

## 10. Conclusions and Recommendations

In the study of the diverse chemical and physical mechanisms which may be used to explain the burning properties of flame retarded polymer systems, molten polymer dripping and sample ignition plays an important role. Dripping is characteristic of most thermoplastic polymers. It is utilised to achieve a low level of flame retardancy in polystyrene, polypropylene and polyester. For example, in polystyrene foam aliphatic bromine compounds in combination with a free radical generating systems are extremely effective.

In most of the standard tests used to evaluate fire retardance of fabrics, it is allowed for molten polymer material to drip away from the flame zone. In the most common laboratory tests, a vertically or horizontally mounted sample is ignited with a Bunsen burner, and the self-extinguishing time or burning rate determined after removal of the flame. It may be argued that dripping molten polymer poses a hazard in the practical application of flame retardant systems. In particular this would be true if the ignited sample produces flaming drips that are capable of spreading flames beyond the initial site of ignition. However the UL 94 flammability test of the Underwriters Laboratory make provision for flaming drips for low level flame retardancy ratings. They specify that a piece of cotton placed beneath the burning sample should not ignite. In some cases, dripping may even detach the flame front from the burning specimen, mechanically extinguishing the burning sample. In any case, dripping behaviour will remove heat from the flame front both during and after ignition. This can result in inadequate ignition or in a retardation of the burning process and can ultimately cause spontaneous extinction of the flame.

Visual inspection during the flame retardancy test conducted with treated samples showed that in most cases dripping was more profuse than for the untreated samples. Yet, the melt viscosity measurements suggest that the additives actually increased the polymer melt viscosity. It is therefore speculated that reductions in surface tensions may have contributed to the increased rate of dripping. In the actual fire test, elongational viscosity is more relevant than the shear viscosity that was measured. It could be that the additives caused a reduction in the elongational viscosity, but this could not be experimentally confirmed.

The dripping rate was up to 80 % faster for the treated samples than for the untreated samples. Dripping must therefore play an important role in the self-extinguishing properties conferred by the additives studies.

Oxygenated hydrocarbon compounds have utility as flame retardants for unsized polyester fabrics. These compounds may be regular food-type additives such as Pentaerythritol, are therefore inexpensive, safe, easy to use, and apply. They render such fabrics flame retarded in terms of conventional vertical flame tests. The flame retardancy effect shows a parabolic dependence on the add-on level. This implies an optimum dosage level beyond which flammability increases again.

It is postulated that the mechanism involves a combination of enhanced melt dripping and fibre shrinkage. These effects result in efficient heat removal from the burning sample allowing it to self-extinguish. Melt viscosity measurements suggest that the increased rate of dripping can not be ascribed to a viscosity reduction alone. It is speculated that melt surface tension effects might be responsible instead.



It is recommended that a mathematical model be developed to explain the flame retardancy mechanisms described above. It is expected that such a model should provide an improved understanding on the relative importance of the different modes of action for this flame retardant system. For example, the relationship between viscosity and surface tension, and their impact on a mass and energy balance.