RAMAN SPECTRA, EFFECTIVE DEBYE PARAMETER AND MAGNETORESISTANCE

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Introduction

Carbon shows an Raman line at about 1360 cm^{-1} in addition to the line at 1575 cm^{-1} which is expected theoretically[1]. This additional line at 1360 cm^{-1} decreases its intensity as well as width with increasing HTT[1,2]. The ratio in intensity, R= I(1360)/I(1575), may be used as a measure of the lattice defects in graphite structure.

The effective Debye parameter B_{eff} has been measured on various well-graphitized carbons and graphites. It was found to decrease with the increase in HTT[3] and to increase with mechanical grinding and neutron irradiation[4]. So, B_{eff} may also be used as a measure of graphitization.

The transverse magnetoresistance $(\Delta\rho/\rho)$ of the soft carbons increases with increasing HTT[5] and approaches to the large value which is observed in graphite.

In the present work, we measured the Raman intensity ratio R, the effective Debye parameter B_{eff} and the maximum transverse magnetoresistance $(\Delta\rho/\rho)_{max}$ on the same graphitized cokes.

Experimental

Cokes from different sources were heat-treated at HTT ranging from 2500° to 3000°C in nitrogen flow, as shown in Table 1. A part of each coke was crushed in an agate mortar for X-ray diffraction and Raman studies. Grinding time was kept as short as possible (less than 1 min.). From the remaining part of the coke, the specimen for magnetoresistance measurement was cut into rectangular prism, size being 1.2×4.4×0.7mm.

Raman spetra were obtained by laser Raman spectrometer with an argon ion laser providing 400 mW of 4800 Å radiation on the sample compressed into pellet with or without KBr. The angle between the laser beam and the sample surface was ca. 20° and the scattered light was observed under 90° from the laser beam.

The effective Debye parameter B_{eff} was determined from the slope of linear relation between diffraction intensities of 00ℓ lines (ℓ =2,4,6 and 8, if possible) and $\sin^2\theta/\lambda^2$.

Magnetoresistance was measured at liquid temperature and the magnetic field of 10 kG by d. c. amplification technique by rotating the field in two modes. By taking account of the preferred orientation of crystallites the maximum transverse magnetoresistance $(\Delta\rho/\rho)_{max}$ was determined.

Results

In Figs. 1 and 2, R and $(\Delta\rho/\rho)_{max}$ are plotted against B_{eff}, respectively. These three parameters are closely related with each other; R increases linearly with increasing B_{eff}, and $(\Delta\rho/\rho)_{max}$ decreases rapidly at first and then gradually but almost linearly with increasing B_{eff}.

Discussion

Both Raman lines at 1575 and 1360 cm^{-1} are assigned to in-plane motion of carbon atoms in graphite lattice [1] and the latter is allowed to appear if there exist parts where the hexagonal symmetry of graphite is no longer maintained. On the other hand, large value of B_{eff} is due to out-of-plane displacement of carbon atoms which is associated with defects in the layer plane. The linear relation observed between R and B_{eff} may suggest that both are related to respective component along a- and c-axes of the same displacement of atoms due to lattice defects.

Magnetoresistance decreases with the increase in the concentration of trapped electrons which are accompanied by lattice defects. At low value of B_{eff} (<0.25), in other words, at the region of less defective structure, $(\Delta\rho/\rho)_{max}$ decreases rapidly with increasing B_{eff}.

Three parameters R, B_{eff} and $(\Delta\rho/\rho)_{max}$ depend on the concentration of lattice defects through in-plane motion, out-of-plane displacement and concentration of trapped electrons. They can be used as parameters for the characterization of graphitized carbons.

References

1) F. Tuinstra & J. L. Koenig, J. Chem. Phys. 53, 1126 (1970)
2) M. Nakamizo et al., Carbon 12, 259 (1974)
3) M. Inagaki, Carbon 13, 307 (1975)
4) M. Inagaki et al., TANSO 1973 [No. 74] 76 (1973)
5) Y. Hishiyama, Carbon 8, 259 (1970)

Table 1 Samples and HTT

Cokes	HTT (°C)	Symbol
QS	3000	⊕
PVC	3000	○
Petro	2800	■
Conoco No.1	2800	●
Texas	3000	×
Wilmington	2800	▲
Kendal	2540 ~ 3000	△
Gilsonite	2800	⊗

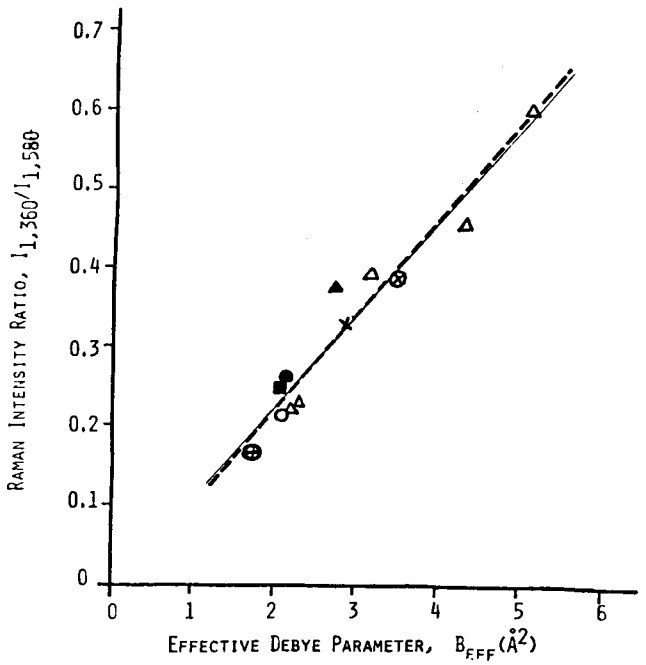

Fig. 1 Relation between R and B_{eff}.

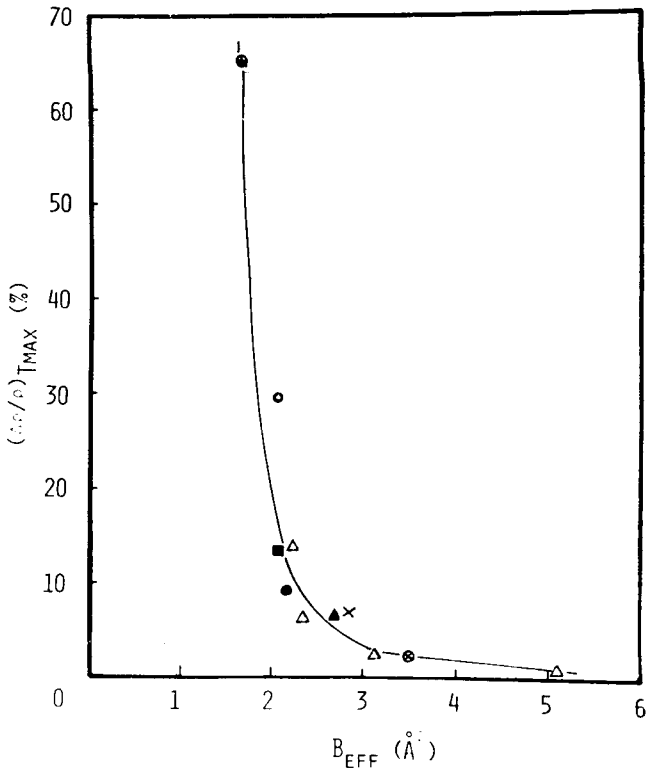

Fig. 2 Relation between $(\Delta\rho/\rho)_{max}$ and B_{eff}.