Photoelectric Properties of Copper Oxide and Copper Sulfide Quantum Dots -Graphene Hybrid Nanostructures

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The increasing energy demand and environmental issue push us to seek environmental friendly alternative energy sources. The emergence of nanomaterials as the new building blocks to construct light energy harvesting assemblies has opened up new ways to utilize renewable energy sources. Graphene, a two-dimensional atomic sheet of carbon atoms, exhibits unique properties, such as zero-band-gap semi-conductivity with a high carrier mobility, high optical transparency and high tensile strength.[1] As one kind of graphene hybrid material, graphene/nanoparticle composites have attracted extensive interests as hybridization improves the performance of graphene materials, such as organic photovoltaic devices.[2] It was found that a bilayer solar cell based on poly (3-hexylthiophene) (P3HT) grafted graphene showed 200% higher power conversion efficiency than that of pure P3HT/C_{60} cell, because graphene could act as a promoter for electron transportation.[3] Graphene supported quantum dots exhibit enormous potential in the fabrication and application of high performance and low cost organic photovoltaics (OPVs). In this work, graphene and graphene supported CuO_2 and Cu_2S quantum dots were synthesized, and their photoelectric properties were studied. The results indicated that the incorporation of quantum dots can improve the photoelectric performance of graphene.

Pristine graphene (PG) was produced in an autoclave by the reaction of tetrachloromethane (CCl_4) with potassium (K) via a solvothermal method at 200 ºC for 10-20 h, and graphene films on glass slides were fabricated using coupling agent and adhesives via a blade coating process. Cu_2O and Cu_2S nanoparticles were synthesized on the surface of graphene films via a chemical-solution route. In brief, copper chloride ($CuCl_2$) was dispersed in deionized water, and hydrochloric acid (HCl, 38%) was added to the mixture. The graphene film was immersed in the solution for 60min, and rinsed with deionized water followed by drying in an oven at 50 ºC for 12 h. Graphene/Cu_2S was prepared by a similar method using $CuCl_2$ and sodium sulfide (Na_2S).

JSM-6700F scanning electron microscope (SEM) and JEM-2100 transmission electron microscope (TEM) were used to study the morphology and structure of the obtained graphene based composites. Energy dispersive X-ray spectrometer (EDS) and X-ray diffraction (XRD) analyses were employed to examine the composition and crystal structures of Cu_2O/Cu_2S-graphene. For the evaluation of the photocurrent response to on/off cycles of illumination, I-t and current -voltage curves (I-V) were conducted on an electrochemical workstation (CHI660D) and semiconductor analyzer (B1500A), respectively.

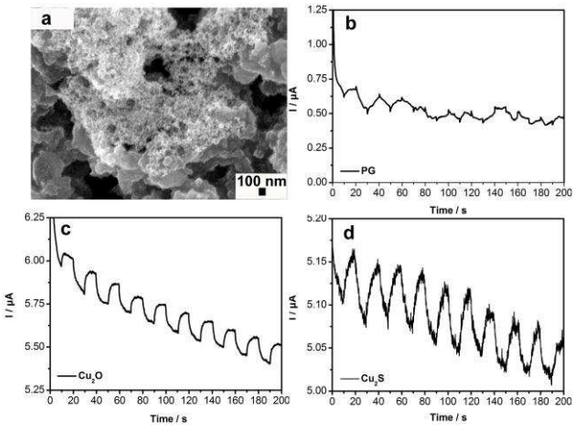

Figure 1 (a) SEM image of graphene/Cu_2S composites, (b-d) photocurrent response of the electrodes to on/off cycles of illuminations: I-t curve of pristine graphene film on glass (b), graphene/Cu_2O film (c), and graphene/Cu_2S film (d). (The electrolyte was 0.1 M Na_2SO_4 in water)

Figure 1a presents SEM image of Cu_2S-graphene nanocomposites. It is evident that Cu_2S nanoparticles were coupled on graphene film, which might interact with the graphene sheets through physical absorption, electrostatic binding or through charge transfer interactions.[4] The photoelectrical properties of the samples are shown in Figure 1b-d. It is observed that there was very small current response for the bare graphene film (Figure 1a). The graphene/Cu_2O and graphene/Cu_2S displayed reproducible and rather stable photocurrent response to on/off light (Figure 1c and Figure 1d). This indicates that the incorporation of copper oxide and copper sulfide quantum dots can significantly enhance the photoelectric activity properties of graphene.

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