Semiconducting Nanocrystals/Graphene Hybrids for Efficient Photo Induced Applications

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The development of graphene oxide (GO) or reduced graphene oxide (RGO)/semiconductor hybrid composite remains a frontier area of research to design optoelectronic, photovoltaic, and light harvesting devices based on an electron transfer process.[1] Therefore, in this consequence electron transfer process from semiconductor to GO/RGO is an important issue for these applications. Here, we have assembled graphene oxide-CdTe QD composite by the attachment of positively charged cysteamine capped CdTe QDs with negatively charged GO.[2] The shifting of G-band and increase of ID/IG intensity ratio reveal the electron transfer from excited QDs to GO. The electron transfer rate (2.24 × 108 to 1.18 × 108 s−1) is found to be decreased with increasing the size of QDs. We analyze the decays of fluorescence by assuming a binomial distribution of number of available sites of QD and the mean fractional surface coverage of QD by GO sheet which control the quenching process. Analysis suggests that the average number of available sites (152 to 396) increases, the mean fractional surface coverage and the total quenching rate (1.3 × 108 to 0.18 × 108 s−1) are decreased with increasing the size of QD. It is noteworthy that an ∼6 fold increase in the photocurrent is found in this composite device under light illumination. On the other hand RGO−CdS hybrid has been developed to improve the efficiency of photocatalysis.[3] Zero-dimensional CdS nanoparticles (0D), one-dimensional CdS nanorods (1D), and two-dimensional CdS nanosheets (2D) are grafted on the RGO sheet (2D) by a surface modification method using 4-aminothiophenol (4-ATP). The strong electronic interaction is found in the case of a CdS nanosheet and RGO, which has been proved by Raman spectroscopy. The degradation of dye under visible light varies with changing the dimension of nanocrystals, and the catalytic activity of the CdS NS/RGO composite is ∼4 times higher than that of CdS nanoparticle/RGO and 3.4 times higher than that of CdS nanorod/ RGO composite samples. The catalytic activity of the CdS nanosheet/RGO composite is also found to be ∼2.5 times than that of pure CdS nanosheet samples. The unique 2D−2D nano architecture would be effective to harvest photons from solar light and transport electrons to reaction sites with respect to other 0D−2D and 1D− 2D hybrid systems. This observation can be extended to other graphene-based inorganic semiconductor composites, which can provide a valuable opportunity to explore novel hybrid materials with superior visible-light-induced catalytic activity.

References:

1. Kamat, P. V. *J. Phys. Chem. Lett.* **2011**, *2*, 242-251.
2. Kundu, S.; Sadhu, S.; Bera, R.; Paramanik, B.; Patra, A. *J. Phys. Chem. C* **2013**, *117*, 23987-23995.
3. Bera, R.; Kundu, S.; Patra, A. *ACS Appl. Mater. Interfaces* **2015**, *7*, 13251-13259.