Synthesis and Application of an Eco-friendly Flame Retardant for Bamboo Viscose Fabric

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1. INTRODUCTION

The most commonly used durable flame-retardant chemicals for cellulosic fibers are based on halogen, nitrogen and organophosphorus compounds, such as tetrakis (hydroxymethyl) phosphonium chloride known as 'THPC' and N-hydroxymethyl-3-(dimethoxy-phosphine acyl) propanamide known as 'Pyrovatex CP' [1,2]. However, textiles finished by THPC or Pyrovatex CP have the defect of releasing free formaldehyde slowly [3]. So, it is necessary to exploit eco-friendly flame retardant with more functions. In this study, an eco-friendly flame retardant (EFFR) was synthesized using silicone, phosphoric anhydride and diethanolamine as raw materials and applied to bamboo viscose fabrics in combination with the water-soluble isocyanate-terminated cross-linker (WIT). The flammability, mechanical strength, handle and whiteness of the treated fabric as well as the durability of this system to multiple laundry cycles were evaluated. It is found that the flame retardant has durable function of fire-proofing and softening to bamboo fabric, moreover it has no free-formaldehyde and halogen.

2. EXPERIMENTAL

2.1 Materials

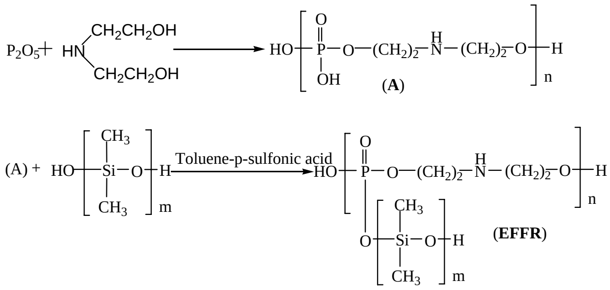
The fabric used in this study was a 100% scoured and bleached bamboo viscose fabric. Silicone (viscosity=100cps, M_w=3000), phosphoric anhydride, diethanolamine, toluene-p-sulfonic acid and magnesium chloride hexahydrate ($MgCl_2·6H_2O$) were all AR grade chemicals. The water-soluble isocyanate-terminated cross-linker (WIT) was a self-produced laboratory product.

2.2 Synthesis of an environmental friendly flame retardant (EFFR)

The synthesis of EFFR was shown in Scheme 1.

2.3 Fabric treatment procedure

Fabric samples were dipped in the finishing solution containing 300g/L EFFR, 50g/L WIT and 20g/L $MgCl_2·6H_2O$ for 1 min and then padded on a two roll padding mangle at a fixed pressure; the wet pick up was about 75% after two dips, two nips. Then the fabric was dried in a heat-setting stenter at 90 ^oC for 2 min, and then cured at 170 ^oC for 2min. Then, the cured fabrics were soaked in water (liquor ratio 1:30) containing neutral soap flakes 2 g/L at 60 ^oC for 20 min, then rinsed with tap water and dried at 105 ^oC for 2h. The finished samples were placed in a desiccator containing silica gel before measurements.



Scheme 1

2.4 Measurements

FT-IR spectra were recorded on a Magna-IR 550 FT-IR spectrometer with KBr pellet method. Thermogravimetric analysis was conducted on a SDT 2960 DSC-TGA instrument under a flow of nitrogen from 100 to 500 ^oC at a nitrogen flux of 50ml/min and an increasing temperature rate of 10 ^oC/min.

Flame-retardant properties were determined by GB/T5455-1997. The oxygen index (LOI) was assessed with HC-2 LOI instrument, according to GB/T5454-1997. Fabric handle evaluation method: The score of original fabric handle was assumed to be 5 and the highest score of fabric handle was 10, but the least was 0. There were at least three people evaluated the handle of bamboo viscose fabrics subjectively, and then got the average scores. Greater data expressed better handle. Laundry endurance was determined according to the GB/T 17596-1998.

3. RESULTS AND DISCUSSION

3.1 Characterization of the flame retardant

The structure of the flame retardant was investigated by FT-IR spectrum. The characteristic bands at 1089, 1400, 2497 and 3408cm^{-1} which corresponds to the P-O-C, P-O, P-OH and –OH groups, respectively. Besides, the silicon groups can be observed through the bands of -$Si(CH_3)_n$, Si-OH and- Si (CH3) $_2$ at 1261, 869 and 800 cm^{-1}.

3.2 Characterization of the treated fabrics

The changes of the chemical structure of bamboo viscose fabric before and after treating were investigated by FT-IR spectra. The FT-IR spectra of treated bamboo viscose fabrics are almost identical to that of the control sample, except in the wavenumbers of about 800 cm^{-1},1000 cm^{-1}, 1085 cm^{-1}, 1250cm^{-1}, 1450cm^{-1}, 1700cm^{-1}, where the new absorption peaks appear, which could be attributed to -$Si(CH_3)_2$, P-O-Si, Si-O-Si,P=O,-NH-, C=O, respectively. This result indicates that the flame retardant (EFFR) and cross-linker (WTI) combined onto bamboo viscose cellulose could occur crosslinking reaction to enhance their durability on bamboo viscose fabrics.

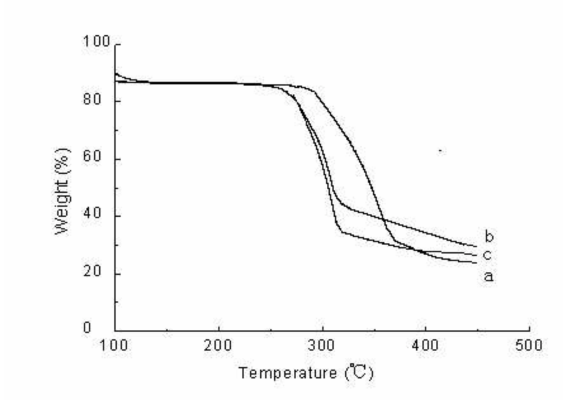


Fig.1. TG curves of (a) original bamboo viscose fabric, (b) finished bamboo viscose fabric before laundering, and (c) finished bamboo viscose fabric after 30 launderings.

The thermal decomposition of bamboo viscose fabrics was investigated by TG in atmosphere of nitrogen (see Fig.1). The main decomposition of the original and treated fabric and the treated fabric after 30 launderings started at 288, 260 and 265 ^oC, respectively. For the original sample, the major decomposition temperature ranged from 288 to 355 ^oC; for the treated sample, the scope of temperature was from 260 to 310 ^oC; for the treated fabric after 30 launderings, the change of this temperature was from 265 to 310 ^oC. Meanwhile, in this major stage the rate of weight loss was 60.2, 48.5 and 53.0%, respectively. From the results of the TG analysis, we concluded that the major decomposition temperature of the treated fabrics was lower than that of the original fabric, which could be attributed to decomposition of the flame retardant (EFFR) combined on the fabric (because the pyrolysis temperature of EFFR is lower than that of bamboo viscose fiber). It also means that EFFR brought to bear flame resistance before the pyrolysis of bamboo viscose fiber. These results indicate that EFFR can protect bamboo viscose fabric from fire in a certain of degree.

3.3. Primary performance changes of the treated fabrics

The experimental results in Table 1 indicate that EFFR and WTI combination with bamboo viscose cellulose had a dramatic effect on the main properties of treated bamboo viscose fabric. The flameretardancy of bamboo viscose fabric had a considerable improvement after it was treated by EFFR and WTI, declined a little even the treated bamboo viscose fabric after 30 laundering, a result which is consistent with the result of fabric weight gain. The handle of bamboo viscose fabric stiffened slightly after the fabric finished by EFFR and WTI, but it would soften gradually along with addition of laundering frequency. We inferred that cross-linking reaction caused EFFR and WTI to become membrane fixing on the surface of fiber, which made the handle of fabric stiffen, however, the flame retardant (EFFR) itself made fabric soften again because of its organosilyl constituent part. Based on an overall consideration of various factors, the effect of EFFR on handle of fabric was wee, but the whiteness and tensile strength of the bamboo viscose fabrics finished by EFFR and WTI dropped slightly.

Table 1 Properties of the bamboo viscose fabrics.

Samples	Control	Treated fabrics	Treated fabrics after 30 launderings
Continued burning time (s)	–	0	3.1
Smoldering time (s)	–	0	0
Length of damaged -carbon (cm)	BEL	10.3	13.2
LOI (%)	18.5	31.0	26.5
Whiteness	80.1	76.8	78.4
Tensile strength (N)	161.2	141.7	139.3
Handle assessment (score)	5	4	5
Weight gain (%)	0	18	16

Notes: EFFR 300 g/L, WTI 40 g/L, and dried at 160 for 2 min ℃; BEL=Burns Entire Length.

4. REFERENCES

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