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Radiation Physics and Chemistry 72 (2005) 511–516
Radiation Physics and Chemistry
www.elsevier.com/locate/radphyschem

Ionizing radiation graft polymerized and modified flame retardant cotton fabric

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Received 11 December 2003; accepted 15 March 2004

Abstract

Halogen free flame retardant cotton (FR cotton) fabric was prepared by grafting 2,3-epoxypropyl methacrylate (GMA) on ordinary or untreated cotton (UT cotton) fabric by γ-rays from ^{60}Co source. Epoxy groups present in GMA grafted cotton (GMA-g-cotton) fabric was reacted with ethylene diamine and subsequently modified with orthophosphoric acid solution to convert in to FR cotton fabric. Effects of imparted dose, concentration of monomer on grafting percentage were studied. The changes in thermal properties after treatment were investigated by using Thermo gravimetric analyser. Limiting oxygen index, char length, time after glow and time after flame were also studied as per ASTM D2863 and IS11871, respectively, for both FR cotton and UT cotton fabrics. The FR cotton fabric was found to pass all the above tests. Washing durability of the FR cotton fabric in different cleaning agents was also studied and a washing solution containing organic solvent mixture is suggested.

Keywords: Halogen free flame retardant; 2,3-Epoxypropyl methacrylate; Radiation-induced grafting; Orthophosphoric acid; Ethylene diamine; Cotton fabric; ^{60}Co source; γ-rays

1. Introduction

Flame retardant (FR) cotton fabrics have got enormous civilian as well as military applications. These fabrics are usually prepared by treating the fabric chemically as a textile finishing process by using different flame retarding agents (Horrocks, 2001a). Most of these flame retarding agents are halogen based, which are not ecofriendly and also toxic in nature because these halogen compounds impart the flame retardancy property by vapor phase mechanism through free radical scavenging and during the process it evolve toxic gases (Schnipper et al., 1995). Another category of flame retardants are intumescent coatings where intumescent agent will provide a thermal and physical barrier to the underlying substrate. This barrier inhibits gaseous products from diffusing in the flame and shield the substrate from heat and air when exposed to fire. But as these protect only the surface, in case of surface damage there may be a fire hazard (Horrocks, 2001b). Another method which has been reported is, blending the flame retarded fibers with non-flame retarded fibers or to develop inherently flame retardant fabrics like aromatic fibers. Recently, there has been interest to develop FR cotton fabrics by using phosphorous compounds, most of these will act as flame retarding agents in condensed phase by increasing the amount of carbonaceous residues or by increased char formation (Shui and Ian, 2002), therefore there is hardly any chance for evolution of toxic gases during combustion unlike in the case of halogen compounds.

Phosphorus containing flame retarding agents are extremely wide and its availability is versatile since the element exists in several oxidation states (Pierce et al., 1975; Stevenson and Guest, 1987). The chemical

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doi:10.1016/j.radphyschem.2004.03.015

transformations of phosphorus containing compounds and their mechanism of action in all the stages of the combustion process are not yet fully understood. But evidence of their practical importance in the development of halogen free flame retarding agents is abundant in the literature (Horrocks, 2001c). Most of these methods are based on conventional chemical process or chemical coatings. However, attempts have also been made to develop flame retardant polymeric materials by chemical graft polymerization techniques (Charles et al., 1996; Geuskens and Kanda, 1991). Radiation-induced grafting is widely known technique and is being used in many cases for modification of properties of the preformed polymers/materials like development of ion-exchange membranes, battery separators, wound dressings, heat resistant synthetic fabrics, etc. (Satoshi et al., 1995; Choi et al., 2000; Sukurada, 1980; Chia et al., 2000).

The objective of this study is to develop a process to make a halogen free phosphorous based FR cotton fabric by using the radiation grafting polymerization technique.

2. Experimental

2.1. Materials

2,3-Epoxypropyl methacrylate (GMA) supplied by E-MERCK was used without further purification. Orthophosphoric acid (OP), ethylene diamine (ED), *N*, N^1 dimethyl formamide (DMF), carbon tetrachloride (CCl_4) and 1, 2 dichloroethane were supplied by S.D. Fine chemicals. Cotton fabric from Century (India) Ltd was used in all the experiments.

2.2. Sample preparation

UT cotton fabric was washed with soap solution followed by ordinary water and dried at room temperature. The initial weight of the dry fabric was measured and then immersed for 24 h in the solution of GMA in DMF.

2.3. Grafting of GMA

GMA monomer solution was prepared in DMF having different concentrations of GMA 10%, 15% and 20% (v/v). Weighed sample of UT cotton fabric was soaked in above solution at room temperature and at ambient conditions for 24 h. The samples containing GMA monomer solution and UT cotton fabric were then irradiated with γ-rays at a dose rate of 0.56 kGy/h at ambient temperature conditions for various total doses to achieve different percentage of grafting. The details of the experimental results are given in Fig. 1.

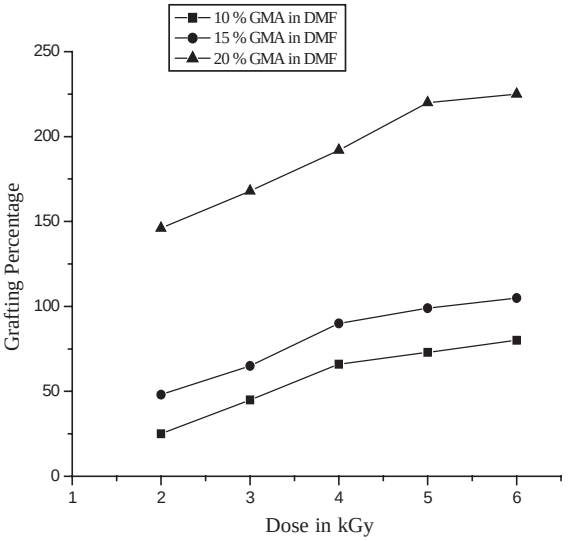

Fig. 1. Grafting percentage vs. dose (kGy) with different concentrations of GMA.

2.4. Reaction with ethylene diamine

After imparting the specific dose of γ-radiation the GMA-g-cotton fabric was removed from solution and washed with DMF to remove the homopolymer and excess of monomer. The washed fabric was treated with 5% (v/v) solution of ED in DMF at room temperature and atmospheric pressure for 8 h. The sample was then removed from solution and washed with ordinary water and then dried at room temperature to a constant weight.

2.5. Reaction with orthophosphoric acid

In order to make FR cotton fabric the above washed and dried fabric is reacted with 3% (v/v) solution of OP in distilled water at room temperature and atmospheric pressure for 8 h. Finally, the fabric was taken out and washed with ordinary water to remove excess phosphoric acid and other residues then dried at room temperature.

3. Characterization

3.1. Estimation of the percentage grafting

The grafting amount was calculated gravimetrically and expressed as a percentage of the grafting monomer weight by the following equation:

$$\% \text{ of grafting} = \frac{P - Po}{Po} \times 100, \quad (1)$$