NEW FACTOR IN MECHANISM OF FIRE RETARDANCY: SYNERGISM OF FIBRES WITH INTUMESCENT FLAME RETARDANTS

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Introduction

The flame retardant mechanism of an intumescent flame retardant (IFR) system is already comprehensively reviewed in the literature[1,2]. Accordingly, at least 15-20 wt% IFR is needed in order to achieve acceptable level of flame retardancy in polyolefins, however even 25-35 wt% of IFR is also generally used. Several chemical substances have been studied as synergetic effect additives when combined with IFR system, thus the needed amount of IFR could be somewhat, but not drastically, lowered. However, the beneficial influence of a physical phenomenon on the effectiveness of the IFR system has not been discussed in the literature, yet. Recently, the authors observed significant synergistic effect between highly oriented polymer fibres and IFR system and utilized successfully in multilayer polypropylene (PP) self-reinforced composites (SRCs).

Materials and methods

The flammability and mechanical properties of multilayer SRCs (with a nominal reinforcement of 45 wt%) comprising highly stretched PP fabrics (T-PPT-181, Stradom S.A.) and IFR (Exolit AP766, Clariant Ltd.) loaded matrix layers, prepared by film stacking method[3], were compared to unreinforced PP compounds with the same IFR content. For evaluating the role of molecular orientation on the flame retardant effectiveness of the IFR system, PP SRCs of identical compositions but with pre-heat-treated (i.e. relaxed) reinforcing PP fabrics were prepared and comprehensively examined.

Results and discussion

Significantly lower grade flammability was observed in case of SRCs than that of compounded mixtures, when concentration series with increasing IFR contents were evaluated (**Table 1**).

Table 1 Flammability characteristics of PP based compounds and SRCs

PP compound	UL-94 Classification*	LOI (vol%)	pkHRR (kW/m^2)	PP SRC	UL-94 Classification*	LOI (vol%)	pkHRR (kW/m^2)
PP-REF	HB (30.5)	18	880	**SRC-REF**	HB (33.5)	19	751
PP-IFR9	HB (22.8)	24	587	**SRC-IFR9**	V-0	26	413
PP-IFR13	HB (19.4)	27	514	**SRC-IFR13**	V-0	30	295
PP-IFR17	V-2	31	340	**SRC-IFR17**	V-0	36	227
PP-IFR21	V-0	35	222	**SRC-IFR21**	V-0	42	160

*in parenthesis the horizontal burning rates (mm/min), if measurable, are indicated

In accordance with our further experimental results, SRCs of identical compositions but comprising pre-heat-treated (i.e. relaxed) reinforcing PP fabrics represent an intermediate flammability state between the unreinforced samples and the high-performance SRCs indicating that the molecular orientation degree of the embedded PP fibres is the key factor for the observed extraordinary flame retardant performance of flame retarded SRCs. The observed beneficial effect may be attributed to a physical interaction between the expanding process of intumescent FRs and the shrinking of highly oriented tapes. It is presumed, that this system exposed to heat forms a special compact charred layer, of reduced oxygen permeability and enhanced heat barrier characteristic, on the surface of the sample. In this case the vaporization of phosphorus compounds and the gas release of the nitrogen containing foaming agent occurs in a much smaller volume, being more effective in the fire extinction (e.g. when the V-0 rating achieved by IFR content of only 9 wt% is considered), as a consequence.

Conclusion

Special synergistic effect was observed between intumescent flame retardants and highly oriented PP fabrics in multilayer SRCs. This interaction resulted in significantly improved flame retardancy, such as UL-94 V-0 classification at as low as 9 wt% of IFR additives, noticeably higher LOI values, and significantly reduced heat release rates than those of intumescent alone. The studied novel synergism promotes the possibility of cost-effective fire retardancy of high mechanical performance and recyclable SRCs.

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