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WS_2 Quantum Dot Graphene Nanocomposite Film for UV Photodetection

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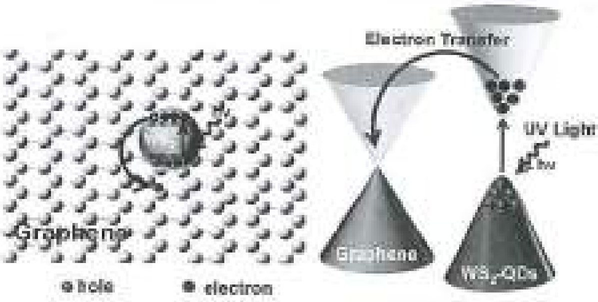
Supporting Information

ABSTRACT: The development of highly responsive, ultrathin, and cost-effective 0D-2D nanocomposite photodetectors, in which light absorption and carrier transportation may be realized separately and independently, has garnered considerable attention. In the present work, we demonstrate the fabrication of atomically thin UV photodetectors based on a hybrid structure (0D-2D) of semiconducting WS_2 quantum dots (0D) with graphene (2D) on SiO_2/Si substrate. Graphene and WS_2 quantum dots (WS_2-QDs) are synthesized through chemical vapor deposition (CVD) and hydrothermal processes, respectively. The proposed photodetector offers a remarkable response to ultraviolet (UV) light of ~365 nm, owing to the high absorption efficiency of WS_2-QDs and excellent charge mobility of graphene. The photodetector exhibits high responsivity of ~1814 A W^{-1} under illumination of UV light (365 nm, power density of 50.74 μW cm^{-2}) and a high photodetectivity of ~7.47×10^{12} Jones (cm $Hz^{1/2}$ W^{-1}). The photodetector fabricated in this work shows a fast photoresponse time of ~2 s (rise time) and ~2.9 s (fall time). We have also elucidated the working principle of the proposed photodetector. Outcomes of the present work are comparable or better than other results available in the literature. Our findings suggest that this nanocomposite structure of WS_2-QDs with graphene sheets is a prospective candidate for high-performance optoelectronic devices.



KEYWORDS: *hybrid photodetectors, TMDs, WS_2, quantum dots (QDs), graphene, UV photodetector*

■ INTRODUCTION

Ultraviolet (UV) radiation, an important constituent of electromagnetic radiations, has a profound impact in the development and survival of humankind. For instance, appropriate doses of UV radiation, which produce Vitamin D from interaction with the human stratum, are essential and required for robust bone growth.[1,2] However, prolonged human exposure to UV radiation may affect the skin, eyes, immune system, and even result in skin cancer.[3−5] Therefore, to identify the presence of UV radiation in a working environment, the development of an electronic device, which converts UV radiation into electrical signals (UV photodetectors), is desperately in demand. Furthermore, UV photodetectors have a wide range of commercial applications including environmental monitoring, video imaging, flame detection, missile-plume detection, space communication, and security.[6−11] However, the firmly established silicon (Si) technology has a few limitations, such as it requires expensive high pass optical filters and phosphorous materials to stop low energy photons.[10] On the other hand, the discovery of graphene, an atomically thin two-dimensional (2D) single sheet of carbon atoms arranged in closely packed honeycomb lattice, has allowed us to fabricate fast next generation ultrathin photodetectors and optoelectronic devices.[12−14] Owing to its excellent carrier mobility with reported theoretical values in excess of 200 000 cm^2 V^{-1} s^{-1} [15] at room temperature and hole mobility nearly equal as its electron mobility, it is a strong front runner for applications requiring highly conductive interconnects. Although this unique capability of graphene has sparked interest, the limitation in light absorption (only about 2.3%) is undoubtedly the bottleneck in developing useful 2D graphene based photodetectors, which show very low responsivity, typically on the order of a few mA W^{-1}.[11,16,17] However, the responsivity of graphene could be enhanced by modifying its surface with semiconducting materials having strong light absorption efficiency.[15,18]

In recent years, semiconducting materials of the layered transition metal dichalcogenide (LTMD) family have drawn ever-increasing attention in the field of photodetection, owing to their strong light− matter interaction and suitable band gaps

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