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PII: S0141-3910(16)30397-4

DOI: 10.1016/j.polymdegradstab.2016.12.018

Reference: PDST 8139

To appear in: *Polymer Degradation and Stability*

Received Date: 19 October 2016

Revised Date: 20 December 2016

Accepted Date: 31 December 2016

Please cite this article as: Zhang Y, Li X, Fang Z, Hull TR, Kelarakis A, Stec AA, Mechanism of enhancement of intumescent fire retardancy by metal acetates in polypropylene, *Polymer Degradation and Stability* (2017), doi: 10.1016/j.polymdegradstab.2016.12.018.

Mechanism of Enhancement of Intumescent Fire Retardancy by Metal Acetates in Polypropylene

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Abstract

The effects of cobalt acetate (CoAc), manganese acetate (MnAc), nickel acetate (NiAc) and zinc acetate (ZnAc) as fire retardant additive in intumescent polypropylene (PP) formulations containing PP/ammonium polyphosphate (APP)/pentaerythritol (PER) are reported. The limiting oxygen index (LOI) and vertical burning (UL94) tests and cone calorimetry were used to quantify the enhancement. Environmental chamber rheometry, thermal gravimetric analysis and the morphology of the residual char were used to investigate the mechanism of enhancement. The incorporation of small quantities of metal acetates had a significant influence on the fire behaviour. As an example, 0.7 wt% MnAc improved the UL 94 rating of PP/APP+PER (mass ratio 100/25, with APP/PER=3/1) sample from V-2 to V-0, while 1 wt% MnAc reduced the peak heat release rate and the total heat release by 18% and 12% in the cone calorimeter. Rheological data, cone calorimetry, and photographs of the residual char showed how the fire retardancy of the systems were affected by the melt viscosity, which depended on the loading of metal acetate. During thermal decomposition, the metal acetates promote the crosslinking of the polymer and the fire retardant, reinforcing the protective intumescent layer. While, the effect is most potent at the optimal metal loadings. At higher MnAc loadings, the benefit of a stronger char is overwhelmed by the adverse effect of crosslinking on the transition char layer. Thus, this paper offers a new insight into the mechanism of the intumescent fire retarded PP system.

Keywords: Fire; intumescent flame retardant; polypropylene; metal acetate; rheology; mechanism