

FRACTURE TOUGHNESS OF POLYSTYRENE THIN FILMS

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The brittle fracture commonly observed in many glassy polymers under tension is due to the formation and breakdown of crazes. The broad aim of this study was to investigate the fracture behaviour of 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 different speeds using a motor driven lifter through a solution of 14 wt% of polystyrene in toluene. 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. Then the slides were dried in a desiccator vacuum oven at 80 °C for 12 hours for complete evaporation of toluene from the films. The samples used in this study were of rectangular shape (40 mm × 15 mm). They were cut into appropriate size and stripped off from the substrate onto the surface of a water bath. The thickness of the films was measured using a Michelson interferometer. A cut of 10 mm was made along the center line of the sample using a scalpel blade. Then the two free ends were separated at a constant rate of $2.7 \times 10^{-4} \text{ m s}^{-1}$ 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 the G_c values were strongly dependant on the film drawing speed. When the films were torn parallel to the film drawn direction, there was a significant increase in G_c , with increasing film drawn speed from 1.0 cm min^{-1} to 2.5 cm min^{-1} , and there after almost a plateau was observed. On the other hand, for all the samples torn perpendicular to the film drawn direction, there was a clear decrease in G_c with increasing film drawn speeds. The value of G_c for the films, which were prepared by spin casting and torn in both perpendicular directions, was 0.24 kJ m^{-2} . This was almost constant for all the films prepared with different spin speeds, and this value was comparable with the G_c value corresponding to the above mentioned plateau. The most likely reason why such a variation was observed would be the high degree of orientation of the polymer chains in the film drawing direction due to the very slow drawing speed. When the drawing speed was increased, the degree of polymer chain orientation decreased and became randomly oriented. The bonds along the polymer chain are covalent bonds, which can bear substantially higher loads than the Van der Waals bonds between the chains.

Fracture surfaces and the crack tip of the tested films were examined using an optical microscope. The craze area ahead of the crack tip in torn polymer films showed birefringence, indicating that there exists a certain degree of orientation of polymer chains in these areas.