

PHOSPHORUS POLYESTERS AS HALOGEN-FREE POLYMERIC FLAME RETARDANTS IN POLY(BUTYLENE TEREPHTHALATE) – INFLUENCE OF THE CHEMICAL STRUCTURE

Sven Brehme^a, Bernhard Schartel^a, Yana Bykov^b, Manfred Döring^b, Oliver Fischer^c, Doris Pospiech^c, Thomas Köppl^d, Volker Altstädt^d

^aBAM Federal Institute for Materials Research and Testing, Unter den Eichen 87, 12205 Berlin, Germany

^bKarlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

^cLeibniz-Institut für Polymerforschung Dresden e.V., Hohe Str. 6, 01069 Dresden, Germany

^dUniversity of Bayreuth, Department Polymer Engineering, Universitätsstr. 30, 95447 Bayreuth, Germany

Halogen-free flame retardancy of poly(butylene terephthalate) (PBT) is at present mainly achieved using low-molecular-weight additives.¹ These additives often suffer from drawbacks, such as deterioration of the mechanical properties of the polymer. Polymeric flame retardants are a promising approach to overcome these drawbacks. Three phosphorus polyesters with altered chemical environment of the phosphorus (**Fig. 1**) are investigated as potential halogen-free flame retardants for poly(butylene terephthalate).

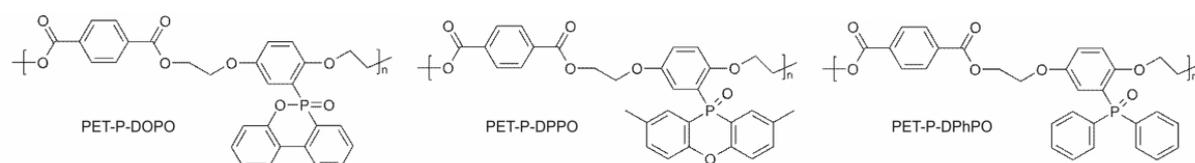


Figure 1. Chemical structures of the phosphorus polyesters.

The outstanding fire properties of the neat PET-P-DOPO as flame retarded polyester material itself and as polymeric flame retardant additive in PBT were reported recently.^{2,3} PET-P-DPPO and PET-P-DPhPO were additionally synthesized⁴ to investigate the influence of the chemical environment of the phosphorus on decomposition mechanisms and fire behavior. Deep insights into structure-property relationships provide the basis for optimizing a flame retardant for a given application.

All three phosphorus polyesters formed strongly intumescent residues under forced-flaming conditions in the cone calorimeter (**Fig. 2**). Three

flame-retardancy mechanisms including flame inhibition, charring, and a protection effect of intumescent char are simultaneously active in all three phosphorus polyesters leading to decreased fire risk. Flame inhibition was similarly strong in the three phosphorus polyesters despite their different structure. The amount of residue formed clearly depended on the structure of the polyester. PET-P-DPhPO (phosphine oxide structure, non-bridged phenyl rings) yielded less residue (27 wt.%) than PET-P-DOPO and PET-P-DPPO. The first step in the formation of char is cross-linking.⁵ Therefore, PET-P-DPPO with its bridged phenyl rings formed more residue (33 wt.%) than PET-P-DPhPO. PET-P-DOPO formed a high residue (40 wt.%) because of its bridged phenyl rings and because of using phosphinate instead of phosphine oxide.⁶



Figure 2. Intumescent fire residues of PET-P-DOPO, PET-P-DPPO, and PET-P-DPhPO (from left to right) obtained with an irradiation of 50 kW/m² in the cone calorimeter.

1. Levchik S.V., Weil E.D., *Polym. Int.* 54(1): 11-35, 2005.
2. Brehme S., Scharrel B., Goebbels J. *et al.*, *Polym. Degrad. Stab.* 96(5): 875-884, 2011.
3. Brehme S., Köppl T., Scharrel B. *et al.*, *Macromol. Chem. Phys.* 2012, doi: 10.1002/macp.201200072.
4. Fischer O., Pospiech D., Korwitz A. *et al.* *Polym. Degrad. Stab.* 96(12): 2198-2208, 2011.
5. Levchik S., Wilkie C.A., *Char Formation*. In: Grand A.F., Wilkie C.A., editors. *Fire Retardancy of Polymeric Materials*. New York: Marcel Dekker, Inc., 2000. p. 171-215.
6. Braun U., Balabanovich A.I., Scharrel B. *et al.*, *Polymer* 47(26): 8495-8508, 2006.