# Synthesis of graphene quantum dot composites and investigation of their photoelectric response

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## Abstract

**In the study, we report the novel structure based on graphene quantum dots (QDs)/ZnO composites, which was produced by a facile method and characterized by transmission electron microscopy and X-ray photoelectron spectroscopy. The result shows graphene QDs were scattered and tightly packed with ZnO nanomaterial. The UV-vis spectroscopy of the sample was also measured. The sensitive structure based on graphene quantum dots/ZnO composites leads to high the photoelectric response at the low bias voltage and entitles the fabricated structure as an efficient sensitive structure under UV illumination. The results highlight the significance of the sensitive structure based on graphene QDs composites in photosensitive devices.**

## Keywords

**Semiconductor, graphene, quantum dots, nanomaterial.**

## 1. Introduction

Graphene, a monolayer $sp^2$ carbon atoms with unique physical properties has attracted great research interest in recent years, which has high mobility and conductivity, high optical transparency and mechanical flexibility,etc [1-6].With cutting zero bandgap graphene into nanoribbon, it demonstrates edge effects and quantum confinement, which can enable graphene quantum dots to exhibit attractive chemical and physical properties. Graphene quantum dots are nanometer-sized structures and their band gap is expected to be controlled by changing the overall size. Different excellent properties of GQDs were discovered in luminescence stability, high water solubility and low toxicity. What's more, it can also be applied in optical, biological, electrochemistry, sensor, catalysis and photovoltaic devices. ZnO is an excellent metal-oxide semiconductor material with its wide direct band gap 3.37 eV and large exciton binding energy 60 meV at room temperature. It has been widely used in different applications [7-11], such as dye-sensitized solar cells, ultraviolet photodetectors, gas sensors, piezoelectric devices and field emission cathodes. The physical and chemical properties of ZnO are strongly affected by the morphology and size. In the last years, the synthesis of zinc oxide structures with different dimension such as nanorods, nanowires and nanoparticles, has aroused much attention for the public and showed new and remarkable physical and optoelectronic properties. If graphene and ZnO are efficiently compounded, the hybrid structure may have a number of combined effects and a good performance in many applications, such as gas sensors, photocatalytic properties, and detectors. The optical properties of different graphene/ZnO hybrid structures have been reported in previous literatures [12-15].

In this work, we prepared graphene quantum dots at first and then mixed with ZnO nanomaterial by a facial method. TEM and XRD measurements characterized the novel hydrid structure. The photoelectric properties of obtained graphene QDs/ZnO composites was recorded under illumination. Marked enhancement was observed as compared to those of ZnO nanomaterial. The performance is ascribed to the enhanced charge separation of photogenerated electron and hole pairs. The results suggest that graphene QDs may have a potential application in photoelectric devices.

## 2. Experimental

Carbon fibers were dispersed in strong acid solution and then treated under ultrasonic container at high temperature. The solution can be adjusted to a certain PH value and filtered by microporous membrane. The resulting suspension can be mixed with ZnO nanomaterial. The ZnO nanomaterial were synthesized through a chemical vapor deposition method. After ultrasonic agitation for 12 hours, the mixed suspension was dropped onto the chip electrodes. The sample can be made as a network to bridge between the electrodes and then be used to study their photoelectric properties.The morphology of the sample was observed by SEM (Carl Zeiss Ultra55). XRD measurement can be carried by X-ray diffractometer (D8 ADVANCE, Bruker, Germany). The UV-vis absorption spectrum was measured by a Perkin-Elmer Lambda 950 UV-vis-NIR spectrophotometer. Agilent 4156C was applied to investigate the current-voltage characteristics of the fabricated devices at room temperature.

## 3. Results and discussion

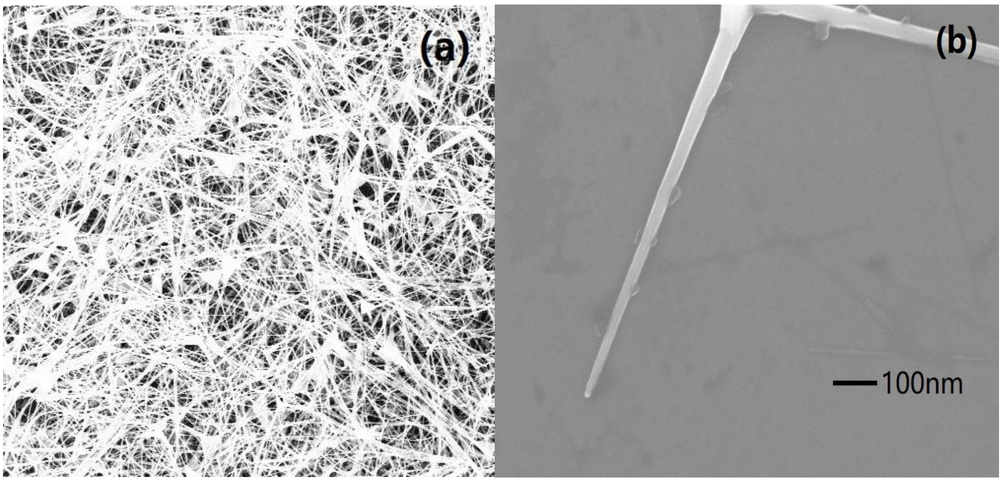


Fig. 1. (a) SEM image of ZnO nanomateral (b) SEM image of graphene QDs/ZnO nanostructure.

Fig. 1. shows the surface morphology of the ZnO and graphene QDs/ZnO composite sample. The morphology reveals that the shapes of ZnO are just like rod and triangle. The graphene QDs can be adhered to on the surface of ZnO nanomaterial. The average diameter of graphene QDs is around 20 nm. The average diameter of ZnO rods was estimated to be about 30 nm. It is obvious that graphene QDs can be very scattered and tightly packed with ZnO nanomaterial.

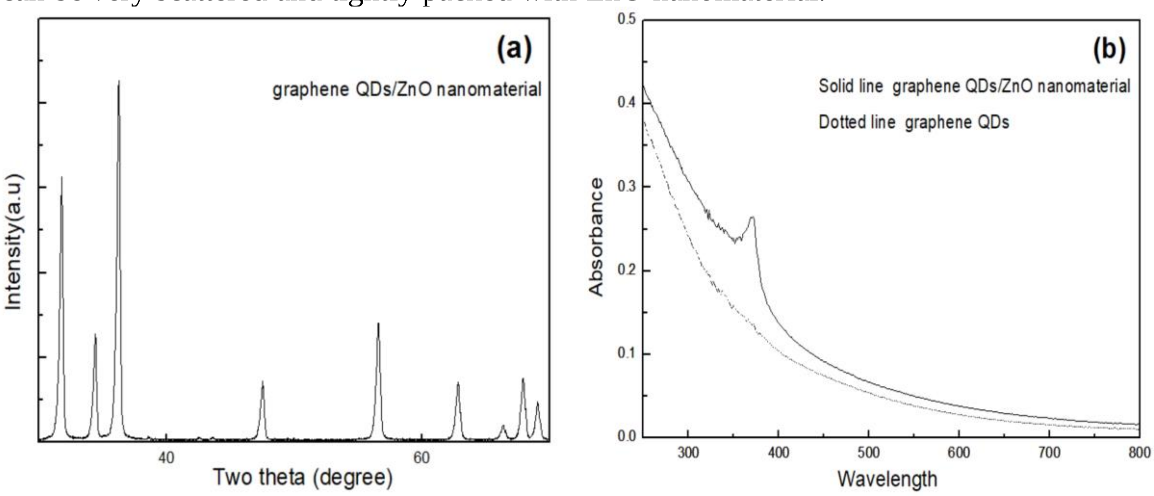


Fig. 2. (a) XRD patterns of graphene QDs/ZnO nanomaterial. (b) UV-vis spectra of graphene QDs/ZnO nanomaterial

Crystalline structure of the prepared samples was characterized by X-ray diffraction (XRD) as shown in Fig. 2 (a). A series of diffraction peaks were observed and was corresponding to the standard planes of hexagonal wurtzite ZnO structure. No diffraction peaks concerning graphene are investigated in graphene QDs/ZnO nanomaterial. So it suggests graphene QDs do not vary the crystal structures of ZnO nanomaterial. Fig. 2 (b). shows the absorption spectra of the graphene QDs/ZnO nanomaterial as well as graphene QDs. Obviously, the graphene QDs/ZnO hybrid has a stronger relative intensity than its counterpart of the graphene QDs across the nearly entire band. The highest emitting peak is 370nm belonging to UV waveband, which means the stronger photoelectric response under UV illumination.

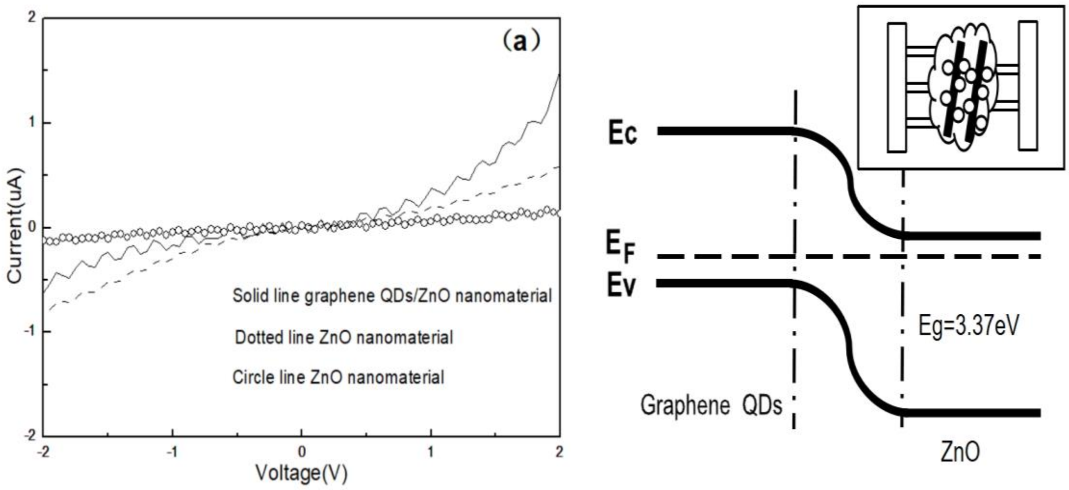


Fig. 3. (a) I–V characteristics of the fabricated samples measured at room temperation (b) Mechanism for graphene QDs compounded with ZnO nanomaterial. Higher inset: top view of the fabricated sample.

Fig. 3 (a). presents the photoelectric response of the fabricated pure ZnO nanomaterial and graphene QDs/ZnO composite sample under the same power of illumination. In this experiment, considering to the small dimension of pure graphene QDs, it could not be easily bridged onto between two electrodes. Thus, the photoelectric reponse of ZnO nanomaterial was regarded to compare graphene QDs/ZnO nanomaterial. This measurement was carried out at a low bias voltage under UV illumination and in dark at room temperature. The response of ZnO nanomaterial in dark is faint, the photocurrent can be controlled by turning on the light illumination. The photocurrent of graphene QDs/ZnO composite is nearly more than twice as large as the current for ZnO nanostructure among the whole voltage range at a low basing voltage under UV irradiation. Fig. 3 (b) shows the schematic diagram of operational mechanism for graphene QDs/ZnO composite under illumination. The photoresponsivity enhancemen can be described by photogenerated carrier transportation. In order to equalize the Fermi levels around the ZnO-C interaction, a space charge region will be generated. The electrical field provides the driving force for separating the photogenerated carriers. The excited electrons on the surface of ZnO can migrate to the conduction band of graphene QDs, which build a conductive transportation pathway in the ZnO structure and facilitate direct transportation of charge carriers[16-19]. Therefore, photocurrent will remarkably be enlarged significantly because of the concentration of the carrier charges. The results implied that photogenerated carriers can be easily moved apart and the photoresponsivity amazingly increased by compounding graphene QDs with some II-VI group semiconductor just as ZnO material. The results emphasis the significance of the sensitive structure based on graphene QDs/ZnO composites in photosensitive devices.

## 4. Conclusion

In this work, highly dispersed graphene QDs compounded with ZnO nanomaterial was prepared by a facile ultrasonic method. The novel structure was characterized by transmission electron microscopy and X-ray spectroscopy. The result shows graphene QDs were scattered and tightly in conjunction with ZnO nanomaterial. The photocurrent of graphene QDs/ZnO composite is nearly more than twice as large as the current of ZnO nanostructure among the whole voltage range. The sensitive structure based on graphene quantum dots/ZnO composites leads to high the photoelectric response at the low bias voltage and entitles the fabricated structure as an efficient sensitive structure under UV illumination. The results highlight the significance of the sensitive structure based on graphene QDs composites for new photoelectric devices.

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