RIBBON-LIKE ACTIVATED CARBON FIBERS

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INTRODUCTION

Activated carbon fibers (ACF) are produced commercially from isotropic pitches and polymers [1]. They have several attractive properties which can provide advantages over other forms of activated carbon in some applications. For example, they can be produced with high surface areas, they allow rapid rates of adsorption and desorption, and they can be incorporated in novel structural forms. Typically, the fibers are microporous, although we have found that significant mesoporosity can be developed in certain types of carbon fibers [2,3]. However, the bulk density of the fibers is very low, which places a limit on their use in situations where volumetric adsorption capacity is of greater or comparable importance than weight-based capacity, such as natural gas storage application [4,5]. The low density is due principally to the large interfiber spacing. Improvements in packing density could, theoretically, be attained if the fiber cross section allowed more efficient packing and a reduction in void volume.

Mesophase pitch-based carbon fibers have been prepared with ribbon-like cross-sections by several research groups, with the aim of improving the structure and properties of carbon fibers for mechanical and thermal management applications [6,7]. In this study, we describe the preparation of ribbon-like activated carbon fibers from an isotropic pitch, and compare their properties with others possessing a circular cross-section that were produced under similar conditions. The effects of fiber cross-sectional shape on the ability to reduce interfiber porosity are also discussed.

EXPERIMENTAL

The precursor pitch used in the study was an isotropic petroleum product (Aerocarb 80), supplied by the Ashland Carbon Fiber Division of Ashland Inc. Ribbon-like fibers were obtained by melt spinning [2], using a racetrack-shaped nozzle. The outline of the nozzles is illustrated in Figure 1. The narrow dimension of the nozzle cross section is 0.3 mm (equal to the diameter of the nozzle used to produce circular cross section fibers) and has an aspect ratio of about five. The spinning conditions for both circular and ribbon-like cross sectional shapes were essentially identical [2]. Green fibers were stabilized at 230 °C by air oxidation. Because of their larger cross-section area, the ribbon-like fibers were held at the oxidation temperature for 60 min. longer than the circular fibers to ensure complete stabilization. The fibers were carbonized at 650 °C in nitrogen, and then activated by pure CO_2 at 1000 °C for 30 - 60 min. The surface area and pore structural characteristics of the activated fibers were determined from nitrogen adsorption isotherms obtained at 77K, using a Coulter Omnisorp 610 [3].

MODELS AND RESULTS

A schematic drawing, illustrating an idealized packing arrangement for fibers with a ribbon-like cross-section, is shown in Figure 1. The fiber cross section is approximated by a rectangle with semicircular edges on the short sides. In the arrangement shown, the basic architecture consists of layers of equal-thickness ribbons laid on one straight side. Therefore, two-directional arrangements, e.g. laminate structure, could also provide the same packing density. The effects of cross-section aspect ratio (x) of the fibers on void volume reduction are shown in Table 1. For circular fibers, the lowest possible specific void volume, 0.215, is obtained by configuring the fiber centers in a hexagonal close packed arrangement. For ribbon-like fibers, the void volume is inversely related to the aspect ratio. There is a sharp drop in void volume as the aspect ratio is increased from one (circular cross-section) to five. Further increases in this ratio have progressively less influence. A reduction in void volume of 90% can be obtained at an aspect ratio of 10.

An SEM micrograph of ribbon-like activated carbon fibers is shown in Figure 2. These materials were activated to 45 wt% burn-off. Clearly, the ribbon shape is retained during processing and most fibers have an aspect of 4 - 6, similar to that of the spinning nozzle. However, the fibers are not completely uniform, and there is a distribution in thickness and aspect ratio, as shown in Table 2. The ribbon thickness is comparable to the diameter of the circular fibers [2]. An examination of the fracture surfaces of the fibers shows no evident pores, but there are some protrusions on the fiber surfaces as has been observed with circular fibers. The surface area and pore volume of the ribbon-like activated fibers are over 1200 m^2/g and 0.60 ml/g, respectively. The shape of the nitrogen adsorption isotherms indicates that both circular and ribbon fibers are microporous. Under the same activation conditions, the circular fibers appear to experience somewhat higher burn-off and correspondingly higher surface area and pore volume (Table 2). This may suggest that the circular fibers have higher gasification reactivity due to their larger specific outer surfaces (when the ribbon width and circular diameter having a similar dimension). Much similar surface area and micropore volume might be obtained if the activation was controlled at the same burn-off.

CONCLUSIONS

Theoretical calculations show that the packing density of carbon fibers could be increased by using a ribbon-like cross section. Preliminary experiments have demonstrated that such fibers can be produced on a laboratory scale, with aspect ratios up to 10, by melt-spinning isotropic pitches. Activating these ribbon-like carbon fibers gave high-surface area activated carbon fibers with pore structures that are similar to those developed in circular cross section ACFs.

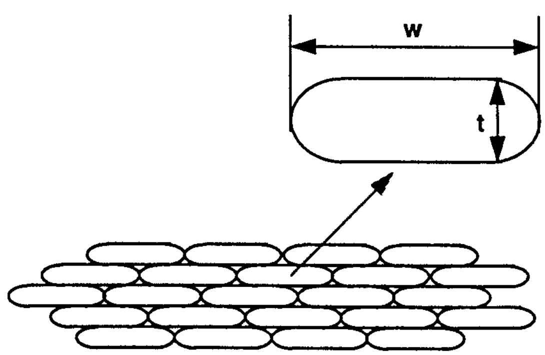

Fig. 1 Schematic illustration of high-density packing of ribbon-like fibers.

Table 1 Effects of aspect ratio of ribbon-like fibers on packing density.

Aspect (x = w/t)	Round	Ribbon type				
	1	2	5	10	20	50
Packing Porosity $[(1-\pi/4)/x]$	0.215	0.107	0.043	0.021	0.007	0.004
Porosity reduction(%)	0	50	67	90	95	98

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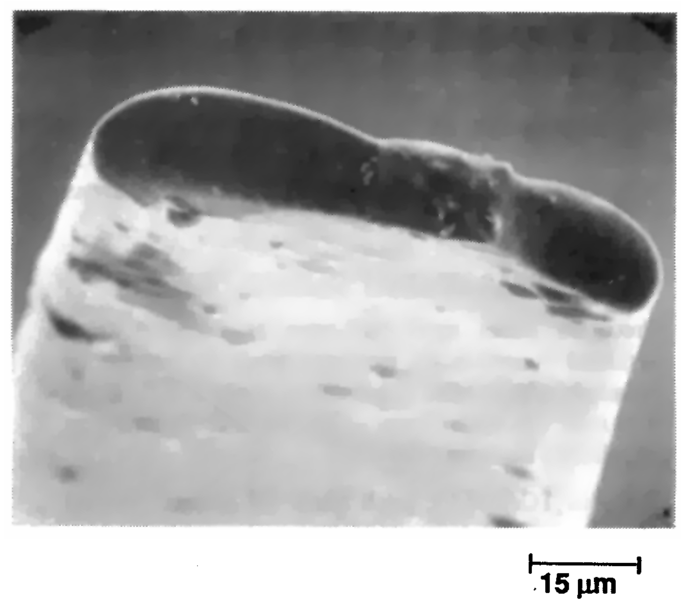

Fig. 2 SEM micrograph of ribbon-like activated carbon fibers prepared from isotropic pitch.

Table 2 A comparison of properties of circular and ribbon-like activated carbon fibers

Fiber shape	Round	Ribbon
Diameter/thick (µm)	8 - 15	6 - 18
Aspect	1	4 - 10
Burn-off (wt%)	51	45
Surface area (m^2/g)	1520	1210
Pore volume (cm^3/g)	0.76	0.60