Chapter 6

Nitrile Rubber Clay Nanocomposites

Synthetic rubbers are more uniform in quality and compounds prepared from them are more consistent in processing and product properties [1]. Natural rubber crystallizes on stretching giving high tensile strength to the gum vulcanisate; on the other hand gum vulcanisate of synthetic rubbers like styrene butadiene rubber, nitrile rubber etc are generally weak and requires the incorporation of reinforcing fillers to produce products having high strength. Acrylonitrile butadiene rubber, known as nitrile rubber (NBR) shows no self reinforcing effect, as it cannot undergo stress induced crystallization on stretching. Since the gum vulcanisates have very low tensile strength, NBR is used in combination with reinforcing fillers to obtain vulcanisates having excellent mechanical properties. Rubber-clay nanocomposite technology has been extended to synthetic rubbers besides natural rubber. The polarity of the polymer chains and the basal spacing of the clay are important for the structure of the polymer-clay nanocomposites. In general, higher the polarity of the polymer chains and the wider the basal spacing of the clay, the more easily the polymer/clay nanocomposites with intercalated or exfoliated structure are formed [2]. NBR is a polar rubber and is generally considered as a special purpose rubber being used for applications requiring oil and solvent resistance. Presence of acrylonitrile (ACN) makes it polar and provides special features to the polymers.

Toyota group synthesized intercalated NBR-clay nanocomposites with 4 percentage of clay by volume which had hydrogen and water vapor permeability 30% lower than pure gum vulcanisate [3]. Similar barrier properties were also observed by Wu et al. [4] with 10% clay by volume, nitrogen permeability decreased by almost 50%. Nanocomposites also showed enhanced tensile strength and modulus [5].
6.1. Nitrile rubber clay nanocomposites

6.1.1 Preparation of nitrile rubber clay nanocomposites

Nitrile Rubber (N-03868) with an acrylonitrile content of 40 weight percentage supplied by Gujarat Apar Polymers Ltd., India was used for the study. In the first part of the work two different types of nanoclay differing in the interlayer distance and in modifying groups were used. They were obtained from Southern Clay Products, USA. The interlayer distance of the clays used were 18.3Å and 30.6Å for cloisite 10A [2MBHT: dimethyl, benzyl, hydrogenated tallow, quaternary ammonium], and cloisite 15A [2M2HT: dimethyl, dihydrogenated tallow, quaternary ammonium] respectively. Other chemicals used were of commercial grade. Compounds were prepared in a two roll mill with various filler loading from 1 to 10 parts per hundred rubber (phr) with the two clays according to the recipe given in table 6.1. In the second part of the study, the clays were modified adopting the procedure mentioned in section 5.1.2 and they are used instead of cloisite 10A and 15A.

The mixed compounds were matured for a period of 24 hours and the cure characteristics like cure time, scorch time, maximum and minimum torque were determined using rubber process analyzer at a temperature of 150 °C. From the respective cure curves, the optimum cure time for the vulcanisation were determined. Sheet for preparing the test specimens were moulded to a thickness of 2 mm using an electrically heated hydraulic press at 150 °C and 200 kg/cm² up to their respective cure times.
Table 6.1 Compounding recipe

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Gum</th>
<th>10A</th>
<th>15A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrile Rubber</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ZnO</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Stearic acid</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>CBS</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Antioxidant-HS</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cloisite 10A</td>
<td>-</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Cloisite 15A</td>
<td>-</td>
<td>-</td>
<td>Y</td>
</tr>
</tbody>
</table>

X = 1, 3, 5, and 10 phr of cloisite 10A
Y = 1, 3, 5 and 10 phr of cloisite 15A

6.1.2 Characterisation using X-Ray diffraction technique

XRD curves of cloisite 15A nanoclay and 10 phr clay filled nanocomposite is shown in figure 6.1. For the nanocomposite the peaks are displaced from the original 2θ value of cloisite 15A, 2.88° to 2.36°. The interlayer distance between the clay layers increased from 30.6 Å to 38.50 Å. This increase in d spacing suggests the intercalation of the polymer chains between the clay layers.
Figure 6.2 shows the X-ray diffraction curves for cloisite 15A nanoclay and an NBR based nanocomposite with 5 and 10 phr of cloisite 10A. For cloisite 10A clay a diffraction peak at $2\theta = 4.80$ which corresponds to an interlayer platelet spacing of 18.39 Å is obtained. For the nanocomposites, with 5 phr nanoclay this peak exhibited two shoulders at $2\theta = 2.18$ and $3.12^\circ$ corresponding to an interlayer spacing of 40.52 and 28.51 Å respectively, which reflect the formation of an intercalated nanocomposite. For 10 phr clay filled nanocomposites also the X-ray diffraction peaks are obtained at almost similar $2\theta$ values which represent the diffraction of the (001) crystal surface of layered silicates in the nanocomposites, corresponding to d-spacing of 39.48 and 27.59 Å. For nanocomposites at higher organoclay concentration, the dispersed silicates have slightly lower d-spacing. Steric hindrance of the silicates at high concentration may decrease the expansion of the layers.
Nitrile Rubber clay Nanocomposites

6.1.3 Scanning Electron Microscopy

The SEM photographs of the fractured surface of the gum vulcanizate and the layered clay filled nanocomposites are shown in figure 6.3. The morphology of the fractured surface of the nanoclay reinforced NBR composite can be studied using the SEM photographs. It can be observed that the NBR matrix is stretched by shear forces, the opposite surfaces move from one side to the other. Material displacement occurred in the direction of applied stresses, channels and raised parts are produced. Sliding surfaces of the polymer can be clearly observed in the case of fractured surfaces of the nanocomposites, since the nanoclays restrict the mobility of the NBR matrix. This is

Figure 6.2 X-ray diffraction curves for cloisite 10A nanoclay and NBR-clay nanocomposites

2.24°
3.2°
2.18°
3.12°
4.80°

Intensity (a.u.)

2θ

Cloisite10A

NBR10A

2 4 6 8 10 12
due to the better interfacial adhesion between the rubber and clay. In the case gum vulcanisate of NBR, such flow imperfections are not noticed.

![Scanning electron microscopy photographs of (a) gum vulcanisate and (b) layered clay filled nanocomposites with 10 phr cloisite 15A](image)

**Figure 6.3** Scanning electron microscopy photographs of (a) gum vulcanisate and (b) layered clay filled nanocomposites with 10 phr cloisite 15A

### 6.1.4 Cure characteristics

Cure characteristics of the NBR based nanocomposites with two different types of nanoclay differing in the interlayer distance at varying filler loading and that of the gum compound are given in table 6.2. As expected, the addition of organoclay results a significant increase in the maximum torque. Maximum torque can be regarded as a measure of the shear modulus which is increased due to improved clay-rubber interactions, including intercalation and exfoliation. The organoclay behaves as a vulcanisation accelerator for NBR, thus decreasing the scorch time and cure time. This effect is essentially attributed to the quaternary ammonium salt present in the nanosilicate structure which comes from the organic modification of the clay. The quaternary ammonium salt involves itself in the cure reaction by forming a complex with zinc salt and sulfur [6].
Table 6.2 Cure characteristics of compounds

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Min. Torque (dNm)</th>
<th>Max. Torque (dNm)</th>
<th>T_{10} (minutes)</th>
<th>T_{50} (minutes)</th>
<th>T_{90} (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gum</td>
<td>0.065</td>
<td>3.308</td>
<td>9.77</td>
<td>11.83</td>
<td>20.31</td>
</tr>
<tr>
<td>10A_1</td>
<td>0.197</td>
<td>3.423</td>
<td>5.99</td>
<td>7.72</td>
<td>14.05</td>
</tr>
<tr>
<td>10A_3</td>
<td>0.192</td>
<td>3.987</td>
<td>4.16</td>
<td>5.42</td>
<td>11.43</td>
</tr>
<tr>
<td>10A_5</td>
<td>0.196</td>
<td>4.095</td>
<td>3.47</td>
<td>4.75</td>
<td>10.39</td>
</tr>
<tr>
<td>10A_10</td>
<td>0.241</td>
<td>4.707</td>
<td>2.12</td>
<td>3.26</td>
<td>8.30</td>
</tr>
<tr>
<td>15A_1</td>
<td>0.167</td>
<td>3.364</td>
<td>7.34</td>
<td>8.88</td>
<td>14.46</td>
</tr>
<tr>
<td>15A_3</td>
<td>0.212</td>
<td>3.435</td>
<td>5.82</td>
<td>7.15</td>
<td>13.10</td>
</tr>
<tr>
<td>15A_5</td>
<td>0.251</td>
<td>3.801</td>
<td>4.79</td>
<td>6.06</td>
<td>12.01</td>
</tr>
<tr>
<td>15A_10</td>
<td>0.320</td>
<td>4.818</td>
<td>2.92</td>
<td>4.19</td>
<td>10.37</td>
</tr>
</tbody>
</table>

6.1.5 Mechanical Properties

From figures 6.4 to 6.8 it can be understood that intercalation of rubber chains in between the silicate layers provided rubber-clay nanocomposites with outstanding mechanical properties. The tensile strength increases by more than 440% for 10 phr of cloisite 15A clay filled NBR vulcanisate compared to the gum vulcanisate with a slight variation in the elongation at break. The tear properties of these NBR-silicate nanocomposites display the similar trend to that of the tensile properties. About 165% increase in the tear strength is obtained with the addition of 10 phr of nanoclay. This effect can be assigned to the silicate surface area, the extent of dispersion of the silicate in the NBR matrix and the increase in the crosslink density. The same trends
are recorded in the case of the modulus at 300% elongation and hardness which are also indicators of the stiffness of the rubber vulcanisate.

![Bar chart showing variation of tensile modulus with clay content](image1.png)

**Figure 6.4 Variation of tensile modulus with clay content**

![Line graph showing variation of elongation at break with clay content](image2.png)

**Figure 6.5 Variation of elongation at break with clay content**
Nitrile Rubber clay Nanocomposites

Figure 6.6 Variation of tensile strength with clay content

Figure 6.7 Variation of tear strength with clay content
The reinforcement of rubbers with fillers combines the elastic behaviour of rubber with the strength and stiffness of the reinforcing phase. Further, the elongation at break (EB) has been improved with increasing nanosilicate content. These results suggest that the nano-scale dispersion controls the tensile strength of the material; the stress applied in the exfoliated nanocomposite can be distributed to each individual layer and the layers may align themselves for maximum elongation. As in the case of natural rubber better physical properties are obtained for NBR based nanocomposite prepared with clay having higher interlayer distance.

### 6.1.6 Strain sweep studies

The storage modulus values at low strain (<15%) are a measure of the filler polymer interactions. So the variation of storage modulus with strain was studied for the uncured compounds with the two types of clays at 1 to 10 phr loading. The values obtained were plotted and shown in figures 6.9 and 6.10.
Figure 6.9 Variation of complex modulus with clay content of 15A nanocomposites

Figure 6.10 Variation of complex modulus with clay content of 10A nanocomposites
From the figures, it is clear that the complex modulus values is increasing with the clay content and is higher for the compound with clay having higher interlayer distance, indicating better rubber filler interactions. The increase in modulus is due to the inclusion of rigid filler particles in the soft rubber matrix, hydrodynamic effect and additional contribution arise from the molecular interaction between the rubber and the filler leading to the additional crosslinks into the polymer network structure. The additional cross-links can be confirmed by equilibrium swelling studies.

6.1.7 Swelling studies

Nano level dispersion of the layered silicate in the polymer matrix results in a greater enhancement in solvent barrier property compared to conventional phase separated composites [7-12]. The presence of the silicate layers may cause a decrease in permeability because of a more tortuous path for the diffusing molecules that must bypass impenetrable platelets. Therefore, to determine how the content of layered silicates in a hybrid composite affects the permeability, we measured the transport properties for all the samples with methyl ethyl ketone as the solvent.

![Figure 6.11 Swelling behaviour of NBR samples with cloisite 15A in MEK at 303 K](image-url)
The samples with filler loading from 0 up to 10 phr of the two types of clays were immersed in the solvent and the solvent uptake was determined in each case. It was observed that all the samples swelled upon immersion in toluene. In figure 6.11 and figure 6.12, the toluene uptake up to equilibrium swelling is plotted against time. It can be seen that for all compositions the uptake is rapid in the initial zone. After this the sorption rate decreases leading to a plateau, corresponding to equilibrium swelling. It is noted that the gum vulcanisate has the maximum uptake at equilibrium swelling.

The diffusion coefficient, D for the nanocomposites are given in table 6.3. The unfilled matrix presents the maximum diffusion coefficient of around $7.12 \times 10^{-7}$ cm$^2$s$^{-1}$. Adding nanoclay within the NBR matrix results in a progressive decrease of D value. Diffusion coefficient decreased to half for nanocomposite with 10 phr of cloisite 15A clay.
The permeation coefficient, the net effect of sorption and diffusion process is also found to be decreased. With an increasing clay loading up to 10 phr, regardless of the type of organoclays, the permeability decreased linearly. This was due to an increase in the lengths of the tortuous paths followed by the solvent molecules and the interaction between the solvent molecules and the alkyl moiety in the organoclays. The intercalated system with highest d-spacing shows the highest tortuosity leading to the lowest permeability. It is seen that the decreasing value of the permeability of the nanocomposites is largely dominated by the diffusion phenomenon, as shown by the respective values of sorption and diffusion coefficient reported in table 6.3.

Contribution of fillers to the reinforcement effect arises from molecular interaction between the rubber and filler. This interaction leads to an increase in the effective increase in crosslink density. The increase in crosslink density can be evaluated by the equilibrium swelling method. From table 6.4 it can be observed that the crosslink density of the nanocomposites is higher than the gum compound. The increased crosslink density of the nanocomposites indicates a better adhesion between the rubber and the clay.
Table 6.4 Variation of cross link density, $\Delta G$ and $\Delta S$ with loading of nanoclay

<table>
<thead>
<tr>
<th>Sample code</th>
<th>gum</th>
<th>10A$_3$</th>
<th>10A$_5$</th>
<th>10A$_{10}$</th>
<th>15A$_3$</th>
<th>15A$_5$</th>
<th>15A$_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosslink density ($\nu$)</td>
<td>1.37</td>
<td>1.69</td>
<td>1.77</td>
<td>1.85</td>
<td>2.07</td>
<td>2.23</td>
<td>2.26</td>
</tr>
<tr>
<td>($\times 10^4$) (moles gm$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta G$</td>
<td>-27.84</td>
<td>-35.64</td>
<td>-37.77</td>
<td>-39.76</td>
<td>-45.37</td>
<td>-49.43</td>
<td>-50.24</td>
</tr>
<tr>
<td>($J$ mol$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta S$</td>
<td>0.91</td>
<td>1.17</td>
<td>1.24</td>
<td>1.31</td>
<td>1.49</td>
<td>1.63</td>
<td>1.65</td>
</tr>
<tr>
<td>($\times 10^2$) (J mol$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.4 demonstrates the influence of the nanoclay loading on the Gibbs free energy, $\Delta G$, and entropy of mixing, $\Delta S$, of the NBR-clay nanocomposites swollen in methyl ethyl ketone. As $\Delta G$ represents the elastic behaviour, the increase in $\Delta G$ for the nanocomposites suggests the increased number of possible rearrangements in the NBR-clay nanocomposites at high overall degree of cross linking. This may imply that a peculiar, heterogeneous network structure was formed in the nanocomposites. This is in accordance with the conclusion obtained by J. Karger-Kocsis et al for SBR silicate nanocomposites [13]. The formation of an exfoliated nanocomposite is responsible for the noticeable increase of entropy as compared with gum compound.

6.2 Modified clay based NBR nanocomposites

In this study, NBR-clay nanocomposites were prepared via melt processing. Three surfactants having different ammonium cations, as mentioned in chapter 5, were used
Chapter 6

and their influence on the morphology and mechanical properties of the NBR/clay nanocomposites were investigated.

6.2.1 Characterisation using X-ray diffraction technique

The variation of the (001) d-spacing of the clay interlayer of the nanocomposites, which was calculated from the observed peaks by using the Bragg formula is shown in figure 6.13 - 6.15.

![Graph showing XRD patterns of BAC-modified clay and 10phr BAC-NBR nanocomposite](image)

*Figure 6.13 XRD patterns of BAC-modified clay and 10phr BAC-NBR nanocomposite*

![Graph showing XRD patterns of CPC-modified clay and 10phr CPC-NBR nanocomposite](image)

*Figure 6.14 XRD patterns of CPC-modified clay and 10phr CPC-NBR nanocomposite*
A shift in d-spacing for the modified clay-nanocomposites to a lower diffraction angles in comparison to that of the modified clay is obtained for the nanocomposites. Increase in d-spacing follows the order NBR - BAC > NBR - CPC > NBR - CTAB. The higher extent of intercalation corresponding to the largest interlayer distance of 32.76 Å in NBR- BAC nanocomposite compared with 23.69 Å for NBR-CTAB which has a relatively bulkier cation than the other two surfactants.

![Figure 6.15 XRD patterns of CTAB-modified clay and 10phr CTAB-NBR nanocomposite](image)

6.2.2 Cure Characteristics

When filler is incorporated into a rubber compound, the increase in maximum curometre torque during vulcanization is directly proportional to the filler loading. Figure 6.16 depicts the relation between $D_{\text{max}} - D_{\text{min}}$ ($\Delta$ torque) and nanoclay loading. Where $D_{\text{max}} - D_{\text{min}}$ is the change in maximum torque during vulcanisation. The increase in $\Delta$ torque with filler loading indicates that the incorporation of nanoclay enhances the crosslinking between the polymer chains. Nanocomposite with BAC modified clay possess higher torque value which is confirmed by the swelling studies.
6.2.3 Mechanical Properties

The stress-strain properties of the vulcanisates prepared from rubber compounds having different nanoclay loading (0 to 10 phr) are given in the figures 6.17 to 6.20.
Figure 6.18 Tear strength of nanocomposites

Figure 6.19 Modulus at 300% elongation of nanocomposites
From these figures (6.17 to 6.20) it can be observed that properties like tensile strength, modulus at 300% elongation, hardness and tear strength of the composites increase with increase in nanoclay content. The largely increased reinforcement and the tear resistance of the nanocomposites should be ascribed to the dispersed structure of clay at the nano level, the high aspect ratio and the planar orientation of the silicate layers [14]. Tensile stress-strain measurements have been one of the standard methods for characterizing rubber vulcanisates [15]. Among the three organoclays used BAC modified clay imparts maximum improvement in mechanical properties for NBR vulcanisates. This is similar to the findings obtained for NR vulcanisates. The tensile strength of NBR – BAC clay nanocomposite exhibited 2.5 times higher value than that of conventional gum vulcanisates. This is followed by the nanocomposites obtained with CPC and CTAB modified clays. The organic part of the organoclay enables conversion of the hydrophilic interior clay surface to hydrophobic and increases the layer distance as well. Under this condition, the polymer chain is capable of diffusing easily into the clay galleries to increase the layer distance further.

Figure 6.20 Hardness of nanocomposites
6.2.4 Strain sweep studies

The complex modulus values of the nanocomposites with three different modified clays as a function of strain is plotted in figures 6.21 – 6.23. The complex modulus values are found to be increased with increase in nanoclay content. This trend is very distinct at lower strain; at higher strain the trend is not very clear. BAC modified clay nanocomposite possess higher storage modulus in all concentrations. The increase in storage modulus is due to the increase in cross linking density.

![Graph](image_url)

*Figure 6.21 Variation of complex modulus with clay content of CPC modified clay nanocomposites*
Figure 6.22 Variation of complex modulus with clay content of CTAB modified clay nanocomposites

Figure 6.23 Variation of complex modulus with clay content of BAC modified clay nanocomposites
6.2.5 Swelling studies

Traditionally, the incorporation of nonporous fillers, such as metal oxides, silicas, or carbon blacks, into polymers reduces gas, solvents or vapor permeability. This decreased permeability is the result of a reduction in the amount of polymer through which transport may occur and an increase in the diffusion path length that penetrant molecules experience as they are forced to take a tortuous course around filler particles to traverse a film. From the figure 6.24, it is seen that at equilibrium swelling the maximum solvent uptake is higher for the gum vulcanisates than the nanocomposites. For NBR–organoclay nanocomposites, the swelling rate and swelling coefficient is decreased as the clay content increases as expected. This is because the solvent diffusion in the nanocomposite is impaired by the clay platelets and that these do not absorb solvent. It is also suggested that a significant clay – rubber adhesion, sufficient to limit rubber chain extension in the film plane in the presence of the solvent.

![Sorption curves of the vulcanisates at 303K](image)

*Figure 6.24 Sorption curves of the vulcanisates at 303K*
Figure 6.25 Variation of Diffusion coefficient with nanoclay loading

Figure 6.26 Variation of Permeation coefficient with nanoclay loading
Nitrile Rubber clay Nanocomposites

From the figures 6.25 and 6.26 it is seen that the diffusion coefficient and permeation coefficient of the NBR vulcanisates is decreasing with increase in clay content. The coefficient of diffusion, \( D \), may serve as an average (over a macro volume) rate of molecular transport. The local rate of moisture diffusion can substantially differ in the close vicinities of the clay particles, where molecular mobility is severely reduced because of intercalation of chains into galleries between platelets, and in the bulk, where mobility of chains is weakly affected by the presence of filler. This implies that the molecular transport in the nanocomposite becomes substantially heterogeneous as in the case of vinyl ester resin matrix-montmorillonite clay composites reported by Drozdov et al [16].

The degree of cross linking of nanocomposite is higher for BAC samples as suggested by the torque values. The amine groups facilitate the crosslink formation [17]. Both \( \Delta S \) and \( \Delta G \), the thermodynamical parameters of the NBR clay nanocomposites are given in table 6.5. It should be noted that \( \Delta G \) values are higher for the nanocomposites. It is assumed that \( \Delta G \) is closely related to the elastic behaviour of the material, the nanocomposites shows better elasticity than the gum vulcanisate and it is higher for vulcanisate with 10phr of BAC modified clay. These results can be attributed to better compatibility between the silicate and rubber, the rubber molecules can penetrate into the galleries more easily giving rise to a process of exfoliation of the silicate layer. This exfoliation is responsible for the noticeable increase of entropy of the clay filled composites compared to gum vulcanisate.
Table 6.5 $\Delta G$, $\Delta S$ and Cross link density for gum and 10 phr of modified clay filled NBR vulcanisates

<table>
<thead>
<tr>
<th>Sample code</th>
<th>gum</th>
<th>CTAB$_{10}$</th>
<th>CPC$_{10}$</th>
<th>BAC$_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crosslink density ($\nu$) x 10$^4$ (moles gm$^{-1}$)</td>
<td>1.37</td>
<td>1.69</td>
<td>1.77</td>
<td>1.85</td>
</tr>
<tr>
<td>$\Delta G$ (J mol$^{-1}$)</td>
<td>-27.84</td>
<td>-35.64</td>
<td>-37.77</td>
<td>-39.76</td>
</tr>
<tr>
<td>$\Delta S$ x 10$^2$ (J mol$^{-1}$)</td>
<td>0.91</td>
<td>1.17</td>
<td>1.24</td>
<td>1.31</td>
</tr>
</tbody>
</table>

6.3 Conclusion

Nitrile rubber-clay nanocomposites were prepared by shear mixing process and characterized by XRD for interlayer spacing. Effect of interlayer distance of the layered nanoclays in modifying the mechanical properties and swelling characteristics of the nitrile rubber based nanocomposites was studied. The tensile strength increases by more than 440% for 10phr cloisite 15A clay filled vulcanisate compared to the gum vulcanisate with a slight variation on the elongation at break. The large improvement in the ultimate properties of the composite is the result of nanolevel dispersed structure of the clay and the planar orientation of the silicate layers in the NBR matrix. The intercalated structure with maximum d-spacing presented the highest tortuosity leading to the lowest permeability for the solvent molecules.

Three different types of organoclays prepared by adopting the procedure mentioned in section 5.1 were used with nitrile rubber, and their nanocomposites were found to be intercalated. The scorch time of the nanocomposites were reduced due to cure acceleration by organic modifier present in the modified clays. Among the three organoclays used BAC modified clay imparts better improvement in mechanical properties for NBR based nanocomposites. This is similar to the findings observed for NR-organoclay nanocomposites.
References


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