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Efficient suppression of flammability in flame retardant viscose fiber through incorporating with alginate fiber

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ABSTRACT

The flame retardancy of flame retardant viscose (FRV) fiber can be significantly further improved by simple blending with alginate (A) fiber, even though with the content of 10 wt%. Cone calorimeter results showed that longer time to ignition (TTI), lower peak heat release rate (PHRR) and total heat release (THR) can be achieved in FRV after mixing with A. For example, the TTI of FRV can be raised from 10 s to 41 s after blended with only 10 wt% A. The mechanism of the effective suppression of flammability mentioned above was put forward by thermogravimetric analysis coupled with Fourier transform infrared analysis (TG-FTIR) and pyrolysis-gas chromatography–mass spectrometry (Py-GC–MS). It was found that the content of released CO_2 for FRV/A was higher than that of pure FRV, and the content of the flammable gases for FRV/A, such as hydrocarbons, aldehydes, ethers and alcohols, was lower than that of FRV. In this way, the flame retardancy of FRV was effectively enhanced after blending with A.

1. Introduction

With the high surface area and flammable performance of fibers, the fire hazards can be easily caused by the ignition of textiles. Therefore, with the demand of the people's safety and the implementation of the fire protection regulations, textiles with flame retardancy have been attracted extensively attention. However, individual fibers have some shortcomings, which cannot balance the flame retardancy, mechanical performance, comfort, dyeability and cost. Therefore, fibers blending method has become a simple and effective approach to make high performance fabrics, which can combine advantages of different categories of fibers. Moreover, the synergistic effect of flame retardancy can also be achieved in some fiber mixtures [1,2].

Alginate (A) fiber is a kind of biopolymer with outstanding flame retardancy and biocompatibility. The flame retardancy of alginate fiber is attributed to the divalent or trivalent metal ions, such as the ions of calcium, barium, copper and zinc [3]. Moreover, the metal ions can improve the flame retardancy of cellulose fibers by grafting method, which can influence the thermal degradation mechanism and pyrolysis behavior of cellulose fibers through forming more chars and fewer kinds of gaseous products [4,5]. In addition, the alginate fibers can also enhance the flame retardancy of cotton fabric by simply blending method [6]. The addition of alginate fiber can reduce the heat release rate and total heat release, which is due to the fact that alginate can influence the thermal decomposition process of cotton.

Viscose is a kind of renewable cellulose fiber, which is widely used in textiles due to its good handle and dyeability. Unfortunately, the highly flammable performance of viscose fiber limits its application, which drives many researchers to enhance its flame retardancy [7,8]. At present, the flame retardant viscose (FRV) fiber containing dithiopyrophosphate (DDPS) has become industrialized production and is widely used in flame retardant viscose fabrics [9]. Considering that viscose fiber is a kind of cellulose fiber, can alginate fiber further improve the flame retardancy of FRV fiber? With this purpose, the flame retardancy and thermal degradation behavior of the fiber mixtures FRV/A were investigated. As it turned out, efficient suppression of flammability in flame retardant viscose fiber can be achieved through incorporating with alginate fiber. The corresponding mechanism was put forward through exploring the evolved gaseous products.

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2. Materials and methods

The fiber mixtures FRV/A with the weight ratio of 90/10, 80/20, 70/30 and 60/40 were simply prepared by small-scale carding machine. The minimum oxygen concentration for the ignition of alginate fiber is 48% [10]. Detailed information of the materials, preparation of the mixtures and relevant characterizations was provided in the Supporting Information (SI).

Table 1
The TTI, PHRR and THR values of FRV, A and their mixtures.

Fiber	TTI (s)	PHRR (kW/m^2)	THR (MJ/m^2)
FRV/A (100/0)	10 ± 1	99 ± 3	7.8 ± 0.2
FRV/A (90/10)	41 ± 2	92 ± 4	5.3 ± 0.3
FRV/A (80/20)	43 ± 2	88 ± 3	4.5 ± 0.2
FRV/A (70/30)	48 ± 3	83 ± 3	4.2 ± 0.2
FRV/A (60/40)	52 ± 2	81 ± 2	3.6 ± 0.2
FRV/A (0/100)	/	25 ± 5	2.3 ± 0.3

3. Results and discussion

The flame retardancy of FRV/A fibers are investigated by cone calorimeter at the heat flux of 35 kW/m^2, in which neat fibers are included as a contrast. The values of time to ignition (TTI), peak heat release rate (PHRR) and total heat release (THR) are shown in Table 1, and the curves of heat release rate (HRR) and THR are displayed in Fig. 1a and b. Obviously, for neat FRV, it is easily ignited with the TTI of 10 s, even though containing the fire retardant of DDPS. The corresponding PHRR and THR is 99.1 kW/m^2 and 7.8 MJ/m^2, respectively. For neat A, it cannot be ignited with much lower PHRR (24.5 kW/m^2) and THR (2.3 MJ/m^2). It's interesting that alginate can significantly increase the TTI of FRV. For example, the TTI can be significantly changed from 10 s to 41 s after

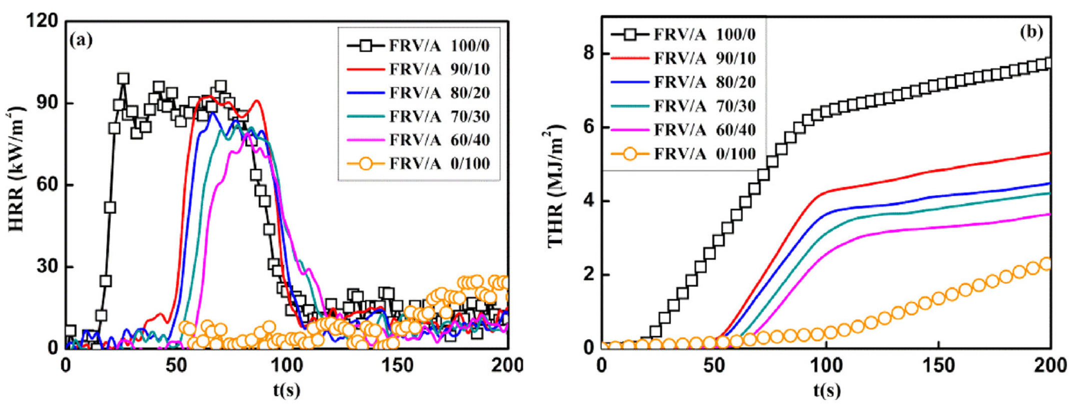

Fig. 1. The variations of HRR (a) and THR (b) versus time of neat FRV, A and their blends.

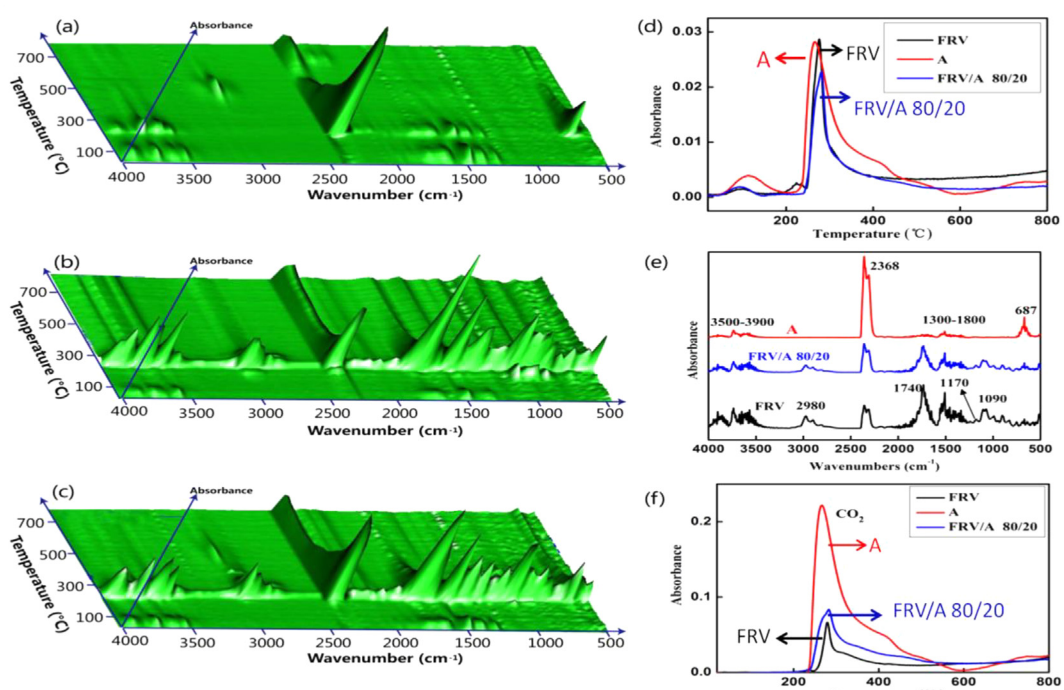

Fig. 2. 3D FTIR spectra of the gaseous products of A (a), FRV (b) and FRV/A 80/20 (c), the Gram–Schmidt curves (d), the FTIR spectra of the decomposition products at the maximum decomposition rate (e) and the absorbance intensity of CO_2 versus temperature (f) for FRV, A and FRV/A 80/20.