Structural and magnetic study of electron- and proton-irradiated graphite tiles

Jin Jung Kweon[1], Kyu Won Lee[1], Jun Kue Park[1], Gi-wan Jeon[1], Hyojung Kim[1]*, Cheol Eui Lee[1], S. J. Noh[2], H. S. Kim[2]

[1]Department of Physics and Institute for Nano Science, Korea University, Seoul 136-713, Korea
[2]Department of Applied Physics, Dankook University, Yongin 448-701, Korea

1. Introduction

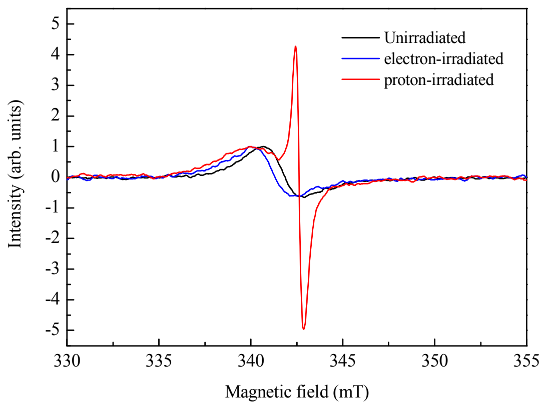
In the development of the nuclear fusion facilities for future energy generation, study of radiation effects on the plasma-facing components (PFCs) is prerequisite. Ion-beam irradiation and heat influx on plasma-facing carbon materials result in modified chemical and physical properties. It is essential to understand the modified properties in actual devices to estimate the usefulness of carbon-based materials. Apart from interest in the fusion industry, ferromagnetism induced by proton irradiation in graphite has been the subject of many studies, its origin not being fully understood. In this work, physical properties of graphite tiles modified by high heat flux and proton irradiation are studied and discussed.

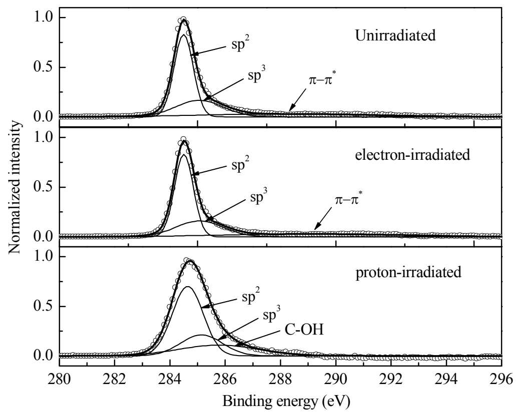
2. Experiment

The samples of graphite tile (Toyo Tanso) were irradiated with a 70-keV, 20-mA electron beam to 4 MW/m^2, and with a 30-keV proton beam to a dose of 5×10^{17} $ions/cm^2$. We have carried out Raman, electron spin resonance (ESR), and X-ray photoemission (XPS) spectroscopy measurements on the graphite tiles modified by electron and proton irradiation. The four-probe electrical conductivity measurements on the surface of the graphite tile samples were made.

3. Results and discussion

Figure 1 shows the ESR spectra before and after the irradiations. The broad ESR line shapes of the unirradiated and electron-irradiated samples are asymmetric, indicating a conducting behavior of the samples. An additional narrow Lorentzian line in the proton-irradiated sample arises from the localized spins, having to do with proton-irradiated ferromagnetism in graphite. The g-values calculated from the peaks of the broad ESR lines are 1.9825, 1.9844, and 1.9845 for the unirradiated, electron-irradiated, and proton-irradiated samples, respectively. Increase in the g-value is related to decrease in the effective carrier density. The decreased electrical conductivity in the electron-irradiated and proton-irradiated samples is thus attributed to the decreased effective carrier density. Moreover, in the proton-irradiated sample, the localized spins corresponding to the Lorentzian line may act as scattering centers, contributing to decrease in the electrical conductivity.





Fig

Fig 1. ESR spectra of graphite tiles before and after the irradiations.

Fig 2. C 1s XPS spectra of graphite tiles before and after the irradiations.

Figure 2 shows the C 1s XPS spectra before and after the irradiations. The C 1s XPS spectra of the unirradiated sample and the electron-irradiated one were well fitted by a sum of Gaussian components corresponding to the sp^2 and sp^3 bonding configurations and the π-π* transition. In the proton-irradiated sample, an additional peak at 285.8 eV, assigned to the C-OH bonding, is observed. The C-OH bonds with a sp^3 configuration in the proton-irradiated sample would give rise to the paramagnetic moments acting as the localized spins observed in the ESR spectrum.

4. Summary

We have carried out spectroscopic studies on the physical properties of graphite tiles modified by electron and proton irradiation. While increase in local order was observed in the electron-irradiated sample, structural disorder and amorphization were revealed in the proton-irradiated sample, with considerably decreased electrical conductivity. Besides, C-OH bond with a sp3 configuration was identified in the proton-irradiated sample, apparently giving rise to a narrow ESR peak ascribed to localized spins.

This work was supported by the National Research Foundation of Korea (Project No. 20090082672).

5. References

[1] M. Kwon et al., Nucl. Fusion. 51 (2011) 094006.

[2] K. Takahiro, A. Terai, S. Oizumi, K. Kawatsura, S. Yamamoto, H. Naramoto, Nucl. Instr. and Meth. B 242 (2006) 445.

[3] K.W. Lee, C.E. Lee, Phy. Rev. Lett. 97 (2006) 137206.

[4] G.A. Baratta, M.M. Arena, G. Strazzulla, L. Colangeli, V. Mennella, E. Bussoletti, Nucl. Instr. and Meth. B 116 (1996) 195.

[5] D. Yang, A. Velamakanni, G. Bozoklu, S. Park, M. Stoller, R.D. Piner et al., Carbon, 47 (2009) 145.