Comparison and Analysis of Thermal Degradation Process of Aramid Fibers (Kevlar 49 and Nomex)

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Abstract: High performance fibers such as polymer material, have extensive applications in aerospace and high temperature environment. When these fibers were used in such high temperature, could be subjected to degradation. To understand and evaluate the thermal degradation process of materials under thermal environment, effective characterization and research methods must be adopted. In this paper, the thermal degradation processes of aramid fibers were analysed by TGA-DTA/FT-IR. The experimental results show that aramid fibers (Kevlar 49, Nomex) have similar thermal stability, but their thermal degradation process and temperatures are different. Kevlar 49 fiber shows higher degradation temperature as a copolymer of para-aramid, and its initial degradation temperature is 548.1℃ in air. It can also be found that the Nomex fiber has a lower thermal degradation temperature and its initial degradation temperature is 423.7℃ in air. Ascending the temperature to 800℃, the two kinds of fibers loose all mass in air. We can get the wave number, absorbance time and three-dimensional images during the heating process by TGA-DTA/FT-IR tests. According to TG curves, the infrared spectra of decomposition products can be obtained and analyzed. The thermal decomposition process can be comprehensively discussed by the infrared spectra of decomposition products.

Keywords: Thermal degradation, TGA-DTA/FT-IR, aramid fibers, process.

1. Introduction

Polymers have found applications in each part of our daily life. Some of these applications require a deep knowledge about the durability and a predictability of the properties under different environmental conditions and over long periods to cover the whole lifetime of the object. In the last few decades, the demand from advanced industries, particularly the aerospace, has been the driving force for the development and applications of high performance fibers in many fields, such as structural, composite, and reinforced materials. Aramid fibers have excellent thermal and oxidative stability and the retention of physical properties at high temperature [1-2], which make the materials very suitable for many purposes. The popular commercial high performance fibers are Kevlar and Nomex fibers. Kevlar fiber has high tenacity, modulus, and remarkable thermal stability, these fibers are widely used as tire reinforced materials, ropes, cables, and ballistic resistance fabrics. Similarly, Nomex fiber has excellent thermal and light protective properties which are widely used in aerospace, military and protective clothing.

Although considerable efforts have been devoted to study the structure, thermal properties, and their relationship for high performance fibers, as well as thermal stability and thermal degradation of aramid fibers [3-6], there are only a few publications on the comparison between their thermal stability and analysis of thermal degradation process .

In this paper, the thermal degradation processes of aramid (Kevlar 49, Nomex) fibers were studied by TGA-DTA/FT-IR. The thermal decomposition temperatures of aramid fibers were obtained and the thermal decomposition compounds were analyzed.

2. Experimental

2.1 Materials

The aramid fibers include Kevlar 49 fiber and Nomex fiber, which are obtained from Dupont. Figure 1 reveals the longitudinal shapes of Nomex and Kevlar 49 fibers observed by scanning electron microscope. The specification of the fiber is listed in Table 1.

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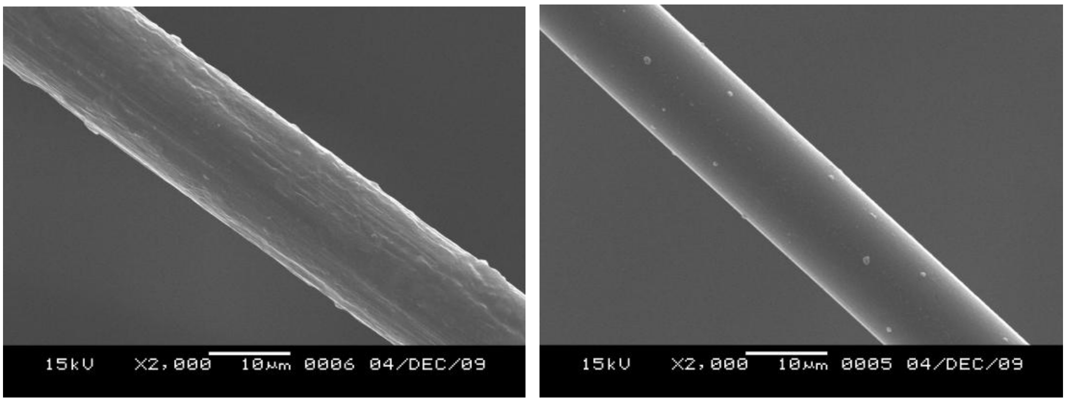

(a) (b)

Figure 1 Longitudinal micrographs of Nomex and Kevlar 49 fiber. a Nomex fiber. b Kevlar 49 fiber.

Table 1 The basic properties of aramid fibers.

Properties	Kevlar 49	Nomex
Diameter/ µm	14	13
Tensile strength cN/dtex	18.2	4.8

2.2 Measurements

Thermal degradation of aramid fibers were performed in a TG 209 F1 Iris device. The thermal scanning mode ranges from 50℃ to 800℃ at a programming heating rate of 20℃/min in atmosphere with a gas flow of 20 mL/min. Each of the samples was controlled within 5-6 mg in primary weight and held in an alumina crucible, and then the loss of the sample weight was measured under a temperature program. The TG and differential DTG curves were recorded and displayed simultaneously during the measurement. The temperature parameters are as follows, the initial temperature of decomposition (T_0), the temperature of half decomposition ($T_{1/2}$), the temperature at the maximum rate of weight loss (T_p), and the temperature of terminal decomposition (T_t), . Fourier transform infrared spectroscopy (Nicolet Corporation U.S., NETXUS750 type) was used to analyze the component of release gas. The thermal degradation products during experimental process were blown into the infrared testing pool by carrier gas and were analyzed. The spectral range is 400 ~ 4 000 cm^{-2} and the resolving power is 1 cm^{-2}.

3. Results and discussion

3.1 The thermal degradation of Nomex fiber by TGA-DTA / FT-IR

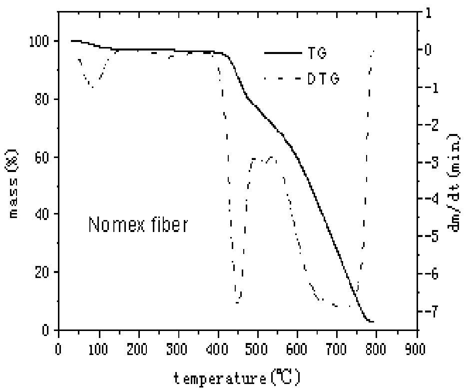

Figure 2 The TG and DTG curves of Nomex fiber.

The thermal decomposition properties of Nomex and Kevlar 49 fiber in atmosphere were studied by TG. Figure 2 shows TG and DTG curves at a heating rate of 20 K min^{-1} obtained during pyrolysis of Nomex fiber in air. The TG curve first exhibits a weight loss ascribable to release of adsorbed moisture that extends from room temperature to 105℃, which coincides with the DTG curve. No further changes in mass occur between 105℃ and 270℃. Above 270℃, a slight weight loss of approximately 2% takes place. The thermally measured results in atmosphere, indicate that the initial degradation temperature of the Nomex fiber is 423.7℃. A temperature of 423.7℃ is the onset of decomposition temperature. The terminal temperature of the decomposition is approximately 800℃. In this