EFFECT OF CARBON BLACK, ALUMINA AND FUMED SILICA FILLERS ON THE FRACTURE TOUGHNESS OF POLYSTYRENE THIN FILMS

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Fillers exist in a variety of systems such as organic, biological and polymeric materials. In polymer systems, nanoscale fillers not only reduce the cost of the material but also improve mechanical properties, such as hardness and tear resistance. The broad aim of this study was to investigate the fracture behaviour of nanoscale filler added polystyrene thin films by the trouser-leg-tearing test. Critical strain energy release rate (G_c) can be regarded as a material property, often equated with toughness.

The thin films, required for the tearing test, were prepared by two different methods. In the first method, a glass slide was dipped and drawn with 2.5 cm/min speed using a motor driven lifter through a solution of 14 wt%, of polystyrene and filler in toluene. The composition of the filler-added films was varied from 0 to 5 wt% of fillers with respect to polystyrene content. In this study, carbon black (0.05 μm), alumina (0.075 μm) and fumed silica (255 m^2/g) fillers were used. The other method was spin casting, in which the above prepared solution was placed on a clean glass slide and spun with different speeds using a photo-resist spinner. The slides were then left overnight in a fume cupboard to allow the toluene to evaporate and dried at 80 °C for 12 hours for complete evaporation of toluene from the films. The rectangular shaped (40 mm x 15 mm) sample was cut into appropriate size and stripped off from the substrate onto the surface of a water bath. A cut of 10 mm was made along the center line of the sample using a scalpel blade. Then two free ends were separated at a constant rate 2.7 x 10^{-4} m s^{-1} using a mechanical testing machine. Tearing was done in two different directions, one parallel and the other perpendicular to the film drawn direction.

The study revealed that, a significant decrease in G_c was observed with the increasing filler wt% in the films which contained alumina and carbon black fillers, prepared by both methods. On the other hand, the films which contained fumed silica and torn in the film drawn direction showed a decrease in G_c value with increasing filler wt%. In contrast, an increase in G_c was observed when the fumed silica added films were torn perpendicular to the film drawn direction. The spin cast films also showed an increase in G_c with fumed silica filler wt%. The most likely reason why such a decrease was observed in alumina and carbon black filler added films is the propagation of the fracture mostly along the filler particles. It can be speculated that there may not be any extraordinary interaction between the polymer and fillers. Unlike other fillers, fumed silica has chain-like particle morphology. The decrease in G_c value in the fumed silica added films which were torn parallel to the film drawn direction may be due to the fumed silica chains and polystyrene chains aligning parallel to the film preparation direction. Tearing parallel to the direction of preferential alignment requires the rupture of fewer bonds as orientation increases and hence, less energy is needed to tear the film in this direction. The polymer chains and fumed silica chains in the spin cast films, were randomly oriented. These fumed silica chains give additional strength to the polystyrene. Fracture surfaces and the crack tip of the tested films were examined using optical microscope and revealed that crazes are the major toughening mechanism in the polystyrene amorphous polymer.