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Assessing Effects of Mixing Parameters on Interphases in Blends of Dissimilar Rubbers Using M-TDSC

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A modulated temperature differential scanning calorimetry (M-TDSC) method was used to calculate the mass fraction of interphase and determine its composition in some SBR/BR and NR/BR blends. Effects of mixing time, mixing temperature, rotor speed, silica nanopillar, and mass fraction of core rubbers on the mass fraction and composition of the interphase in the blends were investigated. It emerged that increases in mixing time and temperature, incorporation of the filler in the rubbers, and changes in the blend composition affected the properties of the interphase. Furthermore, M-TDSC was found to be a useful technique for studying interphases in blends of dissimilar as well as partially miscible rubbers and estimating their compositions. The measurements were also sensitive to the mixing conditions, rubber composition and silica filler in the rubbers.

Key words: styrene-butadiene rubber; polybutadiene rubber; natural rubber; physical mixture; rubber blend; mixing conditions; interphase; modulated temperature differential scanning calorimetry.

The expansion and success of the rubber industry worldwide owes a great deal to the hard work and brilliance of rubber chemists who over the years produced a wide range of synthetic rubbers such as styrene-butadiene rubber, polybutadiene rubber and nitrile rubber. These rubbers and many more were subsequently mixed together with natural rubber to produce blends for use in tyre tread compounds, hoses, and conveyor belts13. To increase durability, performance and service life of rubber blended components, it is essential to optimise the interfacial adhesion strength between dissimilar rubbers such as the ones mentioned above. Moreover, this will help to minimise the risk of unexpected sudden joint failure in service, enhance materials selection and joint design as well as improve environment and safety in service.

The formation of any heterogeneous system, e.g., a polymeric one, is accompanied by the formation of an interphase, which determines important properties of that system1. Thermal diffusion between two miscible or partially miscible polymers results in an interfacial phase developing. With increasing diffusion time, in most cases, the thickness of the interphase increases and the concentration profile changes2. The interface is characterised...

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THEORETICAL

The Hill-Platt model was developed in relation to the composition of the universe. It was based on the idea that the universe was composed of simple, building blocks that could combine in different ways to form complex structures. This model proposed that the universe was a hierarchical system, with simple blocks at the base and complex structures at the top. The model was used to explain the diversity of life, including the existence of complex organisms.

In this study, the Hill-Platt model was used to analyze the composition of the universe. The model was applied to various samples, including rocks and minerals, to determine their composition. The results of these analyses were used to support the Hill-Platt model and to refine it further.

There are many other models of the universe that have been developed, but the Hill-Platt model remains one of the most widely accepted. It continues to be used by scientists to understand the composition of the universe and to guide their research.

Summary

The Hill-Platt model of the universe was developed to explain the diversity of life and the composition of the universe. The model proposes that the universe is a hierarchical system, with simple blocks at the base and complex structures at the top. The model has been refined over time and continues to be used by scientists to understand the composition of the universe.
\[ Cp = \frac{Q}{\Delta T} \]  

where \( Cp \) is the heat capacity, \( \Delta T \) is the change in temperature, and \( Q \) is the amount of heat required to achieve \( \Delta T \). Often, this is the heat stored reversibly in the molecular motion in the material, that is the vibrational and translational motions. Thus, the heat given out by the sample when it is cooled by 1°C is exactly the same as that required to heat it by the same amount. This type of heat capacity is often called vibrational heat capacity. When temperature changes, the rate of heat flow required to achieve this is given by:

\[ \frac{dQ}{dt} = Cp \alpha T / \alpha t \]  

where \( \frac{dQ}{dt} \) is the rate of heat flow, and \( \frac{dT}{dt} \) is the heating rate. Clearly, if one wishes to increase the temperature of the material twice as fast, twice the amount of energy per unit time must be supplied. If the sample has twice the heat capacity, this also doubles the amount of heat required per unit time for a given rate of temperature rise. Considering a linear temperature programme, such is usually employed in scanning calorimetry:

\[ T = T_0 + \beta t \]  

where \( T \) is the temperature, \( T_0 \) is the starting temperature, and \( \beta \) is the heating rate, \( \frac{dT}{dt} \). This leads to:

\[ \frac{dQ}{dt} = \beta Cp \]  

or

\[ Cp = \frac{dQ}{dt} / \beta \]  

This provides one way of measuring heat capacity in a linear rising temperature experiment where one simply divides the heat flow by the heating rate. If the temperature programme is replaced by one comprising of a linear temperature ramp modulated by a sine wave, this can be expressed as:

\[ T = T_0 + \beta t + \omega B \cos \omega t \]  

where \( B \) is the amplitude of the modulation, \( \omega \) is the angular frequency of the modulation, and \( t \) is the time of modulation. The derivative with respect to time of Equation 6 is:

\[ \frac{dT}{dt} = \beta + \omega B \cos \omega t \]  

Thus, it follows that:

\[ \frac{dQ}{dt} = Cp (\beta + \omega B \cos \omega t) \]  

For a special case where \( \beta \) is zero, this yields:

\[ \frac{dQ}{dT} = Cp \omega B \cos \omega t \]  

For the simplest possible case from Equation 2, the resultant heat flow rate must also be a cosine wave. Thus:

\[ A_h \cos \omega t = Cp \omega B \cos \omega t \]  

where \( A_h \) is the amplitude of the heat flow modulation. It follows that \( \omega B \) is the amplitude of the modulation in the heating rate. Therefore:

\[ CP = A_h / \omega B \]  

However, \( \omega B \) can be replaced with \( A_h \) which is the amplitude of modulation in the heating rate. This provides a second method of measuring heat capacity by measuring the amplitude of modulation. The same relationship applies even if there is an underlying heating ramp. In essence, M-TDSC is based on simultaneously measuring the heat capacity of the sample using both methods which consists of responses to the linear ramp and to the modulation, and then comparing them. When there are no significant temperature gradients
The samples were prepared in the HVAKE mixer according to the procedure described in (Ref 1). The samples were then molded into test coupons and aged as per the procedure outlined in (Ref 2) before testing. The test results were then analyzed and compared to the reference data.
period of 60 s were used throughout the investigations which were conducted at a heating rate of 3°C/min. The TA Instrument Graphware software was used to measure the heat flow, the heat capacity and the differential of heat capacity. The calorimeter was calibrated with indium standards. Both temperature and baseline were calibrated as for conventional DSC. Standard aluminium pan and lid were used, samples of rubber approximately 10-15 mg in weight were placed in the pan at ambient temperature and the lid was subsequently closed under some nominal pressure. The assembly was placed in the chamber of the calorimeter and the temperature was lowered to -140°C with the flow of liquid nitrogen at a rate of 35 ml/min, which was used as the heat transfer gas. The temperature was allowed to modulate back to ambient as described above. The T_g of the pure rubbers (Table 1) and the mass fraction of the interphase and its composition for the SBR/BR physical mixture and SBR/BR and BR/NR blends were subsequently calculated for different conditions.

RESULTS AND DISCUSSION

The change of heat capacity, C_p, vs. temperature, and dC_p/dT vs. temperature for the NR/BR (50:50) blend and for a physical mixture of the two samples of NR and BR (50:50) are shown in Figures 1 and 2, respectively. The increase of increment in heat capacity, ΔC_p, at the glass transition temperature of both rubbers can be seen in Figure 1. The value of ΔC_p for a component is proportional to its mass fraction in the system under investigation. The heat capacity vs. temperature does not provide information about the interphase glass transition temperature and its composition distribution but the dC_p/dT vs. temperature data (Figure 2) provides that information.

Figure 2 shows dC_p/dT vs. temperature for a diffuse interphase in the NR/BR (50:50) blend prepared at 50°C for 30 min, and for a physical mixture of the two pure NR and BR samples (50:50) prepared in the same way, respectively. The data in this figure shows that the value of the dC_p/dT vs. temperature for the NR/BR blend is larger than that for the pure NR and BR samples (physical mixture) between the glass transition temperatures of NR and BR. The NR/BR blend has a single interphase and this interphase does not exhibit a separate glass transition temperature, but occurs continually between the glass transition temperatures of the constituent rubbers.

BACKGROUND OF THE ANALYSIS

The dC_p/dT vs. temperature signal can be described by a Gaussian function for polymers and miscible polymer blends. However, the dC_p/dT vs. temperature signals for the rubber 1 + rubber 2 physical mixture cannot be

<table>
<thead>
<tr>
<th>Raw rubber</th>
<th>Specific gravity</th>
<th>Mooney viscosity (MU)</th>
<th>T_g (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>0.92</td>
<td>97</td>
<td>-64</td>
</tr>
<tr>
<td>SBR</td>
<td>0.94</td>
<td>51</td>
<td>-50</td>
</tr>
<tr>
<td>BR</td>
<td>0.91</td>
<td>49</td>
<td>-107</td>
</tr>
</tbody>
</table>
\[ \int_{^{C(0)}}^{C(1/2)} \frac{dx}{C(x)} = \frac{1}{2} \int_{^{C(0)}}^{C(1/2)} \frac{dx}{x} = \ln \frac{C(1/2)}{C(0)} \]

The N-R-P relationship between the capillary pressure \( \phi \) and the relative permeability \( k_r \) is given by the following equation:

\[ \phi = k_r \frac{d\phi}{d\kappa} \]

where \( \phi \) is the capillary pressure, \( k_r \) is the relative permeability, and \( \kappa \) is the saturation. The capillary pressure is related to the surface tension and the contact angle of the fluid at the solid-liquid interface. The relative permeability is a function of the saturation and is used to describe the fluid flow in porous media.

The diagram illustrates the relationship between the capillary pressure and the relative permeability, with different zones indicated for different ranges of capillary pressure and relative permeability.
where $\Delta C_p$ is the increment of heat capacity, $T_g$ is the glass transition temperature, and $\omega_0$ is the half width of the $i^{th}$ sub-system at the interphase. Using Equation 12, the interphase can be analysed quantitatively. Figure 5 shows a typical interphase region after baseline correction and peak resolution. Finally, an interphase curve was obtained (Figure 6) by subtracting the blend curve from a Gaussian simulation of the same blend curve shown in Figure 5.

After determining the area under the curve of physical mixture for individual peaks as well as the simulated Gaussian one, the following equations may be used to determine the mass fraction of interphase and its composition:

\[
\delta_i = \omega_{0i} \left(1 - \frac{\Delta C_{p_{1i}}}{\Delta C_{p_{0i}}}ight) \quad \text{... 13}
\]

\[
\delta_2 = \omega_{02} \left(1 - \frac{\Delta C_{p_{2i}}}{\Delta C_{p_{0i}}}ight) \quad \text{... 14}
\]

where $\delta_i$ and $\delta_2$ are the mass fractions in the interphase of rubbers 1 and 2, respectively, $\omega_{0i}$ is the mass fraction of the rubbers before mixing, $\Delta C_{p_{1}}$ and $\Delta C_{p_{2}}$ are increments of $dC_p/dT$ at glass transition temperatures of pure rubbers in blend (area under curve of the Gaussian simulation curve), $\Delta C_{p_{10}}$ and $\Delta C_{p_{20}}$ are increments of $dC_p/dT$ at glass transition temperatures of pure rubbers (area under curve of physical mixture). The amount of interphase in a blend is given as follows:

\[
\text{Percent of interphase} = \frac{\text{Amount of interphase}}{\text{Total amount of blend}} \times 100 = (\delta_i + \delta_2) \quad \text{... 15}
\]

**Figure 2.** $dC_p/dT$ versus temperature for NR/BR (50:50 by mass) blend (dotted line), and NR/BR (50:50 by mass) physical mixture (black line). Samples prepared at 50°C for 30 min.
Figure 5. $dC_dT$ versus temperature for NR/BR (50:50 by mass) blend after peak resolution in Figure 3 showing the interphase region.

Figure 6. $dC_dT$ versus temperature for NR/BR (50:50 by mass) blend showing typical interphase obtained by subtracting the blend curve from Gaussian simulation of the same blend curve shown in Figure 5. The area under the curve is a measure of the mass fraction of the interphase. Sample was prepared at 50°C for 30 min.
It is important to set the $M_p$ value accurately. The quantity $\Delta C_p$ is defined as follows:

$$\Delta C_p = \int T \left[ \frac{dH(T)}{dT} \right] dT$$

where $T$ and $F$ are the initial and final values of the temperature in the glass transition region (see Figure 4). Thus, according to Equation 16, it is possible to obtain accurate $M_p$ values experimentally.

**Effect of different mass fractions of SBR and BR rubbers on the mass fraction and composition of the interphase in the SBR/BR blend**

Understanding how increases in mixing time and temperature affect the mass fraction and composition in blends of dissimilar and partially miscible rubbers is of significant importance in optimizing adhesion development. Table 2 shows the effect of temperature changes on the mass fraction of the SBR and BR rubbers in the blend. The mass fraction of the SBR increased from 50 to 100°C, while the mass fraction of the BR decreased from 50 to 100°C. The mass fraction decreased approximately 25% at 50°C.
### TABLE 2. COMPOSITION AND MASS FRACTION OF INTERPHASES IN NR/BR AND SBR/BR BLENDS PREPARED AT DIFFERENT TEMPERATURES FOR 10 MIN

<table>
<thead>
<tr>
<th>Blend</th>
<th>NR/BR (50:50)</th>
<th>NR/BR (50:50)</th>
<th>SBR/BR (50:50)</th>
<th>SBR/BR (50:50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>25</td>
<td>100</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>I* (%)</td>
<td>0</td>
<td>22.9</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>I**</td>
<td>(NR=49%, BR=51%)</td>
<td>0</td>
<td>(SBR=89%, BR=12%)</td>
<td>7.33</td>
</tr>
</tbody>
</table>

* Mass fraction of the interphase  
** Composition of the interphase  
*** Mass fraction of NR to BR and SBR to BR in the blends.

The mass fraction of the rubber in the interphase was calculated as follows: For NR/BR, 49/51 = 0.96, and for SBR/BR, 89/12 = 7.33.

### TABLE 3. COMPOSITION AND MASS FRACTION OF INTERPHASES IN NR/BR AND SBR/BR BLENDS PREPARED AT DIFFERENT TEMPERATURES FOR 30 MIN

<table>
<thead>
<tr>
<th>Blend</th>
<th>Temperature (°C)</th>
<th>I* (%)</th>
<th>I**</th>
<th>I***</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR/BR (50:50)</td>
<td>50</td>
<td>16.5</td>
<td>(NR=79%, BR=21%)</td>
<td>5.06</td>
</tr>
<tr>
<td>NR/BR (50:50)</td>
<td>100</td>
<td>23.4</td>
<td>(NR=87%, BR=13%)</td>
<td>6.69</td>
</tr>
<tr>
<td>SBR/BR (50:50)</td>
<td>50</td>
<td>49</td>
<td>(SBR=83.5%, BR=16.5%)</td>
<td>1.76</td>
</tr>
<tr>
<td>SBR/BR (50:50)</td>
<td>100</td>
<td>44</td>
<td>(SBR=79%, BR=21%)</td>
<td>3.76</td>
</tr>
</tbody>
</table>

* Mass fraction of the interphase  
** Composition of the interphase  
*** The mass fraction of NR to BR and SBR to BR in the interphase was calculated as described in Table 2.

### TABLE 4. COMPOSITION AND MASS FRACTION OF INTERPHASES IN NR/BR AND SBR/BR BLENDS PREPARED AT DIFFERENT MIXING TIMES AND AT 100°C

<table>
<thead>
<tr>
<th>Blend</th>
<th>Mixing time (min)</th>
<th>I* (%)</th>
<th>I**</th>
<th>I***</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR/BR (50:50)</td>
<td>10</td>
<td>22.9</td>
<td>(NR=49%, BR=51%)</td>
<td>0.96</td>
</tr>
<tr>
<td>NR/BR (50:50)</td>
<td>30</td>
<td>23.4</td>
<td>(NR=87%, BR=13%)</td>
<td>6.69</td>
</tr>
<tr>
<td>SBR/BR (50:50)</td>
<td>10</td>
<td>39</td>
<td>(SBR=88%, BR=12%)</td>
<td>7.33</td>
</tr>
<tr>
<td>SBR/BR (50:50)</td>
<td>30</td>
<td>44</td>
<td>(SBR=75%, BR=25%)</td>
<td>3.76</td>
</tr>
</tbody>
</table>

* Mass fraction of the interphase  
** Composition of the interphase  
*** The mass fraction of NR to BR and SBR to BR in the interphase was calculated as described in Table 2.
was detrimental to the mass fraction of the interphase and altered its composition, at least for the SBR/BR blend.

For the SBR/BR (30/50) blend, the mass fraction of the interphase was increased to 60/40 and 75/25, the mass fraction of pure SBR and BR in the blend was increased to 44/44 and 44/44, respectively. Evidently, an increase in the mass fraction of pure SBR in the blend was not detrimental to the mass fraction of the interphase in the blend. Moreover, the mass fraction of the interphase in the blend increased from 3.76 to 1.86 in the case of using a significantly larger mass of SBR in the blending process.

Effect of different mass fractions of pure SBR and BR rubbers on the mass fraction and composition of the interphase in the SBR/BR blend

<table>
<thead>
<tr>
<th>Blend</th>
<th>3rd pass (rpm)</th>
<th>1st (%)</th>
<th>2nd (%)</th>
<th>Interphase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBR/BR (50/50)</td>
<td>45</td>
<td>64.7</td>
<td>35.3</td>
<td>3.76</td>
</tr>
<tr>
<td>SBR/BR (60/40)</td>
<td>90</td>
<td>58.2</td>
<td>41.8</td>
<td>0.27</td>
</tr>
<tr>
<td>NR/BR (30/70)</td>
<td>45</td>
<td>45.0</td>
<td>55.0</td>
<td>2.4</td>
</tr>
<tr>
<td>NR/BR (30/90)</td>
<td>90</td>
<td>30.0</td>
<td>70.0</td>
<td>6.60</td>
</tr>
</tbody>
</table>

Table 5: Composition and mass fraction of the interphase in the SBR/BR blend as a function of the rotor speed

TABLE 5. COMPOSITION AND MASS FRACTION OF THE INTERPHASE IN THE SBR/BR BLEND AS A FUNCTION OF THE ROTOR SPEED.

<table>
<thead>
<tr>
<th>Blend</th>
<th>1st (%)</th>
<th>Interphase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBR/BR (50/50)</td>
<td>44</td>
<td>3.76</td>
</tr>
<tr>
<td>SBR/BR (60/40)</td>
<td>41</td>
<td>3.45</td>
</tr>
<tr>
<td>SBR/BR (70/30)</td>
<td>3.2</td>
<td>1.56</td>
</tr>
</tbody>
</table>

Table 6: Composition of the interphase in the SBR/BR blend as a function of mass fraction of pure SBR and BR rubbers in the blends. Blends were prepared at 100°C for 30 min.

Table 2.
When the SBR/BR (50:50) and (75:25) blends were prepared at 50°C for 30 min, the mass fraction of the interphase and its composition were substantially affected. For the SBR/BR (50:50) blend, the mass fraction of the interphase was 49%, and for the SBR/BR (75:25) blend, it was 22.2%. The mass fraction of SBR to BR in the interphase also reduced from 5.06 to 1.40 (Table 7).

Effect of silanised silica nanofiller on the mass fraction and composition of the interphase in the SBR/BR blend

Silanised silica nanofiller is used extensively in green tyres where SBR and BR rubbers are blended. To investigate the effect of this filler on the mass fraction of the interphase and its composition in the SBR/BR blend, raw SBR and BR rubbers were mixed for 30 min and then, 60 phr silica was added and mixed for an extra 10 min at 100°C to produce SBR/BR (60:40) and SBR/BR (75:25) blends (Table 8). In addition to these blends, SBR/BR (60:40) and SBR/BR (75:25) blends with no silica filler were also made. For the SBR/BR (60:40) blend, the mass fraction of the interphase increased from 41 to 60% when silica was added. However, the mass fraction of SBR to BR in the interphase decreased from 3.35 to 2.57, which indicated a change in the composition of the interphase. Similarly, for the SBR/BR (75:25) blend, the mass fraction...

<table>
<thead>
<tr>
<th>Blend</th>
<th>I* (%)</th>
<th>I**</th>
<th>I***</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBR/BR(50:50)</td>
<td>49.0</td>
<td>(SBR=83.5%, BR=16.5%)</td>
<td>5.06</td>
</tr>
<tr>
<td>SBR/BR(75:25)</td>
<td>22.2</td>
<td>(SBR=58.3%, BR=41.7%)</td>
<td>1.40</td>
</tr>
</tbody>
</table>

I* Mass fraction of the interphase
I** Composition of the interphase
I*** The mass fraction of SBR to BR in the interphase was calculated as described in Table 2.

<table>
<thead>
<tr>
<th>Blend</th>
<th>I* (%)</th>
<th>I**</th>
<th>I***</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBR/BR(75:25)</td>
<td>31.2</td>
<td>(SBR=51%, BR=49%)</td>
<td>1.56</td>
</tr>
<tr>
<td>SBR/BR(75:25)+60 p.h.r. silica</td>
<td>50.0</td>
<td>(SBR=76%, BR=24%)</td>
<td>3.17</td>
</tr>
<tr>
<td>SBR/BR(60:40)</td>
<td>41.0</td>
<td>(SBR=77%, BR=23%)</td>
<td>3.35</td>
</tr>
<tr>
<td>SBR/BR(60:40)+60 p.h.r. silica</td>
<td>60.0</td>
<td>(SBR=72%, BR=28%)</td>
<td>2.57</td>
</tr>
</tbody>
</table>

I* Mass fraction of the interphase
I** Composition of the interphase
I*** The mass fraction of SBR to BR in the interphase was calculated as described in Table 2.
CONCLUSIONS

The results from the experiments indicate that the addition of the rubber compounds to the NRIR led to an increase in the tensile strength and elongation at break of the rubber. The NRIR blend with 30% SBR had the highest tensile strength and elongation at break compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in tensile strength and elongation at break compared to the NRIR blend without SBR.

The addition of the rubber compounds also improved the abrasion resistance of the NRIR blend. The NRIR blend with 30% SBR had the highest abrasion resistance compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in abrasion resistance compared to the NRIR blend without SBR.

The NRIR blend with 30% SBR had the highest hardness compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in hardness compared to the NRIR blend without SBR.

The NRIR blend with 30% SBR had the highest oil resistance compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in oil resistance compared to the NRIR blend without SBR.

The NRIR blend with 30% SBR had the highest heat resistance compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in heat resistance compared to the NRIR blend without SBR.

The NRIR blend with 30% SBR had the highest ozone resistance compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in ozone resistance compared to the NRIR blend without SBR.

The NRIR blend with 30% SBR had the highest aging resistance compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in aging resistance compared to the NRIR blend without SBR.

The NRIR blend with 30% SBR had the highest weathering resistance compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in weathering resistance compared to the NRIR blend without SBR.

The NRIR blend with 30% SBR had the highest abrasion resistance compared to the NRIR blend with 20% SBR. The NRIR blend with 20% SBR showed a slight increase in abrasion resistance compared to the NRIR blend without SBR.
When 60 phr silanised silica nanofiller was incorporated in the raw SBR/BR blend at 100°C for 40 min, the mass fraction of the interphase changed. It was concluded that:

- For the SBR/BR (60:40) and SBR-BR (75:25) blends, the mass fraction of the interphase increased.

In all cases, the composition of the interphase in the blends also changed. In summary, MTDSC was found to be a useful technique for measuring the mass fraction of the interphase and estimating its composition in the SBR/BR and NR/BR blends.

ACKNOWLEDGEMENT

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Date of acceptance: December 2007

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