PREPARATION OF VAPOR-GROWN BIOMIMETIC CARBON FIBERS WITH FRACTAL-ROOT STRUCTURE

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INTRODUCTION

Modern materials science has entered an era of developing composite, intelligent and environment conscious materials through theoretical design. Biomimetic design and exploration of composite materials exactly reflect this new trend. Recently, a few researchers have theoretically and experimentally studied biomimetics of composites [1-3]. The structural and functional suitability of biomaterials and structures was analyzed from the viewpoint of materials science, and then biomimetic models of composites were proposed and evaluated with model experiments.

For example, it can be often observed that trees even in sandy soil cannot be pulled out by very strong winds. A detailed investigation indicates that this is due to their well-developed fractal root structures. Based on this observation and fractal theory, an approximate theory of pull-out of fibers with a fractal-root structure (branched fibers) from a matrix has been proposed and model experiments accomplished[3]. It was found that the force and energy of fiber pull-out increase with both branching steps and branching angles, and the strength and fracture toughness of composites reinforced by the fibers with a fractal-root structure are greater than those of composites by plain fibers. The results of model experiments were greatly consistent with them. However, for the practical design and fabrication of composites reinforced by branched fibers, one must at first solve the problem of the synthesis of this kind of reinforcements in a large scale. On the other hand, carbon fibers are an excellent reinforcement and have wide applications. Moreover, it was reported that vapor-grown carbon fibers (VGCFs) have different many morphologies with different preparation conditions [4,5]. Thus, the present work was carried out to synthesize carbon fibers with a fractal-root structure through vapor growth.

EXPERIMENTAL

The vapor-grown carbon fibers were grown on a ceramic substrate using benzene as the carbon source, iron as the catalyst, and hydrogen as the carrying gas. The preparation procedure of the iron catalyst is following: 0.5 wt% $Fe(NO_3)_3$ aqueous solution was sprayed on the substrate and dried; then the substrate was heated to decompose $Fe(NO_3)_3$ to Fe_2O_3; and Fe_2O_3 was reduced to Fe by hydrogen at 873 K. Then the carbon fibers were synthesized on the substrate at 1473 K for a certain time. The morphology of the carbon fibers obtained was observed using scanning and transmission electron microscopies.

RESULTS AND DISCUSSION

Scanning electron microscopy has given us some insight as to the appearance of the VGCFs. As expected, the VGCFs obtained show plain and straight, branching (Y-like), crossing (X-like), and curving morphologies. As the purpose of this work is to prepare fractal-root structured carbon fibers, special attentions were paid to preparation of branched VGCFs. Fig.1 illustrates the morphology of the branched VGCFs (a) and the structure of a branching point (b). The diameter of the branched VGCFs was about 6 μm and very consistent. As also shown in Fig.1b, the VGCFs have a laminar structure, similar to the annual rings of a tree. The formation mechanism of branched fibers seems to be that, during the growth of VGCFs, a catalytic iron particle or drop on the top of the growing VGCF can be separated into two smaller ones and two VGCFs grow with them to form a Y-like branched carbon fibers. On the other hand, the X-like branched carbon fibers are supposed to be formed due to the crossing of two VGCFs in a early growth stage. With further growth, the crossing part becomes smooth and cannot be identified. However, two important problems remain unsolved. One is that not all the VGCFs obtained were branched and the synthesis parameters need to be optimized; another is that the mechanical properties of the branched VGCFs are not yet understood. They are under investigation.

CONCLUSIONS

The carbon fibers with a fractal-root structure, a novel reinforcement suggested from the biomimetic design of composites have been grown through decomposing benzene at 1473 K in hydrogen. Two branched VGCFs, Y-like and X-like, were synthesized with a laminar structure and a consistent diameter of 6μm.

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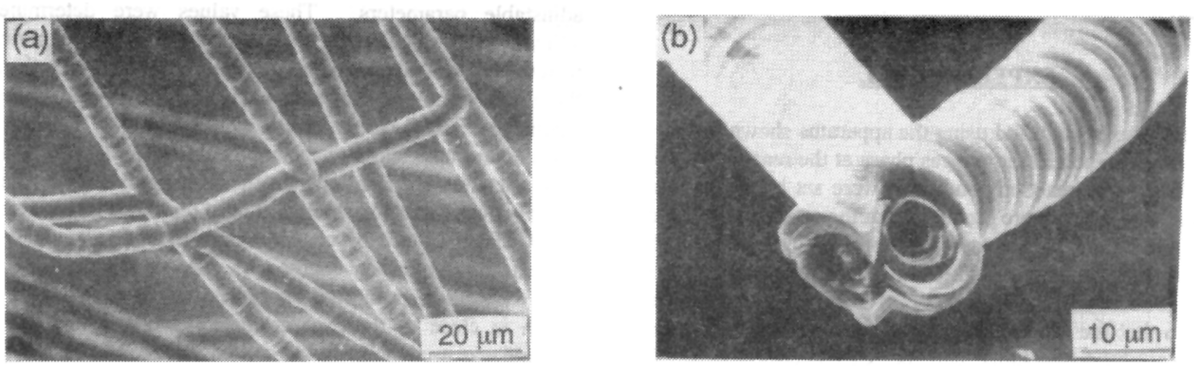

Fig.1 (a) Morphology of vapor-grown carbon fibers and (b) structure of a branching point.