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Preparation and characterization of flame retarded self-reinforced poly(lactic acid) composites

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Self-reinforcement is a possible way to provide high impact resistance to polymers without compromising their inherent advantageous characteristics (such as strength, stiffness, biodegradability, etc.), still, this approach has not been employed to the brittle poly(lactic acid) (PLA) substrate yet. Nevertheless, PLA is an easily flammable polymer, its heavy dripping implies increased fire danger during its burning. Therefore, the flame retardancy of PLA based composites is indispensable when applications in electronics, transportation or construction are targeted.

In this study, the preparation of high-impact-strength all-PLA composites by film-stacking and subsequent hot pressing of fully amorphous PLA films and cross-plyed reinforcing layers, composed of highly crystalline PLA multifilament yarns, is described. The self-reinforced PLA composites (PLA-SRCs) were flame retarded by incorporating intumescent flame retardant (IFR) additive system in combination with MMT clays into the matrix films. The prepared PLA-SRCs were comprehensively characterized by optical and scanning electron microscopy, flammability tests (UL94, Limiting Oxygen Index (LOI) measurements and cone calorimetry) and static (tensile and three point bending tests) and dynamic mechanical tests (falling weight impact tests and dynamic mechanical analyses).

Flame retardant loading of 16 wt% ensured self-extinguishing behaviour to PLA-SRCs, i.e. UL94 V-0 rating and a LOI value as high as 34 vol% were achieved. The cone calorimeter tests results showed that already 10 wt% FR content results in 45% reduction of peak of heat release rate compared to the additive free reference composite. Nevertheless, as the PLA fibres are the main load bearing substances, the flame retardant particles in the matrix did not cause noticeable deterioration in the tensile and flexural strength of the PLA-SRCs, in contrast, the stiffness of the composites increased with increasing additive contents. Furthermore, compared to the very low impact absorption energy value of about 1 J/mm characteristic for the inherently very brittle non-reinforced PLA, the perforation energy values corresponding to the PLA-SRCs reveal prominent (one order of magnitude) improvement in impact resistance.

The preparation of flame retarded self-reinforced PLA composites proved to be a promising way to overcome two serious drawbacks, brittleness and easy flammability, of PLA, simultaneously. Besides their indisputable environmental benefits such as renewable source and full biodegradability, the manufactured PLA-SRCs prove to have competitive mechanical characteristics with conventional petrol-based fibre reinforced polymeric composites, even in effectively flame retarded form.