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MoS_2 Quantum Dots Decorated 2-Dimensional Bi_2S_3 for Photocatalytic Hydrogen Production under Broad Solar Spectrum

Hydrogen (H_2) is a promising candidate to replace fossil fuels owing to its high fuel value of ~143 kJ/g. Furthermore, the combustion of H_2 produces only water as by-product, rendering the process environmentally benign [1]. There are a variety of methods to produce H_2, among them photocatalytic splitting of water to generate H_2 has been widely regarded as one of the most sustainable approaches [2, 3]. In view of solar energy utilization, the search for semiconductor photocatalysts that can harvest the wide spectrum of solar light, from ultraviolet (UV) to near-infrared (NIR) wavelength, and simultaneously achieve efficient solar energy conversion remains is one of the most challenging missions. Although noble metals have been studied extensively to achieve high photocatalytic activity for H_2 production, the scarcity of these precious metals and high production costs limit the practicality of using noble metals for photocatalytic H_2 production. Molybdenum disulfide (MoS_2) has emerged as an attractive non-noble metal catalyst with high catalytic efficiency based on theoretical and experimental studies. Among the different shapes and sizes of MoS_2, zero-dimensional (0D) MoS_2 quantum dots (MoS_2QDs) possess unique optical and electronic properties, which are vital in many applications, particularly photocatalysis [1, 4]. The quantum size of MoS_2QDs not only results in an increase in unsaturated bonds, but higher exposed edges per surface area as well. The latter will in turn enable more hydrogen atoms to be bonded to the photocatalyst, thereby increasing the photocatalytic activity for H_2 generation. In this work, MoS_2QDs decorated 2D-bismuth sulfide (Bi_2S_3) photocatalyst was synthesized via a facile solvothermal route. Photoluminescence characterization showed that the synthesized MoS_2QDs possessed up-conversion and down-conversion properties, indicating their capability to harness energy from the light spectrum ranging from ultraviolet (UV) to near-infrared (NIR). The performance of the synthesized MoS_2QD/Bi_2S_3 photocatalysts revealed the highest hydrogen yield of 17.7 mmol/h.g was achieved by 0.14MoS_2QD/Bi_2S_3, which was almost 3 and 4.5 folds higher than that of control MoS_2 nanosheets-decorated Bi_2S_3 and undoped Bi_2S_3, respectively. Furthermore, examination of the 0.14MoS_2QD/Bi_2S_3 photocatalysts under NIR irradiation showed a significant photocurrent response and an accumulative H_2 yield of 53.6 µmol/g after 6 h reaction. Besides that, 0.14MoS_2QD/Bi_2S_3 was able to retain more than 90% of photoactivity after 4 consecutive reaction run, thus indicating its superior photostability. Photoelectrochemical measurements also revealed a significant improvement in the charge transfer rate of MoS_2QD/Bi_2S_3 as compared to the control samples. This work demonstrated the importance of MoS_2QDs and their potential in replacing noble metal co-catalysts for photocatalytic H_2 production under broad solar spectrum.

References

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