Charge Separation Properties of CdSe/Reduced Graphene Oxide Nanoheterostuctures: Graphene Size Effect

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Reduced graphene oxide (RGO) has received much attention in recent years due to its large surface area and remarkable electron conductivity. RGO can attract photoexcited electrons of semiconductor nanocrystals to improve the overall charge separation property. Such capability of electron trapping for RGO has rendered it promising potential in relevant photoconversion processes such as photocatalytic water splitting, photocatalytic degradation of pollutants and photovoltaics.[1-3] In this work, we presented the fabrication of CdSe-RGO nanoheterostructures and investigated the effect of RGO size on their charge separation properties by using time-resolved fluorescence spectroscopy. With the reduction of the lateral size of RGO and thus the regulation of its work function, a further improved charge carrier separation for CdSe-RGO can be achieved.

The samples were prepared by depositing CdSe quantum dots (QDs) on the surface of RGO. RGO was obtained from typical Hummers' method. By applying the multiple chemical exfoliation treatment and hydrothermal reduction,[4] the lateral size of RGO can be decreased from micrometer (1~10 μm) to nanometer scale (5~50 nm). On the other hand, CdSe QDs with the size of 5~8 nm were synthesized by reacting L-cysteine-Cd^{2+} complex with Na_2SeSO_3 at room temperature in a chemical precipitation process. Afterwards, CdSe QDs were functionalized with chitosan for further deposition on RGO surface.

Steady-state photoluminescence (PL) spectra were first collected to study the charge separation properties of the products. As shown in Figure 1, CdSe-RGO with micrometer and nanometer sized RGO both exhibited significantly quenched PL relative to pure CdSe, verifying the inhibited charge recombination by RGO. Figure 2 shows the time-resolved PL spectra in which the electron transfer event between CdSe and RGO for CdSe-RGO can be quantitatively analyzed. Evidently, CdSe-RGO had a shorter PL lifetime than pure CdSe, signifying the occurrence of pronounced charge separation. This phenomenon is consistent with the result of Figure 1. Besides, an even shortened PL lifetime was noticed for CdSe-RGO with nanometer sized RGO, suggesting improved charge separation efficiency with the reduction of RGO size. The ability to improve charge separation efficiency of CdSe-RGO by reducing the RGO size is beneficial to the development of semiconductor/graphene nanoheterostructures, especially when they are used in photoelectrochemical system for photoconversion applications.

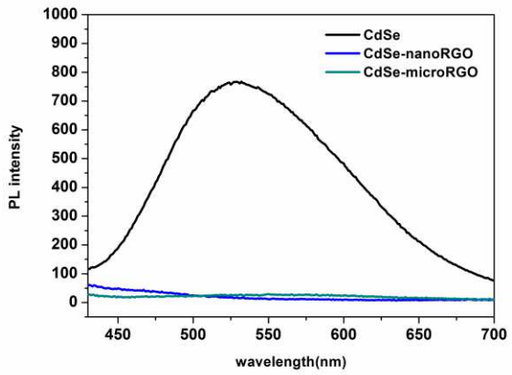

Figure 1. Steady-state PL spectra of CdSe-RGO samples with different sizes of RGO.

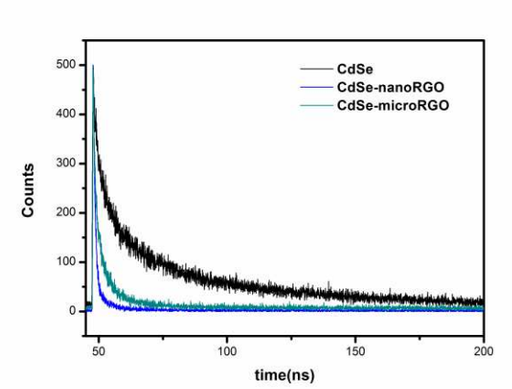

Figure 2. Time-resolved PL spectra of CdSe-RGO samples with different sizes of RGO.

References

[1] X. Y. Zhang, H. P. Li, X. L. Cui, and Y. Linb, J. Mater. Chem. **2010**, 20, 2801–2806.
[2] Q. P. Luo, X.Y. Yu, B. X. Lei, H. Y. Chen, D. B. Kuang, and C.Y. Su, J. Phys. Chem. C. **2012**, 116, 8111−8117.
[3] S. Sun, L. Gao, Y. Liu, and J. Sun, Appl. Phys. Lett. **2011**, 98, 093112.
[4] B. D. Pan, J. Zhang, Z. Li, and M. Wu, Adv. Mater. **2010**, 22, 734–738.