Polyurethane foams with reduced flammability based on oligoetherols synthesized from 1,3-bis(2-hydroxyethyl)uracil, boric acid and ethylene carbonate

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Abstract – Polyurethane foams using oligoetherols synthesized from 1,3-bis(2-hydroxyethyl)uracil, boric acid and ethylene carbonate are obtained. Some properties of the foams, such as apparent density, water uptake, dimensions stability, thermal stability, compression strength, thermal conductivity, oxygen index and horizontal burning were investigated. The obtained foams show an improved thermal stability and reduced flammability.

Keywords – 1,3-pyrimidine ring, 1,3-bis(2-hydroxyethyl)uracil, boric acid, ethylene carbonate, oligoetherols, polyurethane foams, improved thermal stability, reduced flammability.

Introduction

The main disadvantages of plastics are low thermal resistance and relatively low decomposition temperature. The thermal resistance of typical polyurethane foams usually does not exceed 120°C, and the degradation of polyurethane foams is accompanied by the formation of flammable substances, which creates a fire hazard. In the course of burning, polyurethanes emit toxic gases, among others hydrogen cyanide, carbon monoxide and carbon dioxide, and nitrogen oxides. This is a danger to human life and health, and for this reason methods to reduce the flammability of polyurethane foams and improve their thermal resistance are sought. Foams of improved thermal stability can be obtained by using a polyetherols component containing some heterocyclic rings, e.g., 1,3-pyrimidine [1-3]. Unfortunately, they are flammable. Flammability can be reduced by incorporating organic compounds with boron atoms [4, 5].

Results and Discussion

The syntheses of polyurethane foams based on oligoetherols with a 1,3-pyrimidine ring and boron atoms has been proposed. Syntheses the oligoetherols were carried out in two ways. In the first method 2,4-dioxopyrimidine-1,3-diethanol bis(dihydroborate) in the reaction of 1,3-bis(2-hydroxyethyl)uracil with boric acid was obtained, and next it was then treated with excess of ethylene carbonate in the presence of potassium carbonate. The second method relied on the direct reaction of 1,3-bis(2-hydroxyethyl)uracil with boric acid and ethylene carbonate. The structure of the obtained oligoetherols was determined by instrumental methods (IR, ^{1}H-NMR and MALDI-ToF spectra). The physicochemical and thermal properties of oligoetherols were examined. In the next stage, the obtained oligoetherols as polyol components to prepare polyurethane foams were used. Foaming was carried out in a laboratory scale. The composition of foaming samples was selected experimentally. Polymeric MDI was used as a isocyanate agent, and water was a foaming agent. Triethylamine was used as a catalyst and silicone L-6900 was applied as a surfactant. It has been found that foams with regular, small pores are obtained using 3 wt% of water, 2.7–3.85 wt% of catalyst, 1.95 wt% of surfactant and 140–160 g of isocyanate per 100 g of oligoetherol (Fig. 1).The physical properties of selected polyurethane foams: apparent density, water uptake, dimension stability, compression strength, thermal conductivity coefficient, thermal resistance and flammability of selected polyurethane foams

were studied. The apparent density of the foams was in the range of 56.09–91.34 kg/m^3, so they are classified as rigid materials. Along with the increase in the content of boron in foams, their apparent density increases. Water absorption after 24 h of exposition was between 8.05–27.62 wt%. Dimensional stability tests show that shrinkage of the foams after 40 h exposure at 150ºC is very small. The thermal conductivity of the obtained materials falls in the range 0.0349–0.0368 [W/(K·m)]. Dynamic thermal analysis shows that 50% weight loss of foams occurs at 299–322°C. Mechanical properties were evaluated on the basis of compression strength measurements. Before the thermal treatment compression strength at 10% deformation strain of the foams was in the range of 0.29–0.33 MPa. It has been observed, that one month long thermal treatment at temperature 150°C resulted in higher compression strength (0.58–1.27 MPa). Flammability of the foams were studied as follows: horizontal burning tests were made and oxygen index was measured. The horizontal burning test shown, that all the resulting foams are self-extinguishing in the air. The oxygen index of the obtained foams has values in the range of 22.0–24.1vol%. The foams with the highest boron content presented the lowest flammability. The flammability tests allow to state that the obtained materials are self-extinguishing and flame-retardant.

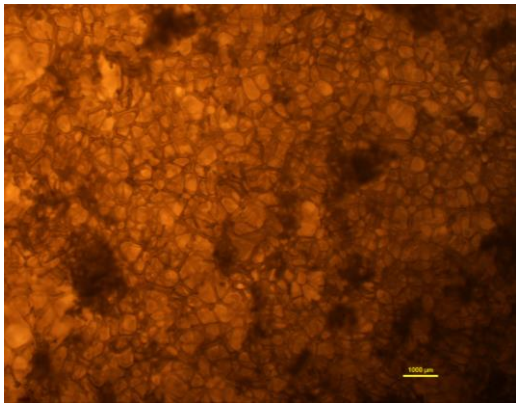

Fig.1. Microscope image of the foam obtained from oligoetherol synthesized from 1 mol 2,4-dioxopyrimidine-1,3-diethanol bis(dihydroborate) and 16 moles ethylene carbonate.

Conclusion

Polyurethane foams obtained from oligoetherols synthesized from 1,3-bis(2-hydroxyethyl)uracil, boric acid and ethylene carbonate characterized an reduced flammability and improved thermal stability compared to classic, rigid polyurethane foams.

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