Solvent Resistance and Mechanical Properties in Thermoplastic Elastomer Blends Prepared by Dynamic Vulcanization

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Mixing Methods

High shear melt mixing

- Without curing agents → *non-vulcanized blends*
  - Continuous phase dependent on proportions in the blend

- With curing agents → *dynamic vulcanization*
  - Non-vulcanized component becomes continuous phase, almost independent of proportion in blend
Non-Vulcanization vs. Dynamic Vulcanization
Objective of Present Work

- Dynamic Vulcanization on a Variety of Thermoplastic / Rubber Combinations
  - Thermoplastics (PA, PP, and PBT)
  - Rubber (CIIR, NBR)

- Measure
  - Mechanical properties
  - Exposure to solvents (hexane and CHCl₃)
    - % insolubility, swelling index
  - DSC and SEM
Effect of % Thermoplastic on Properties

**PP-CIIR Blends**

- **Tensile Strength (MPa)**
  - % Polypropylene:
    - 18: 20
    - 20: 25
    - 25: 30
    - 30: 35
    - 35: 40
    - 40: 50
    - 50: 60-90
    - 60-90: 100

- **Hardness (Shore D)**
  - % Polypropylene:
    - 18: 18
    - 20: 20
    - 25: 25
    - 30: 30
    - 35: 35
    - 40: 40
    - 50-90: 60
    - 100: 90
Tensile Strength Comparison in Blends

- PA-CIIR
- PP-CIIR
- PA-NBR
- PP-NBR
- PBT-NBR

Tensile Strength

Blend Type

% Plastic
## DSC Results – Thermoplastic Phase

<table>
<thead>
<tr>
<th>Material</th>
<th>Tm (°C)</th>
<th>$\Delta H_f$ (J/g plastic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>178.7</td>
<td>60.6</td>
</tr>
<tr>
<td>PA/CIIR</td>
<td>175.6</td>
<td>58.1</td>
</tr>
<tr>
<td>PA/NBR</td>
<td>176.5</td>
<td>58.5</td>
</tr>
<tr>
<td>PP</td>
<td>163.3</td>
<td>80.9</td>
</tr>
<tr>
<td>PP/CIIR</td>
<td>161.6</td>
<td>83.1</td>
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<tr>
<td>PP/NBR</td>
<td>161.5</td>
<td>80.6</td>
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<tr>
<td>PBT</td>
<td>223.0</td>
<td>38.1</td>
</tr>
<tr>
<td>PBT/NBR</td>
<td>222.6</td>
<td>46.0</td>
</tr>
</tbody>
</table>

- Phase separation
- Dynamic vulcanization effects
  - rubber phase (curing, particle formation)
  - thermoplastic phase (MW reduction, graft formation, crystallization effects)
SEM OF PA/NBR BLEND

PA-NBR Blend

PP-NBR Blend
Solvent Uptake – Kinetic Studies

- Rate of solvent uptake determined on rubber and blend samples
- Blends achieve equilibrium relatively quickly
- Example of 100 NBR and 40 PA/60 NBR
Swelling Index: PA – CIIR Blend at Different Compositions

- S.I. Values consistently below theoretical line (physical mixture)
- Continuous thermoplastic phase prevents solvent expansion of cured rubber phase
Swelling Index Values for Other Blends

**PP-CIIR Blends**

Swelling Index

**PA-NBR Blends**

Swelling Index
Swelling Index Values for Other Blends

**PP-NBR Blends**

- **Swelling Index**

**PBT-NBR Blends**

- **Swelling Index**
Relationship Between Swelling Index and % Elongation

- Minimum elongation reached at similar composition as change in S.I. Curve
  - Phase inversion
- Similar results for all blends studied.
Conclusions

1. Dynamic vulcanization – variety of rubber plastic blends, many with elastomeric properties.
   - Elastomeric properties seen between 20-40% thermoplastic

2. Both rubber and plastic phases affected during the dynamic vulcanization process.

3. Solvent exposure – rapid swelling upon exposure to solvent (tested on hexane and CHCl₃). Similar performance expected with other solvents.
4. S.I. values of blends are significantly less than expected “theoretical” values.
   - “caging effect” at higher thermoplastic compositions.

5. Minimum elongation values reached at phase inversion.

6. Increased compatibility in blends
   - reduced particle size (discrete phase)
   - frequently produces less caging effect on the rubber phase
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