MECHANICAL AND ELECTRICAL PROPERTIES OF RAPIDLY GROWN VAPOR GROWN CARBON FIBERS

S. R. Mukai, T. Masuda and K. Hashimoto
Division of Chemical Engineering
Graduate School of Engineering, Kyoto University
Kyoto 606-8501, Japan

Introduction

Typical vapor grown carbon fibers (abbreviated to VGCFs) grow in the axial direction through the catalysis of ultra-fine metal particles (*e.g.* iron). They grow in the radial direction as pyrolitic carbon deposits on the surface of the fiber. Therefore, these VGCFs are formed by carbon layers arranged like a tree-ring structure. Such VGCFs possess extremely high mechanical strengths and electric conductivities, due to this unique structure. Since VGCFs can be obtained using a single entrained bed, there is a possibility to drastically decrease the production cost of short carbon fibers.

Previously, we developed a new method to produce long VGCFs at high growth rates, the Liquid Pulse Injection (LPI) technique [1]. VGCFs as long as 45 mm can be obtained within 30 s by employing this new method. However, the question remains whether thus rapidly grown fibers possess the same structure and properties as those produced using conventional production methods.

In this work, the tensile strengths, electrical resistivities and oxidation resistivities of VGCFs grown using the LPI technique were measured. It was confirmed that although these fibers were grown at high growth rates, they possess the same superior properties as VGCFs produced using conventional production methods.

Experimental

VGCFs were produced using the LPI technique according to the method previously reported [1]. Hydrogen and benzene were respectively used as the carrier gas and carbon source. The reaction temperature was set to 1373 K.

Single fibers from the obtained VGCFs were mounted individually on insulator plastic sheets using silver paste, and their resistivities were measured using the conventional dc four terminal method. The diameter of the fiber and the distance between the voltage terminals were measured using scanning electron microscopy. On the determination of the fiber diameter, a circular cross-section of the fibers was assumed. Measurements were conducted at room temperature.

The tensile strength of the obtained VGCFs were measured by pulling the fibers at a constant rate of 10 mm min^{-1}, and recording the force loaded on the fiber using a strain guage (Kyowa Electronic Instruments; LTS-50GA). After the fiber broke, its diameter was measured from the observation of the fractured cross section using scanning electron microscopy. The tensile strength of the fiber was calculated using the measured maximum force on the fiber before fragmentation, and the measured diameter of the fiber.

The oxidation resistivities of the obtained VGCFs were measured using a thermogravimetric analyzer (Shimadzu; TGA-50H). Air was used as the oxidizing agent. Approximately 2 mg of the samples was set in the analyzer. Experiments were conducted at a constant temperature increment rate of 5 K min^{-1}, and the weight loss of the sample was recorded. The oxidation resistivities of VGCFs grown using the Floating Catalyst technique were also conducted for comparison.

Results and Discussion

In typical VGCFs, the core region of the fibers is formed by catalysis, and the graphitic planes that form this region exhibit a high degree of preferred orientation parallel to the fiber axis. The outer part of the fiber is formed through the chemical vapor deposition of the carbon source, and the degree of orientation of the graphitic planes forming it is lower than that of the core region. Therefore, thin VGCFs are expected to posess very high tensile strengths and electrical conductivities, and these values are thought to decrease with the increase in the diameters of the VGCFs.

Figure 1 shows the electrical resistivities (ρ) of the obtained VGCFs, as a function of the diameters of the fibers (d). As can be also seen in typical VGCFs, the resistivities of thin fibers are extremely low considering the fact that these fibers were grown at 1373 K. The resistivities of such fibers are comparable to those reported

by several authors [2-4]. Moreover, the resistivities increase with the increase in the diameter of the fibers, as was expected.

Figure 2 shows the tensile strengths of the obtained VGCFs (σ) as a function of the diameters of the fibers. The tensile strengths of the fibers increase with the decrease in the diameter of the fibers, which trend can be seen in typical VGCFs. The average tensile strength of fibers which diameters are less than 5 μm is in the range 2500 to 3500 GPa. This value is similar to those reported by several authors [2,3,5]. It is noteworthy that values over 5000 GPa have been obtained. This value is extremely high, considering the fact that the fibers were produced at 1373 K.

Figure 3 shows a typical weight loss curve of the obtained VGCFs during oxidation in an air atmosphere. That of VGCFs grown using the Floating Catalyst technique is also shown for comparison. Both curves are almost identical, which implies that the VGCFs produced using the LPI technique possess the same structure as those produced using the floating catalyst technique.

From the results shown above, it can be concluded that although the VGCFs produced using the LPI technique are rapidly grown, they possess the same superior properties as those produced using conventional production methods. From the behavior of the obtained fibers, it is assumed that they possess the same structure as typical VGCFs.

References

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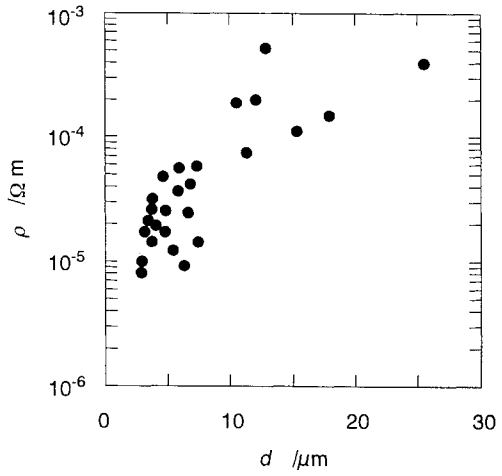

Figure 1 Electrical resistivities of the obtained VGCFs

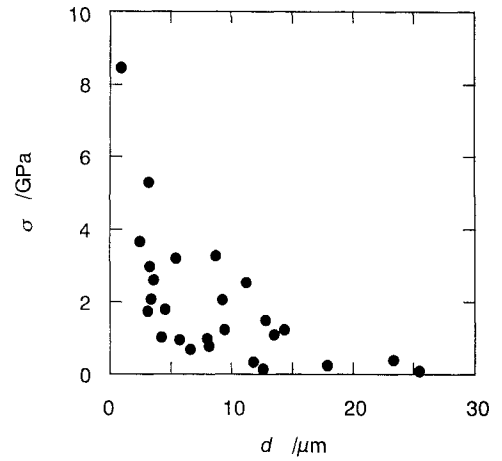

Figure 2 Tensile strengths of the obtained VGCFs

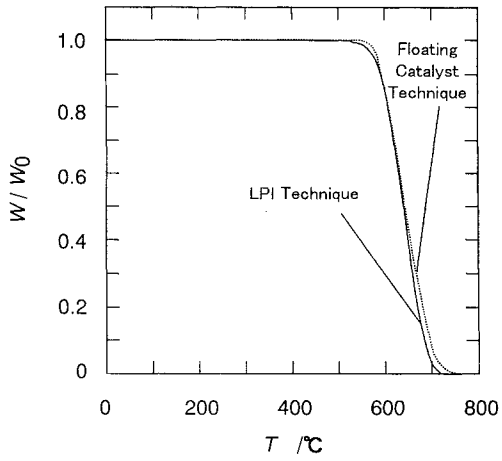

Figure 3 Oxidation resistivities of VGCFs