

Edge-state in Nanographite, HNO₃-Doped Nanographite and Its Residue Compounds

Manabu Kiguchi*, Si-Jia Hao, Satoshi Kaneko, Jun-ichi Takashiro, Kazuyuki Takai, V. L. Joseph Joly, Toshiaki Enoki

¹Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo 152-8551, Japan

Introduction

Graphene, the 2D one-atom-thick monolayer of carbon atoms arranged in a honeycomb lattice, has recently attracted tremendous interests from the scientific community for both fundamental and applied researches owing to its unconventional electronic structure of massless Dirac fermions which gives rise to unprecedented physical properties such as the room-temperature half-integer quantum Hall effect, the extremely high mobility of its charge carriers, the tunable band gap of graphene nanoribbons, and the potential for realizing ballistic conduction. In investigating the properties of the nanographene, it is particularly important to confirm the presence of edge-states. Here, we pay attention to the activated carbon fibers (ACFs). ACFs are nanoporous carbon consisting of a three dimensional disordered network of nanographite domains, each of which is a stack of 3-4 nanographene sheets with the mean in-plane size of about 2-3nm. ACFs have a high density of edge carbon atoms (the number ratio of edge carbon atoms to the interior carbon atoms is ca. 30/200) due to the small size of nanographene sheets. To understand more comprehensively behavior of edge-state in the nanographite system, in the present research we investigated the electronic structure of the edge-state for ACFs, HNO₃ doped ACFs, and its residue compounds

Experiment

Pristine ACFs were commercially available samples (Kurary Chemicals, FR-20; specific surface areas of 2000 m²/g) prepared by the activation of phenol-based precursor materials. The nitric acid adsorbed samples (HNO₃-ACFs) were prepared by placing the ACFs in the HNO₃ gas shower at room temperature and the duration of the adsorption was at least 2 h which was enough to reach the equilibrium. In addition, the residue compounds (RC) were made by evacuating these as-prepared HNO₃-ACFs samples to $\sim 10^{-6}$ Torr again at room temperature (RC-RT), 100 °C (RC-100), 200 °C (RC-200), 300 °C (RC-300), 400 °C (RC-400), 500 °C (RC-500), 600 °C (RC-600) and 800 °C (RC-800) for 12 hours. The carbon K-edge NEXAFS was measured at the soft x-ray beam line BL-7A in the Photon Factory in the Institute of Materials Structure Science. The ground powder sample was mounted on a Ta plate and loaded into the chamber maintained in ultrahigh-vacuum (10^{-7} Pa). NEXAFS spectra were then obtained by measuring the sample photocurrent.

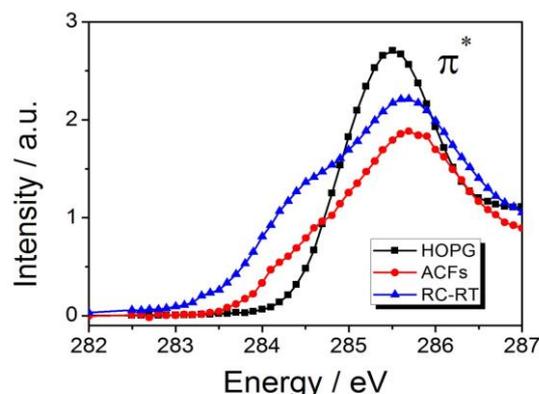


Fig. C C K-edge NEXAFS for the ACFs-RT, RC-RT and HOPG.

Results

Figure shows the C K-edge NEXAFS for the ACFs-RT, RC-RT and HOPG, with the photon energy between 282 eV and 287 eV. It is clear to see that compared to the HOPG, a shoulder located at the low-energy side of the π^* -state peak of the ACFs is presented. Moreover as shown in the Figure, the feature of such unoccupied state is enhanced for the evacuated HNO₃-ACFs sample at room temperature (RC-RT). The feature decreased with heating temperature.

The existence of the additional peak originates from the edge state of the nano graphene [1,2]. The edge state peak becomes enhanced in the HNO₃-ACFs since Fermi energy is shifted down through the charge transfer process. The heat-treatment under evacuation to the HNO₃-ACFs recovers the electronic structure to that of non-adsorbed ACFs, indicating the disappearance of the charge transfer interaction through desorption of the HNO₃ molecules.

References

- [1] J. Joly et al., *Phys. Rev. B* 81, 245428 (2010).
- [2] M. Kiguchi et al., *Phys. Rev. B* 84, 045421 (2011).

* kiguti@chem.titech.ac.jp