric-Mean, Agari, Rayleigh-Maxwell, Meredith-Tobias etc. of two phase systems have been used to predict the thermal conductivity of the blends. The experimental values of thermal conductivity of SBR/HDPE blends showed a closest approximation to the Rayleigh-Maxwell model at low SBR content and to Geometric-Mean model at high SBR content. The effect of sulfur and mixed crosslinking systems on the above parameters was also evaluated.

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**Key words:** Blends, thermal conductivity, thermal diffusivity, vulcanization

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### Introduction

The study of thermal transport properties such as the thermal conductivity and thermal diffusivity of polymeric materials is important because of the crucial role played by these properties in both processing stages and product applications. Thermal conductivity describes the ability of materials to transport heat. The thermal diffusivity is the thermo physical parameter which characterizes the rate of temperature diffusion in the material due to heat flux in the unsteady state heat transfer process and is an important parameter influencing the rate of heating and cooling of solid bodies during the manufacturing process. It is closely related to the thermal conductivity according to the formula  $K = \lambda/\rho C$  where,  $\lambda$  is the thermal conductivity,  $\rho$  is the density and  $C$  is the specific heat. The value of thermal conductivity and thermal diffusivity are required for heat flow calculations, the determination of structure property relationships and material selection and comparison. Thermal conductivity plays an important role in the understanding of structural and dynamical differences between amorphous and crystalline materials. Contribution from variables such as the nature and extent of crystallinity, molecular orientation, the position of  $T_g$  with reference to the operating temperature and the presence of additives require recognition of different mechanism of heat conduction. Frequently these properties also exhibit a strong dependence on temperature and pressure. Crystalline polymers have higher conductivities and diffusivities than amorphous polymers, reflecting the increased order

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and high density, which provide more optimal pathways for thermal transport. Despite the importance of this quantity, thermal diffusivity data are available in the literature only for a limited number of substances (Agari *et al.*, 1997; Killian *et al.*, 1978; Hatta *et al.*, 1985). Most polymers are insulating systems, therefore any electronic effects are absent in them and heat conduction occurs as a result of lattice vibrations. In polymers heat is conducted by two mechanisms (Bala *et al.*, 1990). Molecular transmission or molecule-to-molecule transfer of energy occurs by the excitation of adjacent groups, i.e., by the translation, rotation or vibration of energized groups. Such a process is diffusional in nature and is relatively slow, contributing to the thermal conductivity of an amorphous solid. The second mode of heat conduction is due to the lattice vibration within a crystalline structure (intra molecular), in which thermal excitation creates waves of disturbance often referred to as phonons. This gives rise to a more efficient transfer of heat. In polymers both mechanisms of heat conduction may operate at the same time. Generally polymers exhibit strong temperature dependent properties, the relative contribution of each mechanism may vary with temperature.

Various attempts have been made to measure the thermal conductivity of polymeric materials (Bhowmick and Pattanayak, 1990; Saxena, 1990; Hatta *et al.*, 1998). Agari *et al.*, (1993, 1987, 1986, 1991) published a series of articles on the thermal conductivity of polymer blends. In this paper the thermal conductivity and thermal diffusivity of SBR/HDPE blends at room temperature, with specific reference to blend composition, dynamic crosslinking with sulfur crosslinking system and a mixed system, composed of sulfur and dicumyl peroxide (S+DCP) were reported. The applicability of different models for the thermal conductivity of two phase systems are examined by considering the polymer blend as a composite.

## **Materials and Methods**

### *Materials*

SBR used for the experiment was synaprene-1502 grade, supplied by Synthetics and Chemicals, Ltd., Bareilly (U.P) India. HDPE was injection grade (with trade name Relene) having MFI 20 g/10 min. The material was supplied by Reliance industries Ltd. Hazaria, Gujarat, India. All other additives such as sulfur (S), dicumyl peroxide (DCP), zinc oxide (ZnO), N-cyclohexyl benzothiazyl sulfenamide (CBS) and stearic acid were of commercial grade. The characteristics of the starting polymers are given in Table 1.

### *Method of Preparation of Blends*

Blends of HDPE and SBR were made by melt mixing in a Brabender plasticorder with a rotor speed of 60 rpm, at a temperature of 180°C. First HDPE was melted for two minutes then SBR was added. The mixing was continued for another six minutes. In the case of crosslinked blends after melting HDPE, SBR was added and blending was continued for 2 min followed by the addition of the additives and the blending was continued for further 4 min. Cylindrical samples of diameter 3 cm and thickness 1.2 cm were prepared by compression molding in polished molds of an electrically heated hydraulic press at the same blending temperature by giving pressure on the mold surface for 4 min. Moldings were then cooled under compression by passing cooled water through the molds. SBR/HDPE blends with 0, 30, 40, 50, 60 and 100% of SBR were designated as S<sub>0</sub>, S<sub>30</sub>, S<sub>40</sub>, S<sub>50</sub>, S<sub>60</sub> and S<sub>100</sub>, respectively. The cross linked blends were designated as S<sub>30</sub>S, S<sub>50</sub>S, S<sub>60</sub>S, S<sub>30</sub>M, S<sub>50</sub>M, S<sub>60</sub>M etc. where the suffix S denotes the sulfur crosslinking system and M denote the mixed system. The compounding recipe for dynamic vulcanization is given in Table 2.

Table 1: Blend materials and their characteristics

Material	Characteristics	Source
High density polyethylene Injection grade (Relene) (-CH <sub>2</sub> -CH <sub>2</sub> -CH <sub>2</sub> -) <sub>n</sub>	MFI 20 g min <sup>-1</sup> Density 0.964 g/cc	Reliance industries Ltd Hazaria, Gujarat, India
Styrene butadiene rubber (Synaprene 1502 grade) (CH-CH <sub>2</sub> -CH <sub>2</sub> -CH=CH-CH <sub>2</sub> -) <sub>n</sub>	Density 0.938 g/cc Styrene content 21.5-25.5%	Reliance industries Ltd. Bareilly(U.P), India

Table 2: Mpownding recipe of crosslinked blends

Ingredients	Sulfur system	Mixed system
Polymer	100.0	100.0
ZnO	5.0	5.0
Stearic acid	2.0	2.0
CBS*	1.0	1.0
Sulfur	2.2	1.5
DCP**	-	2.0

Note: Values are given in phr. \* N-Cyclohexyl -2- benothiazyl Sulfonamide. \*\* Dicumyl peroxide

*Chracterization by Scanning Electron Microscopy (SEM)*

Phase morphology studies were performed by the use of a scanning electron microscope (Hitachi-Model2400). The samples were cryogenically fractured to avoid any deformation of the phase were immersed in toluene at ambient temperature for a 5 days for the selective extraction of SBR phase without affecting HDPE. The samples were then dried and a thin coating of gold was applied to avoid charging under an electron beam and to improve image resolution. The accelerating voltage of the microscope was 15 kV.

*Method of Determination of Cross-link Density*

The cross-link densities of various vulcanized samples were measured by the equilibrium swelling method by estimating the molar mass  $\mu_c$  between cross-links of the sample using Flory-Rehner theory (Flory, 1953).

$$\mu_c = \frac{-\rho_p V_s V_{rf}^{1/3}}{\ln(1 - V_{rf}) + V_{rf} + \chi V_{rf}^2} \tag{1}$$

Where,  $\rho_p$  is the density of rubber,  $V_s$  is the molar volume of solvent and  $V_{rf}$  and  $\chi$  are the volume fraction of rubber in the solvent swollen sample and the rubber-solvent interaction parameter respectively given by the Eq. 2 and 3.

$$V_{rf} = \frac{(d - fw) \rho_p^{-1}}{(d - fw) \rho_p^{-1} + A_s \rho_s^{-1}} \tag{2}$$

Where,  $d$  is the deswollen weight of the sample,  $f$ , the volume fraction of filler,  $w$ , the initial weight of the sample (here,  $f = 0$ )  $\rho_s$  is the density of the solvent and  $A_s$  is the amount of solvent absorbed. The interaction parameter  $\chi$  is given by

$$\chi = \beta + (V_s/RT) (\delta_s - \delta_p)^2 \tag{3}$$

Where,  $\beta$  is the lattice constant, R is the gas constant, T is the temperature in Kelvin scale  $\delta_s$  and  $\delta_p$  being the solubility parameters of the solvent and polymer, respectively. The values of degree of cross-linking ( $\nu$ ) were determined as  $1/2 \mu_c$  for different samples.

*Method of Measurements for Thermal Conductivity and Diffusivity*

Thermal conductivity and thermal diffusivity of the blends have been simultaneously measured at room temperature and normal pressure using Transient Plane Source (TPS) method. The technique is based on three-dimensional heat flow inside the sample.

*Theory of the TPS Method*

In the TPS technique the source of heat is a hot disc made out of a bifilar spiral, which also serves as a sensor for the temperature increase in the samples. The description of the apparatus is described elsewhere (Carslaw *et al.*, 1959). Assuming that the conducting pattern is in the y-z plane of a coordinate system placed inside an infinite solid with a thermal conductivity  $\lambda$ , a thermal diffusivity K and a specific heat per unit volume  $\rho C$ , the rise in temperature at a point y,z at time t, due to an output power per unit area Q is given by Carslaw *et al.* (1959) and Gustafsson (1991).

$$\Delta T_{(y,z,t)} = \frac{1}{4\pi^{3/2}a\lambda} \int_0^t \frac{d\sigma}{\sigma^2} \int_A dy' dz' Q \left( y', z', t - \frac{\sigma^2 a^2}{K} \right) \exp \left[ \frac{-(y-y')^2 - (z-z')^2}{4\sigma^2 a^2} \right] \quad (4)$$

where,

$$K(t-t') = \sigma^2 a^2, \theta = (a^2 / K), \iota = (t/\theta)^{1/2}$$

'a' is a constant (radius of the disc) which gives a measurement of the overall size of resistive pattern and is known as the characteristic time. The temperature increase  $\overline{\Delta T(\tau)}$ , because of flow of current through the sensor gives rise to a change in the electrical resistance  $\Delta R(t)$  that is given as:

$$\Delta R(t) = \alpha R_0 \overline{\Delta T(\tau)} \quad (5)$$

where,  $R_0$  is a resistance of TPS element before the transient recording has been initiated,  $\alpha$  is the temperature coefficient of resistance (TCR) and  $\overline{\Delta T(\tau)}$  is calculated by averaging the increase in temperature of TPS element over the sampling time because the concentric ring sources in the TPS element have different radii and are placed at different temperature during the transient recording. Following Gustafsson (1991).

$$\overline{\Delta T(\tau)} = \frac{P_0}{\pi^{3/2}a\lambda} D_s(\tau) \quad (6)$$

where,

$$D_s(\tau) = [m(m+1)]^{-2} = \int_0^\tau \frac{d\sigma}{\sigma^2} \left[ \sum_{l=1}^m l \left\{ \sum_{k=1}^m k \exp \left( \frac{-(l^2 + k^2)}{4\sigma^2 m^2} \right) L_0 \left( \frac{lk}{2\sigma m^2} \right) \right\} \right] \quad (7)$$

$P_0$  is the total output power;  $L_0$  is the modified Bessel function. To record the potential difference variations, which normally are of the order of a few milli volts during the transient recording, a simple

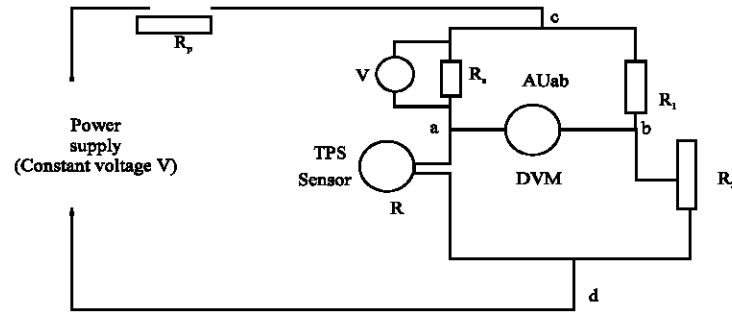


Fig. 1: Bridge circuit diagram for TPS technique.  $R_1$  and  $R_2$  are the resistances,  $R_p$  is the effective resistance of the wires outside the arms of the bridge.  $R$  is the resistance of the TPS element and DVM is the digital voltmeter

bridge arrangement, as shown in Fig. 1 has been used. If we assume that the resistance increase will cause a potential difference variation  $\Delta U(\tau)$  measured by the voltmeter in the bridge, the analysis of the bridge indicates that:

$$\Delta E(t) = \frac{R_s}{R_s + R_0} I_0 \Delta R(t) = \frac{R_s}{R_s + R_0} \frac{I_0 \alpha R_0 P_0}{\pi^{3/2} a \lambda} D_s(\tau) \quad (8)$$

where 
$$\Delta E(t) = \Delta U(t) [1 - C \Delta U(t)]^{-1} \quad (9)$$

and 
$$C = \frac{1}{R_s I_0 \left[ 1 + \frac{\gamma R_p}{\gamma(R_s + R_0) + R_p} \right]} \quad (10)$$

The definition of various resistances is found in Fig. 1.  $R_s$  is a standard with a current rating that is much higher than  $I_0$ , which is the initial heating current through the arm of the bridge containing the TPS element.  $\gamma$  is a constant, which is chosen to be 100 in the present measurement. Calculating  $D_s(\tau)$  using a computer programme and recording the change in potential difference,  $\Delta U(\tau)$ , one can determine  $\lambda$ . Similarly  $K$  can be determined by finding the  $\theta$  values from the transient event.

*Modeling*

There have been several attempts to formulate the thermal Conductivity of a multiphase system where one component forms the continuous phase and the other components dispersed as inclusions. Among them the components in parallel and in series as well as the Geometric-Mean Model are the first approximations for all models.

According to parallel arrangements of components for a two phase system,

$$\lambda = \lambda_m \phi_m + \lambda_d \phi_d \quad (11)$$

where,  $\lambda$  is the thermal conductivity of the blend and  $\lambda_m$  and  $\lambda_d$  are the thermal conductivities of the matrix and dispersed phase, respectively.  $\phi_m$  and  $\phi_d$  are the volume fraction of the matrix and dispersed phase respectively.

For the parallel model heat flow is parallel to each layer and a constant temperature gradient is applied to each phase.

When heat is applied normally to the layers its flow is constant and the temperature gradient across this phase is different. For the series model,

$$\frac{1}{\lambda} = \frac{\phi_m}{\lambda_m} + \frac{\phi_d}{\lambda_d} \quad (12)$$

For all compositions of the two-phase system, the series model has the lowest conductivity and the parallel model the highest. The surfaces of each arrangements perpendicular to the direction of heat flow are assumed to be isothermal.

According to Geometric-Mean Model,

$$\lambda = \lambda_m^{\phi_m} \lambda_d^{\phi_d} \quad (13)$$

According to Agari *et al.* (1993, 1990, 1987, 1986, 1991) model the logarithms of the thermal conductivity of the composition is linearly related to the volume percentage of the inclusions

$$\text{Log } \lambda = A \phi_d + B \quad (14)$$

where

$$A = C_f \log \left[ \frac{\lambda_d}{(C_p \cdot \lambda_m)} \right] \text{ and } B = \log(C_p \cdot \lambda_m) \quad (15)$$

Here  $\lambda_m$  and  $\lambda_d$  are the thermal conductivity of the matrix and inclusions respectively.  $C_f$  and  $C_p$  are the constants and  $\phi_d$  volume percentage of the inclusions. Coefficients  $C_p$  and  $C_f$  in Eq. 15 were calculated by the experimental data from this work and are equal to 0.9014 and 0.7133, respectively.

Considering a random distribution of the dispersed phase, Rayleigh and Maxwell (Choy *et al.*, 1977; Maxwell, 1904) derived the expression for the effective thermal conductivity for a two phase dispersion of spherical particles in a medium of thermal conductivity  $\lambda_m$ . The expression can be written as:

$$\lambda = \lambda_m \left[ \frac{2 - 2\phi_d + (1 + 2\phi_d) \frac{\lambda_d}{\lambda_m}}{2 + \phi_d + (1 - \phi_d) \frac{\lambda_d}{\lambda_m}} \right] \quad (16)$$

where the symbols have their usual meaning.

Considering a homogeneous distribution of the dispersed phase, Meredith and Tobias (1960) calculated the effective conductivity of the two-phase material by the following Eq. (17)

$$\lambda = \lambda_m \frac{\left( A - 2\phi_d + 0.409B\phi_d^{1/3} - 2.133C\phi_d^{10/3} \right)}{\left( A + \phi_d + 0.409B\phi_d^{1/3} - 0.906C\phi_d^{10/3} \right)} \quad (17)$$

where,  $A = (2+X)/(1-X)$ ,  $B = (6+3X)/(4+3X)$  and  $C = (3-3X)/(4+3X)$ , where  $X = \lambda_d/\lambda_m$

### Results and Discussion

Thermal conductivities of the pure polymers and their blends were measured and were indicated in Fig. 2. The addition of SBR to HDPE continuously decreases the thermal conductivity of the HDPE matrix. It has been reported that in a two-phase system in which one phase is dispersed in a continuous phase, the former can affect crystallinity of the polymer, producing in changes in thermal conductivity (Agari *et al.*, 1991). Since SBR being amorphous, its random structure interfere with the movement of phonons and the thermal conductivity of the blend becomes lower (Lovell *et al.*, 1981). The thermal conductivity of HDPE continuously decreases with the addition of SBR. A decrease in thermal conductivity by the addition of SBR to Natural Rubber (NR) has been reported by Saxena *et al.* (1999) in the case of SBR/NR blends. It is also clear from Fig. 2 that the thermal conductivity values of SBR/HDPE blends lay below the additivity line, due to the lack of interfacial adhesion between the two phases. The dependence of thermal diffusivity of the blends on wt% of SBR is also depicted in Fig. 2. Thermal diffusivity (K) of the blends exhibits the same trend as obtained in the case of the thermal conductivity values, showing the proportionality between  $\lambda$  and K.

Log of the experimental values of the thermal conductivity of the blends are also plotted as a function of the volume percentage of the dispersed phase and shown in Fig. 3, which confirms the linear pattern (Agari *et al.*, 1993, 1991).

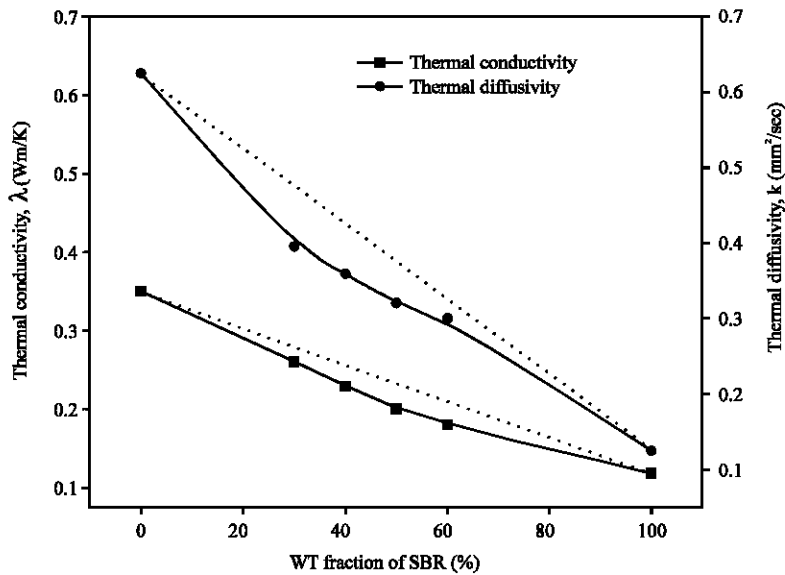


Fig. 2: Dependence of thermal conductivity and thermal diffusivity of the blend on SBR content



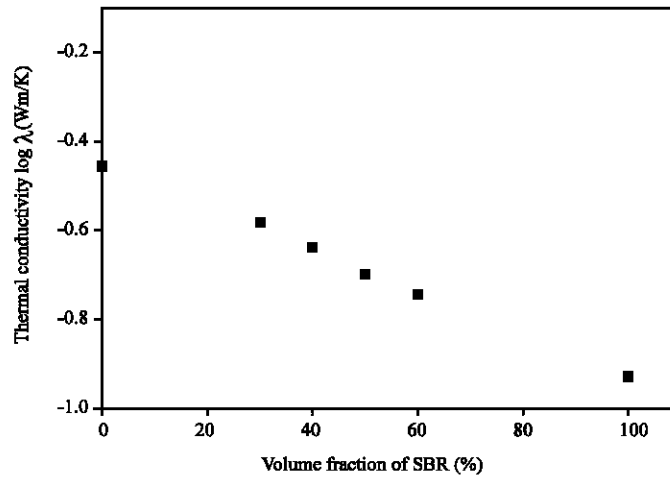


Fig. 3: Log  $\lambda$  versus volume percentage of SBR content

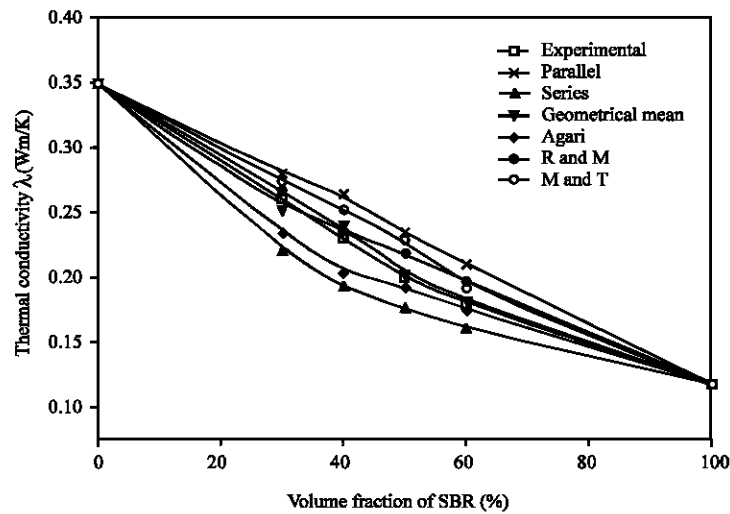


Fig. 4: Theoretical modeling of thermal conductivity of SBR/HDPE blends

Figure 4 shows the comparison between the theoretical values of the thermal conductivity of the blends obtained through different models and the experimental one. It has been found that the experimental values of thermal conductivity of SBR/HDPE blends lie very close to the Rayleigh and Maxwell model at low SBR content (30 and 40 wt.%) and to Geometric-Mean model at high SBR content. Rayleigh and Maxwell considered the shape of the inclusions to be spherical. The closeness of the experimental value of thermal conductivity at low wt.% of inclusions may be due to morphology of the composition. In  $S_{30}$  and  $S_{40}$  compositions the dispersed droplets are more or less spherical as evident from the SEM shown in Fig. 5a and b. However in  $S_{50}$  composition (Fig. 5c) the spherical morphology changes to somewhat elongated pattern followed by an interpenetrating co-continuous morphology at 60 wt.% of SBR content (Fig. 5d).

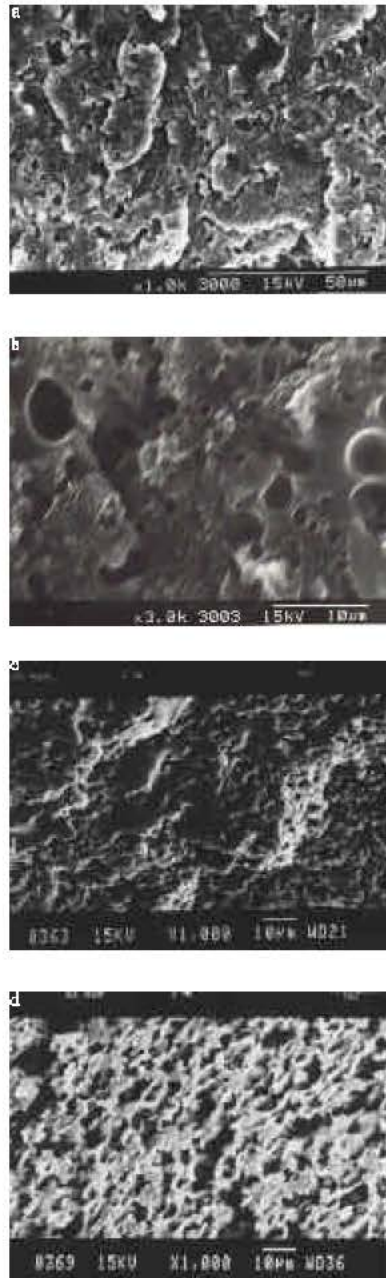


Fig. 5: Scanning electron micrographs showing the morphology of SBR/HDPE blends  
a)  $S_{30}$ , b)  $S_{40}$ , c)  $S_{50}$  and d)  $S_{60}$  compositions

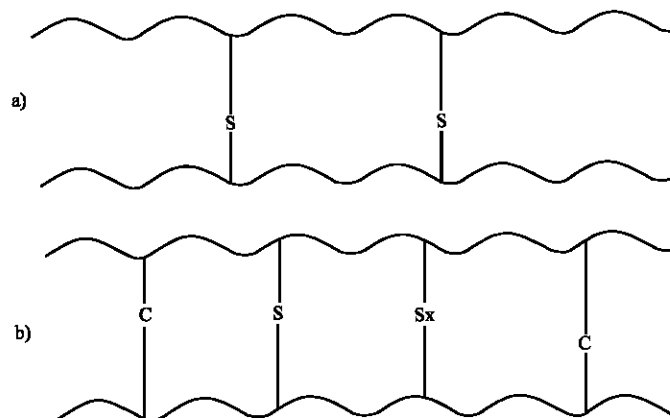


Fig. 6: The schematic representation of the network structures formed by a) sulfur and b) mixed crosslinking systems

The dependence of thermal diffusivity of the blends on wt.% of SBR is also depicted in Fig. 2. Thermal diffusivity (K) of the blends exhibits the same trend as obtained in the case of the thermal conductivity values, showing the proportionality between  $\lambda$  and K.

#### *Effect of Cross Linking*

Dynamic crosslinking is a technique to vulcanize the rubber phase with a thermoplastic while it is being mixed in the melt state. It has been investigated as a way to improve the physical properties of several thermoplastic elastomers based on rubber/plastic blends (Charles *et al.*, 1990; Bhowmick *et al.*, 1988). Dynamic vulcanization reduces the particle size of the rubber phase and the crosslinked rubber particles become uniformly dispersed in the continuous thermoplastic matrix, attaining a stable morphology. In this study two types of crosslinking systems have been used, namely sulfur and mixed (sulfur and peroxide) crosslinking systems. Schematic representations of the crosslinks formed in these two cases are shown in Fig. 6. In the mixed cure system, the crosslinks are provided by both peroxide and sulfur. Crosslinks in peroxide vulcanization is a carbon-carbon bond, which is similar in bond strength to every other bond in the polymer backbone. In sulfur vulcanization, the polysulfidic units become the crosslinks between polymer chains resulting in interchain bonds, which are more flexible and not as strong as the carbon bonds in the polymer backbone. These differences in the nature and mechanism in the crosslinks translate in important physical and process differences in these types of vulcanization.

Effects of sulfur and mixed crosslinking systems on the thermal conductivities of the SBR/HDPE blends were measured and compared with those of the uncross linked blends in Fig. 7. The changes in the thermal conductivities of SBR/HDPE blends in the crosslinked systems can be traced to the extent of crosslinking of the two phases of the blend system. The crosslink densities of different blends are given in Table 3. The extent of crosslinking of the elastomer phase in the blends of present investigation was mixed cure > sulfur cure.

In this study all compositions show a decrease in thermal conductivity upon dynamic crosslinking. Generally an increase in cross link density results in a decrease in thermal conductivity, since adjacent chains are united as a result of the formation of cross links between them

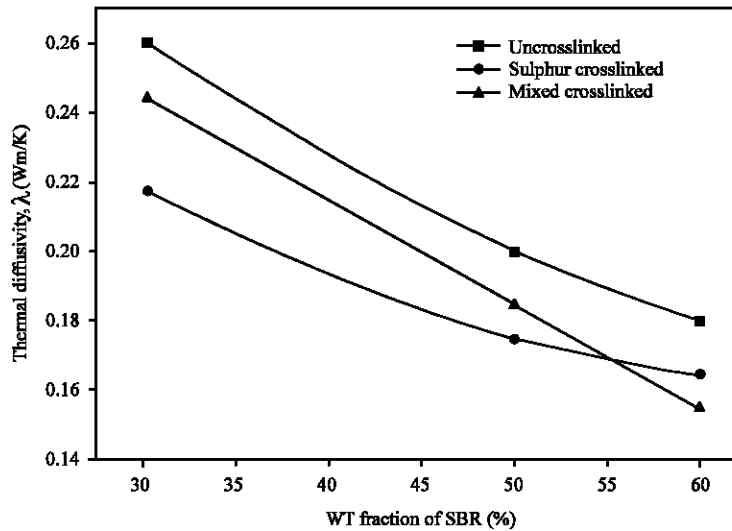


Fig. 7: Comparison of thermal conductivities of crosslinked and uncrosslinked the SBR/HDPE blends

Table 3: Crosslink density of SBR/HDPE blends

System	Crosslink density ( $\nu$ ) (gmol/cc)
S <sub>30</sub> S	$0.126 \times 10^{-3}$
S <sub>50</sub> S	$0.09 \times 10^{-3}$
S <sub>60</sub> S	$0.081 \times 10^{-3}$
S <sub>30</sub> M	$0.362 \times 10^{-3}$
S <sub>50</sub> M	$0.18 \times 10^{-3}$
S <sub>60</sub> M	$0.12 \times 10^{-3}$

(Evseeva *et al.*, 1995). Morgan and Scovell (1977) recently proposed a postulate to this phenomenon. They postulate the existence of one-dimensional wave packets, which travel along the chains and have long mean-free paths. The wave packets may be scattered by chain ends, crosslinks or interactions with other molecules, which reduces the thermal conductivity.

So it is expected that, thermal conductivity to be decreased with increase in crosslink density values. However, in crosslinked S<sub>30</sub> and S<sub>50</sub> compositions, the decrease in conductivity values is not in accordance with their crosslink densities. The crosslink density of S<sub>30</sub>M > S<sub>30</sub>S and that of S<sub>50</sub>M > S<sub>50</sub>S. Here blends crosslinked with mixed system exhibit greater thermal conductivity values than sulfur crosslinked blends. But in S<sub>60</sub> blend as expected, the conductivity value of sulfur cured blend is greater than that of mixed cured one. This behavior can be explained as follows: If the degree of crosslinking is increased the distance between the crosslinks decreases. According to Bermann *et al.* (1969), if the average distance between the cross links was less than the range of the elastic disorder ( $10A^0$ ), thermal conductivity continuously increases with increases in cross link density (which is the case in S<sub>30</sub> and S<sub>50</sub> blends). In a case where this criterion was not satisfied,  $\lambda$  was seemed to decrease with increase in crosslinks (which is the case of S<sub>60</sub> blend).

Thermal diffusivity of the crosslinked SBR/HDPE blends were compared with that of uncross linked blends in Fig. 8. The thermal diffusivity values of the crosslinked blends also show the same trend as that of thermal conductivity.

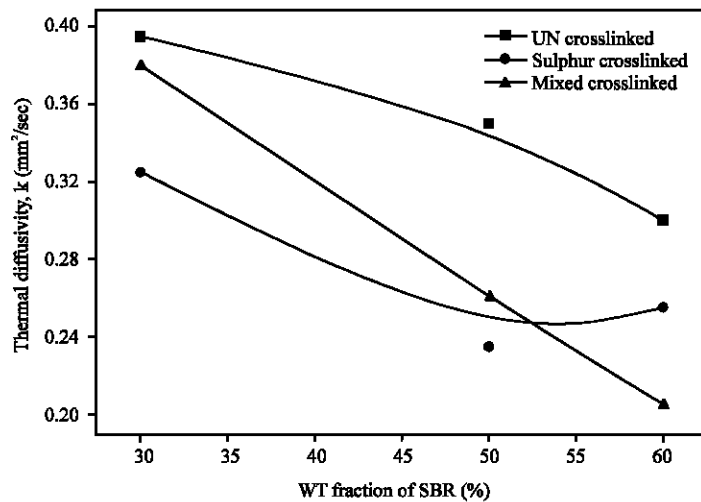


Fig. 8: Comparison of thermal diffusivities of crosslinked and uncrosslinked SBR/HDPE blends

### Conclusions

In conclusion, the addition of SBR to HDPE continuously decreases the thermal conductivity and thermal diffusivity of the blends from that of the HDPE matrix, which is attributed to the superposition effect. Thermal conductivities of the blends were compared with several models from the literature. The experimental values of thermal conductivity of SBR/HDPE blends found to lie very close to the Rayleigh and Maxwell model at low SBR content (30 and 40 wt.%) and Geometric-Mean model at high SBR content. The closeness of the experimental value of conductivity at low wt.% of SBR may be due to the spherical shape of the inclusions in this composition. All compositions show a decrease in thermal conductivity and diffusivity by dynamic crosslinking. The effect of the two cross linking systems is different in different blend compositions. In  $S_{30}$  and  $S_{50}$  compositions, the decrease in conductivity values is not in accord with their crosslink density values. But in  $S_{60}$  blend, thermal conductivity values decrease with the increase in crosslink density of the blend.

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### References

- Agari, Y., M. Shimada and A. Ueda, 1997. Thermal diffusivity and onductivity of PS/PPO blends. *Polymer.*, 38: 2649-2655.
- Agari, Y. and A. Ueda, 1987. Thermal conductivity of PVC/Polycaprolactone blends. *J. Applied Polym. Sci. Part Polymer Phys.*, 34: 1429.
- Agari, Y. and A. Ueda., 1993. Thermal conductivity of a polymer composite. *J. Applied Polym. Sci.*, 49: 1625-1634.

- Agari, Y., A. Ueda, M. Tanaka and S. Nagai, 1991. Thermal conductivities of composites in several dispersion system. *J. Applied Polym. Sci.*, 42: 1665-1669.
- Agari, Y., A. Ueda, M. Tanaka and S. Nagai, 1993. Thermal conductivities of blends of PE/SEBS block copolymer and polystyrene/SEBS Copolymer. *J. Applied Polym. Sci.*, 47: 331-337.
- Agari, Y. and T. Uno, 1986. Estimation on thermal conductivities of filled polymers. *J. Applied Polym. Sci.*, 32: 5705-5712.
- Bala, K., P.R. Pradhan, N.S. Saxena and M.P. Saksena, 1990. Thermal Conductivity and thermal diffusivity of Ebonite. *J. Phys. D: Applied Phys.*, 23: 748-750 .
- Berman, B.L., R.P. Madding and J.R. Dellinger, 1969. Effect of crosslinking on the Thermal conductivity of Polystyrene between 0.3 K and 10 K. *Phys. Lett.*, 30A- 5: 315-316.
- Bhowmick, A.K. and H.L. Stephens, 1988. *Handbook of Thermoplastic Elastomers-new Developments and Technology*, Ch. 2, Marcel Dekker, New York.
- Bhowmick, T. and S. Pattanayak, 1990. Thermal conductivity, Heat capacity and diffusivity of rubbers from 60 to 300 K. *Cryogenics*, 30: 116-121.
- Carslaw, H.S. and J.C. Jaeger, 1959. *Conduction of Heat in Solids*, (Oxford University Press), pp: 510-514.
- Choy, C.L. and K. Young, 1977. A composite model for the Thermal conductivity of semi-crystalline polymers. *Polymer*, 18: 769-775.
- Charles, P.R. and A.S. Sabet, 1990. *Thermoplastic Elastomers from Rubber/Plastic blends*, Chap. 6, Ellis Horwood, NewYork.
- Evsееva, L.E. and S.A. Tanaeva, 1995. Thermophysical Properties of Epoxy composite materials at low temperatures. *Cryogenics*, 35: 277- 279.
- Flory, P.J., 1953. *Principles of Polymer Chemistry*. Cornell University Press, Ithaca, New York, pp: 237-248.
- Gustaffson, S.E., 1991. TPS technique for thermal conductivity and thermal diffusivity measurements in solid materials. *Rev. Sci. Instrum.*, 62: 797-804.
- Hatta, I., Y. Sasuga, R. Kato and A. Maesono, 1985, Thermal diffusivity measurement of thin films by means of an ac calorimetric method. *Rev. Sci. Instrum*, 56: 1643-1647.
- Hatta, I., R. Kato and A. Maesono, 1987. Development of AC Calorimetric method for Thermal diffusivity measurement. *anese. J. Applied Phys.*, 26: 475-478.
- Killian, H.G. and M. Pietralla, 1978. Anisotropy of thermal diffusivity of uniaxial stretched polyethylenes. *Polymer*, 19: 664-671.
- Lovell, M.C., A.J. Avery and M.W. Verson, 1981. *Physical properties of materials*, ELBS and Van Nostrand Reinhold (UK) Co. LTD. Clarendon Press, Oxford, pp: 108-111.
- Maxwell, J.C., 1904. *A Treatise on Electricity and Magnetism*. Clarendon Press, Oxford, pp: 108-111.
- Meredith, R.E. and C.W. Tobias, 1960. Evaluation of the thermal conductivity of rubber composites. *J. Applied Phys.*, 31: 1270-1275.
- Morgan, G.J. and P.D. Scovell, 1977. Effective conductivity of short carbon Fiber-reinforced polychloroprene rubber and mechanism of conduction *Polym. Lett.*, 15: 193-198.
- Reese, W. and J.E. Thucker, 1965. Thermal conductivity and specific heat of some polymers between 4.5 and 1K. *J. Chem. Phys.*, 43: 105-114.
- Saxena, N.S., P.R. Pradhan, K. Suchdev, K. Bala and M.P. Saxena, 1991. Temperature dependence of thermal conductivity and thermal diffusivity of some plastic materials. *High Temperatures- High Pressures*, 23: 303-308.

- Saxena, N.S., P. Predeep, G. Mathew, S. Thomas, S. Gutafsson and S.E. Gustafsson, 1999. Thermal conductivity of Styrene butadiene rubber compounds with natural rubber prophylactics waste as filler. *Eur. Poly. J.*, 35: 1687-1693.
- Simpson, A. and A.D. Stuckes, 1986. Thermal conductivity of porous materials: Theoretical treatment of conduction processes. *Building Services. Eng. Res. Technol.*, 7: 78-86.