Preparation and Electrical Properties of Nanostructured Periodic Porous Carbon

Tetsuya Matsumoto, Hiroyoshi Take, and Katsumi Yoshino
Department of Electronic Engineering,
Graduate School of Engineering, Osaka University,
2-1 Yamada-oka, Suita, Osaka, 565-0871, Japan
Tel: +81-6-6879-7759, Fax: +81-6-6879-7774
E-mail: tmatsumo@ele.eng.osaka-u.ac.jp

1. INTRODUCTION

Recently carbon materials such as fullerene and carbon nanotube were discovered. They are very interesting carbon materials. As the other interesting carbon material, graphite is mentioned and it is used variously in our life. In the present study, we prepared 'nanostructured periodic porous carbon', which is the bulk-form carbon that has many pores with three-dimensional periodicity at optical wavelengths, and we researched the electrical properties. Furthermore nanostructured periodic porous carbons were graphitized by pyrolyzing at high temperature of about 3000℃, and the properties of the graphitized samples were researched. A lot of new phenomena have been observed in meso-scopic structure recently. So it is possible that new phenomena appear in nanostructured periodic porous carbon.

2. EXPERIMENT

Nanostructured periodic porous carbons were prepared by using the method that the pristine products infiltrating the voids in synthetic opals by starting materials pyrolyze in a high-purity Ar atmosphere for carbonization of samples and subsequently removing the SiO_2 spheres by immersing into the aqueous solution of hydrofluoric acid. In the present study, phenolic resin was used as the starting material. These samples were pyrolyzed at various heat treatment temperatures (HTTs) for 1h in a high-purity Ar atmosphere again. Electron microscope images of the structure of nanostructured periodic porous carbon were obtaind by a scanning electron microscope (SEM) (S-2100 A, Hitachi). X-ray diffraction measurements using CuKα radiation were performed with a powder x-ray diffractometer (RINT1100, Rigaku). The temperature dependence of electrical conductivity and magnetoresistance of nanostructured periodic porous carbon were measured by a conventional four-probe technique using a Quantum Design PPMS.

3. RESULTS AND DISCUSSION

Nanostructured periodic porous carbons with diameter of 120nm, 300nm were observed with a SEM. Nanostructured periodic porous carbons have three-dimensional periodic structure as can be seen from the SEM images in Fig. 1.

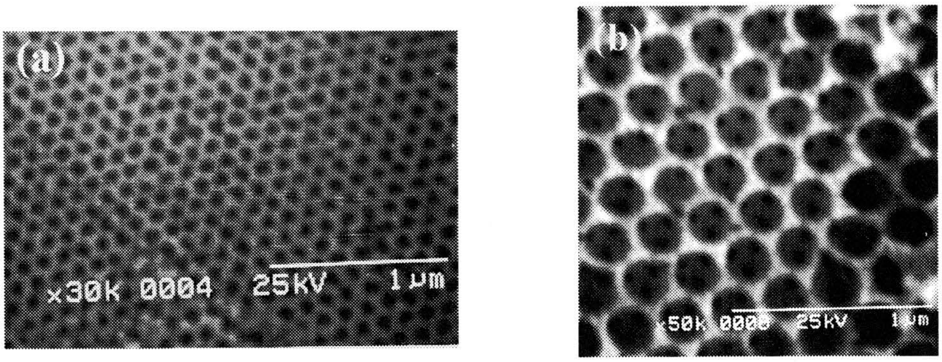

Fig. 1. The SEM images of nanostructured periodic porous carbons with the diameter of (a) 120nm and (b) 300nm.

As evidenced in Fig. 2, a predominant (002) diffraction peak is observed, but other peaks of (100) and (004) also appear in the range of 5° ≪ 2θ ≪ 90° in the sample pyrolyzed with a HTT of 2800℃. The interlayer spacings of the samples with HTTs of 700℃ and 2800℃ are 3.70 Å and 3.42 Å, respectively. The interlayer spacing of nanostructured periodic porous carbon decreases and approaches that of highly oriented pyrolytic graphite (HOPG), 3.35 Å with increasing HTT.

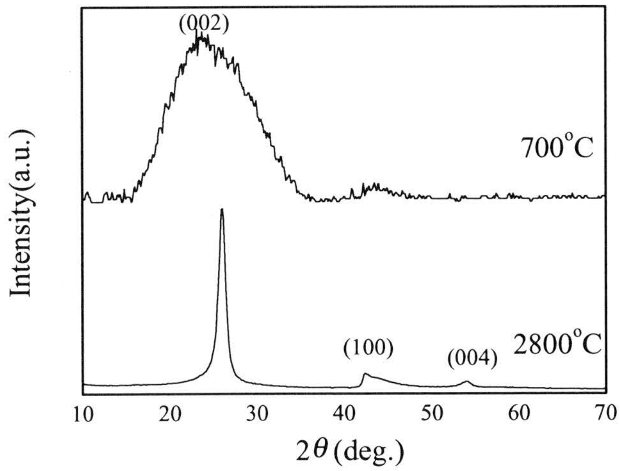

Fig.2. X-ray diffraction patterns of nanostructured periodic porous carbon of the diameter 300nm with HTTs of 700℃ and 2800℃.

Figure 3 shows the normalized temperature dependence of resistivity, $\rho_r(T) = \rho(T) / \rho(290K)$ in nanostructured periodic porous carbon with HTTs of 1000℃ and 2800℃.The resistivity of nanostructured periodic porous carbon does not decrease exponentially with temperature. In the critical region of the metal-insulator transition, the temperature dependence of the resistivity obeys the power-law dependence given by $\rho(T) \propto T^{-\beta}$, where β lies within the range of $1/3 < \beta < 1$.[2] β values of pyrolized nanostructured periodic porous carbons of diameter 120nm and 300nm with

HTT of 2800℃ were evaluated to be 0.27 and 0.15 respectively. In general, the conduction system is metallic if $\beta < 1/3$. So it was considered that the conduction systems of the two samples were metallic.

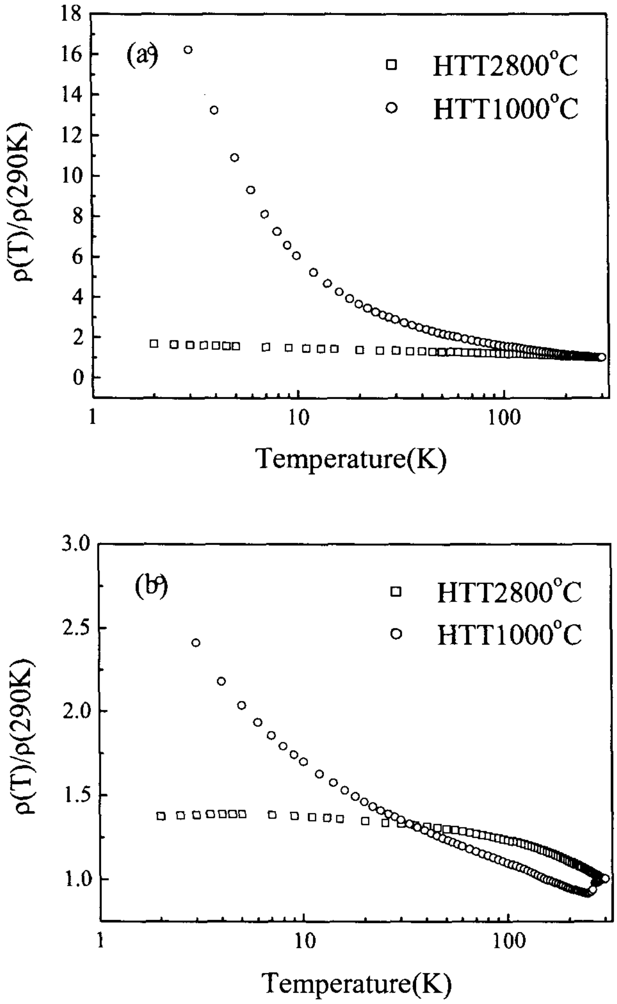

Fig.3. Normalized temperature dependence of resistivity, $\rho_r(T) = \rho(T) / \rho(290K)$ in nanostructured periodic porous carbons of diameters of (a) 120nm and (b) 300nm with HTTs of 1000℃ and 2800℃.

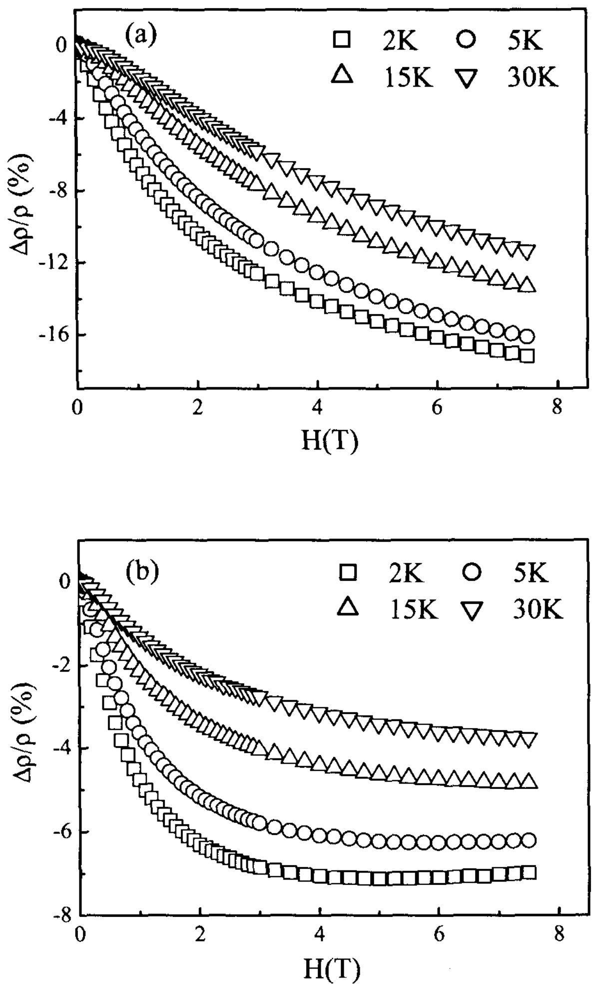

Fig. 4. $\Delta\rho / \rho$ as a function of magnetic field for nanostructured periodic porous carbons of diameters of (a) 120nm and (b) 300nm with HTT of 2800℃.

The magnetoresistances (MR), $\Delta\rho / \rho = [\rho(H) - \rho(0)] / \rho(0)$, of nanostructured periodic porous carbon with HTT of 2800℃ are plotted at various heat treatment temperatures in Fig. 4, where $\rho(H)$ and $\rho(0)$ are the resistivity at a certain magnetic field H and 0T, respectively. In both samples, negative MR was observed. The negative MR of graphitic material has been explained as a process based on a weak localization effect due to the quantum interference between elastically scattered carrier waves.[3-5] The negative MR in weak localization arises from dephasing of the quantum phase coherence of backscattered paths by a magnetic field.[6,7] The negative MR is more remarkable in the sample which diameter is 120nm than in the sample which diameter is 300nm. From this result, the electronic localization effect is thought to be stronger in the sample which diameter is 120nm than in the sample which diameter is 300nm, but more researches are needed.

4. SUMMARY

Nanostructured periodic porous carbons with diameter of 120nm, 300nm were prepared, and they had three-dimensional periodic structure. The interspacing of nanostructured periodic porous carbon pyrolyzed at 2800℃ approached that of HOPG and their conduction system became metallic with increasing HTT. The occurrence of negative MR indicated the existence of a quantum effect at law temperature. The electronic localization effect is thought to be stronger in the sample which diameter is 120nm than in the sample which diameter is 300nm from the result that the negative MR is stronger in the sample which diameter is 120nm than in the sample which diameter is 300nm.

References

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