Photoelectrochemistry of Graphene Oxide Nanosheet

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Abstract

We report the photoelectrochemical properties of graphene oxide (GO) and reduced GO nanosheets. The photoelectrochemical measurements show GO probably has a nature of n-type semiconductor by conducting electrochemical reduction. The bandgap energy was estimated to be about 2.6 eV by means of action spectral and UV-vis measurement.

Introduction

Graphene has high electrical and thermal conductivity. These outstanding properties have strongly attracted their potential applications for ultracapacitors, solar cells, and liquid crystals etc. Graphene oxide (GO), oxidized graphene, is also attractive functional material, due to the high catalytic and electrocatalytic activities as well as high specific surface area. It may have a possibility to be used as a photoelectrode material in solar cells and/or photocatalysts. Nevertheless, their fundamental photoelectrochemical properties have not been reported yet. In this study, for the first time, we have challenged to reveal photoelectrochemical properties involving bandgap, flatband potential, and the band energy positions of GO and electrochemically reduced one.

Experimental

Graphene oxide (GO) was obtained by the modified Hummers method[1]. 60 mg of GO was added to 50 mL of distilled water. The mixture was sonicated followed by ultracentrifuging for removing aggregated GO nanosheet. The electrode to measure the photoelectrochemical properties of GO nanosheet was prepared by dropping the solution on ITO glass substrate (DGO) and electrophoretic deposition technique (EGO), and then followed by drying in vacuum. In the case of EGO, the bias voltage was 5 V under the electrode distance of 1 cm in the solution 3 cycles as for 10 minutes, and the deposition occurred at the anode ITO. The photoelectrochemical properties were measured using three electrode systems consisting of working (GO/ITO), counter (Pt), and reference (Ag/AgCl) electrodes. 0.1 M K_2SO_4 solution was used as electrolyte in a quartz cell. A high pressure 500 W Hg lamp was used as the light source. The action spectral measurement and surface analysis of the GO nanosheet was made by monochromater and X-ray photoelectron spectroscopy, respectively.

Results and Discussion

Figure 1A shows cyclic voltammogram (CV) of GO and reduced GO nanosheet electrodes under chopped light illumination. The anodic photocurrent was generally larger than cathodic one. An anodic photocurrent was observed hardly in initial cycle from 0 to 0.8 V for DGO (a), while large anodic photocurrent was obtained during potential sweep from -0.8 V to 0.8 V after the initial sweep (b). The anodic photocurrent was observed more clearly in 2nd and 3rd cycles (c). EGO gives larger photocurrent even under initial sweep than DGO (d), likely due to the partial reduction of GO in electrophoretic deposition process. The reaction is redox reaction depended on functional groups existing GO surface. It is revealed by XPS measurements. The results show oxidation degree of GO observed photocurrent (samples are (b), (c) and (d)) is lower than that GO of photocurrent hardly observed (sample is (a)). These anodic photocurrents are based on the GO nanosheet, as ITO substrate shows no remarkable anodic photocurrent under the given experiment condition. Figure 1B shows action spectrum measured at 0.8 V. The onset is about 450~500 nm, indicating that the bandgap energy correspond to ca. 2.6 eV. The same value was also observed in the UV-vis absorption spectrum as shown in Figure 1C. From above the photoelectrochemical results, we concluded GO probably has a nature of n-type semiconductor by conducting electrochemical reduction and the bandgap energy is about 2.6 eV.

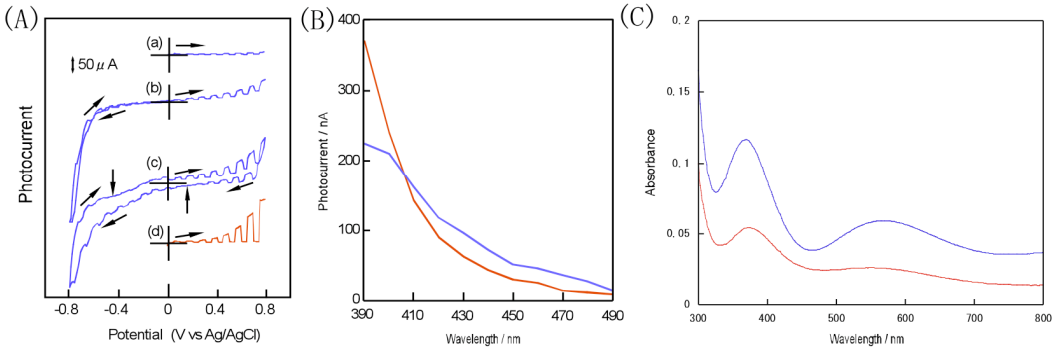

Figure 1 (A) CV curves are (a) initial cycle of DGO, (b) cycle after sweep from 0 to -0.8 V for DGO, (c) 3rd cycle of DGO, (d) initial cycle of EGO. (B) Action spectrum is DGO (blue) and EGO (red) at 0.8 V. (C) UV-vis absorption spectrum is DGO (blue) and EGO (red).

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