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Studies of Nylon/PC blends

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A thesis submitted in partial fulfilment of requirements for the degree of
Master of Engineering

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Abstract

This report presents an investigation of the interchange reactions and morphology in a partially miscible blend composed of bisphenol-A-polycarbonate and Nylons with and without polycaprolactone by the use of DSC, SEM and DMTA.

DSC results show that NY6 is faster than NY66 in interchange reaction with PC and incorporation of polycaprolactone improves the compatibility of NY66 with PC. At longer heat treatment time, $T_g$s of both component polymers approach each other, which suggests that interchange reaction occurs between two immiscible homopolymers, making them homogenize and resultant block and graft copolymers serve as a link between two polymers.

The general features of incompatible and biphasic system were displayed by Scanning Electron Microscopy in the morphology of the NY66/PC blends without polycaprolactone. In Nylon-rich blends, there is less gap between globule PC and matrix NY66, while PC-rich blends have a clear gap between the boundaries of NY66 and PC. The formation of voids can be explained considering the different volume contraction occurring during the thermal transitions of the two polymers. Polycaprolactone changes the morphology of NY66/PC blend, in which distributed globule sizes become small and deviation of the globule sizes is decreased. This implies that polycaprolactone serves as a thermodynamic plasticizer controlling the particle size, and it can reduce the melt viscosity of the PC.

Two kinds of mode, 3-point bending and tensile mode, were used in Dynamic Mechanical Thermal Analysis. Two $T_g$s are present in most compositions except those between 20/80 and 5/95 (NY66/PC wt%), in which $T_g$ of NY66 was not detected. $T_g$ of PC was decreased largely in 95/5. These results may explain immiscibility in most compositions and partial miscibility of each abundant proportion of component, which maybe enable an interchange reaction. Polycaprolactone shows a huge effect in lowering $T_g$s of NY66/PC blend.
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## Notation and Terminology

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>a, b</td>
<td>Depth, width</td>
</tr>
<tr>
<td>$\Delta C$</td>
<td>Overall difference in the total heat capacity of the two cells, and</td>
</tr>
<tr>
<td></td>
<td>can be subdivided into instrument and sample contributions</td>
</tr>
<tr>
<td>$\Delta C_E$</td>
<td>Difference between the two cells in the empty state (subscript E)</td>
</tr>
<tr>
<td>$C_p$</td>
<td>Specific heat capacity</td>
</tr>
<tr>
<td>E</td>
<td>Tensile, or Young’s modulus</td>
</tr>
<tr>
<td>$E^*$</td>
<td>Complex dynamic modulus</td>
</tr>
<tr>
<td>$E'$</td>
<td>Storage modulus</td>
</tr>
<tr>
<td>$E''$</td>
<td>Loss modulus</td>
</tr>
<tr>
<td>F</td>
<td>Force</td>
</tr>
<tr>
<td>G</td>
<td>Shear modulus</td>
</tr>
<tr>
<td>$G'()$</td>
<td>Storage modulus.</td>
</tr>
<tr>
<td>$G''()$</td>
<td>Loss modulus</td>
</tr>
<tr>
<td>$\Delta G$</td>
<td>Change in free energy on mixing</td>
</tr>
<tr>
<td>H</td>
<td>Enthalpy</td>
</tr>
<tr>
<td>H, W</td>
<td>Distance and width of the plane, respectively</td>
</tr>
<tr>
<td>k</td>
<td>Conversion factor</td>
</tr>
<tr>
<td>l</td>
<td>Length</td>
</tr>
<tr>
<td>LCST or UCST</td>
<td>Lower or upper critical solution temperature</td>
</tr>
<tr>
<td>$mC_p$</td>
<td>Additional heat capacity due to the presence of a mass m</td>
</tr>
<tr>
<td>Symbol</td>
<td>Definition</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>P</td>
<td>Hydrostatic pressure</td>
</tr>
<tr>
<td>ΔQ</td>
<td>Complex heat transfer functions</td>
</tr>
<tr>
<td>S</td>
<td>Entropy</td>
</tr>
<tr>
<td>S</td>
<td>Signal from a DSC</td>
</tr>
<tr>
<td>S</td>
<td>Total stress tensor</td>
</tr>
<tr>
<td>$S_{xx}$</td>
<td>Ratio of tensile stress</td>
</tr>
<tr>
<td>T</td>
<td>Temperature</td>
</tr>
<tr>
<td>t, δ</td>
<td>Time and the phase angle</td>
</tr>
<tr>
<td>tan δ</td>
<td>Loss tangent</td>
</tr>
<tr>
<td>$v_x$</td>
<td>Constant speed at $x$ direction</td>
</tr>
<tr>
<td>y</td>
<td>Deflection</td>
</tr>
</tbody>
</table>

| Δ      | Differential nature of the signal, which may be a differential power or temperature |
| δ      | Unit vector |
| ε      | Tensile strain or elongation |
| γ      | Shear strain |
| $\gamma$ | Shear rate (the dot is Newton’s notation for the time derivative) |
| $\dot{\gamma}_E$ | Rate of elongation (or elongation rate) |
| $\gamma_0$, $\sigma_0$ | Maximum values of strain and stress, respectively |
| η      | Viscosity |
\( \eta_E \)  
Elongation viscosity

\( \eta(\dot{\gamma}) \)  
Viscosity function

\( \eta'(\omega) \)  
Dynamic viscosity

\( \sigma \)  
Extra stress tensor

\( \sigma \)  
Normal tensile stress

\( \sigma_{xy} = \sigma_{yx} \)  
Shear stress

\( \sigma_{xx}, \sigma_{yy} \text{ and } \sigma_{zz} \)  
Normal stresses.

\( \tau \)  
Tangential, shearing stress

\( \nu \)  
Poisson’s ratio

\( \omega \)  
Circular frequency

\( \psi_1(\dot{\gamma}), \psi_2(\dot{\gamma}) \)  
First and second normal stress coefficients, respectively

Subscript

\(E, S, C\)  
Empty pan, sample and calibrant, respectively

\(x, y, z\)  
Direction of flow, direction perpendicular to the flow and the neutral direction.