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Study on Raman spectra of aliphatic polyamide fibers

Na Tong [a], Changjun Zhu [a,*], Chonghui Zhang [a], Yixin Zhang [b]

[a] Department of Physics, School of Science, Xi'an Polytechnic University, Xi'an, 710048, China
[b] School of Textile and Materials, Xi'an Polytechnic University, Xi'an, 710048, China

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ABSTRACT

Raman spectrometry was employed to study the characteristics of Raman spectra of aliphatic polyamide fibers, which were treated with sodium hydroxide, sulfuric acid and copper sulfate, respectively. Raman spectra under different conditions were obtained and the characteristics of the Raman spectra were analyzed. The influences of sodium hydroxide, sulfuric acid and copper sulfate on the lifetime of vibrational modes relating to the main and secondary peaks and relative intensity of the main and secondary peaks were discussed. The results show that Raman peaks beyond 1200 cm^{-1} appear for aliphatic polyamide fibers processed by sodium hydroxide, while the Raman peaks beyond 1000 cm^{-1} disappear for aliphatic polyamide fibers processed by sulfuric acid. The variations of the Raman spectra are primarily related to the chemical bonds and molecular structures which can be changed by alkali and acids.

1. Introduction

Global trends in textile industry are oriented toward development and manufacture of high-added value products with multifunctional properties [1]. In addition to fashion and comfort demands, the garments are required to possess conformal property and wrinkle resistance simultaneously. Aliphatic polyamide fibers possess high chemical stability, mechanical strength and shape stability. Polyamide fibers, also known as aliphatic polyamide fibers, are made of w-amino acid condensation or by lactam ring opening polymerization, the general formula is $[-NH(CH_2)_xCO-]n$ [2,3], where n is an integer, which falls in the range from 2 to 11 for commercial applications. The polymers are semi-crystalline with the CH_2 chain in the all-trans conformation in crystalline regions [4]. At present, IR spectra of polyamide have been investigated extensively [5,6] and the molecular vibration behaviors of a number of aliphatic polyamide fibers have been calculated [7] and compared with the existing IR spectrum data. Furthermore, studies have been conducted on the spectrum aliphatic polyamide fibers Raman fluorescent [8,9] with near infrared laser. There also has been certain study about polyamide [10,11], of which the surface modification is the most significant. Vibration spectrum of polymer is an important means of researching structure, Raman spectroscopy is an effective method to study molecular vibration and rotation. However, little research has been reported on Raman vibration spectrum of aliphatic polyamide fibers [12]. Aliphatic polyamide fibers have been widely applied in many fields, investigation into their Raman characteristics not only plays a key role in revealing macroscopic properties of materials, such as mechanical, optical and thermal properties, but also has important significance in material modification. In this paper, we study the characteristics of molecular vibrational modes of aliphatic polyamide fibers using Raman spectroscopy.

2. Experimental setup

The arrangement of Raman spectrometer is shown in Fig. 1. The inVia microscopic Raman spectrometer (Renishaw) was employed to perform experiments. The wavelength of Ar^+ laser is 514.5 nm, with a resolution of 4 cm^{-1}, the depth of interaction is 100 nm. Using CCD as photoelectric detector and two-stage filter, the setup has high sensitivity and can block laser Rayleigh scattering, light transparent efficiency is higher than 90%. The Raman spectrometer has high stability, high repeatability, continuous scanning features. In addition, the inVia microscope has high heat stability and mechanical stability.

3. Sample preparation

Proper amount of distilled water was added to sodium hydroxide, sulfuric acid and copper sulfate, respectively. A 3% of sodium hydroxide, 5% of sulfuric acid and 3% of copper sulfate were obtained. First, aliphatic polyamide fibers were put in four beakers numbered as 1, 2, 3, 4, respectively. Then, 30 ml of 3% sodium

* Corresponding author. Tel.: +86-029-82330236.
E-mail address: changjunzhu@yahoo.com (C. Zhu).

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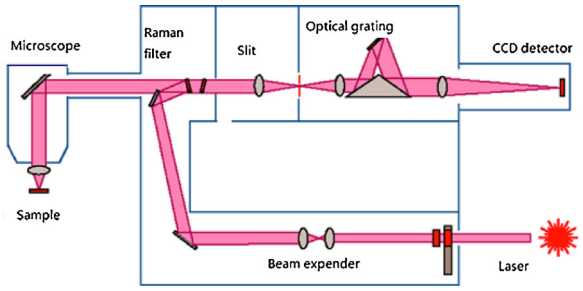

Fig. 1. Renishaw Raman spectrum diagram.

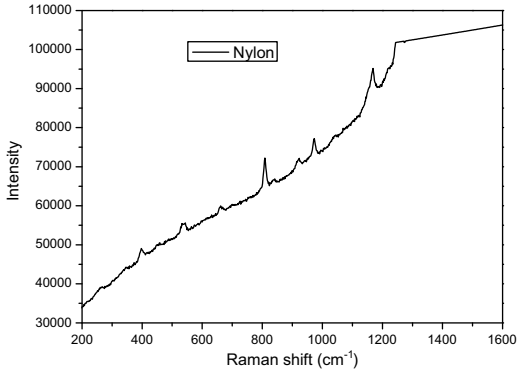

Fig. 2. Raman spectrum of aliphatic polyamide fibers.

hydroxide, 30 ml of 5% of sulfuric acid, 30 ml of 3% of copper sulfate and distilled water were put in beakers 1, 2, 3, 4, respectively. All the beakers were put in the ultrasonic water scrubbers and the temperature was set at 50 °C and the washing time was 60 min. The solution was taken out of the beakers, and then the aliphatic polyamide fibers in the four beakers were washed three times with distilled water and, then, dried for 24 h, and put in the sample bags. Finally, we fixed aliphatic polyamide fibers on the slide, and measured the Raman spectra using the inVia microscopic Raman spectrometer.

4. Results and discussions

Raman spectrum was obtained for aliphatic polyamide fibers without any processing, as shown in Fig. 2, and Raman peaks appear in the range from 400 to 1200 cm^{-1}. The Raman frequency shifts of different peaks in order are 399.5, 542.3, 661.4, 804.5, 923.6, 971.2, 1166.4 cm^{-1}, in which two highest peaks at 804.5, 971.2 cm^{-1} are referred to as the main peak and secondary peak, respectively.

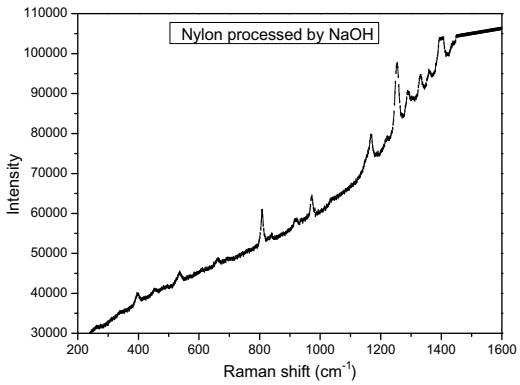

Fig. 3. Raman spectrum of aliphatic polyamide fibers processed by sodium hydroxide.

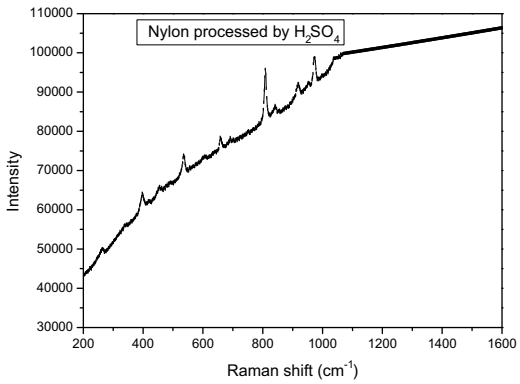

Fig. 4. Raman spectrum of aliphatic polyamide fibers processed by sulfuric acid.

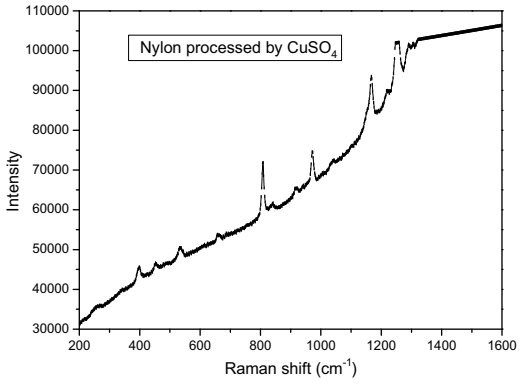

Fig. 5. Raman spectrum of aliphatic polyamide fibers processed by copper sulfate.

To gain an insight into the influences of sodium hydroxide on the chemical bonds and molecular structures of aliphatic polyamide fibers, aliphatic polyamide fibers were processed by sodium hydroxide, and Raman spectrum was acquired, as shown in Fig. 3. Comparing Figs. 2 and 3, it is clear that, within the range of 400–1200 cm^{-1}, there is no distinct change in Raman spectra, including central wavelength, width and shape. Whereas, above 1200 cm^{-1}, Raman peaks appear for aliphatic polyamide fibers processed by sodium hydroxide, indicating that the interaction of aliphatic polyamide fibers and sodium hydroxide changes chemical bonds and molecular structures and, consequently, activates high-frequency vibrational modes of aliphatic polyamide fibers.

Insight into the influences of sulfuric acid on chemical bonds and molecular structures of aliphatic polyamide fibers was provided by examining Raman spectrum of aliphatic polyamide fibers processed by sulfuric acid, as shown in Fig. 4. It shows from Fig. 4 that the slope of the aliphatic polyamide fibers Raman spectra processed by sulfuric acid increases obviously, compared with

Table 1
Intensities of Raman peaks under different conditions.

Different conditions	Intensity	
	Main peak	Secondary peak
Aliphatic polyamide fibers without any processing	137874.8	150740.6
Aliphatic polyamide fibers processed by sodium hydroxide	114053.6	124249.2
Aliphatic polyamide fibers processed by sulfuric acid	180145	192130.8
Aliphatic polyamide fibers processed by copper sulfate	132302.6	142359