Quantum sized semiconductor for photocatalytic solar fuels production

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Abstract:
Photocatalytic solar fuels production represents one of the most potential strategies for replacing the dying-up fossil feedstocks and dealing with the environmental problems caused by the combustion of fossil fuels. However, this technology has not been widely applied because of its low solar energy conversion efficiency which is usually limited by the microstructure and the electronic structure of the semiconductor photocatalysts. We found well designed quantum sized materials have peculiar advantageous as high performance photocatalysts for solar fuels production under ambient conditions. The material is focused on atomic scale bismuth, tungsten, and molybdenum based semiconductor material.
Keywords: photocatalyst, solar fuels, quantum sized material.

1. Introduction (11-point boldface)

Solar energy conversion to chemical fuels by photocatalytic water splitting or CO_2 reduction is a promising strategy to solve the problems of energy crisis and global warming from CO_2 emissions. Up to the present, the solar energy conversion efficiency by photocatalysis is still unsatisfying and requires further promotion for commercialization. Compared with ordinary bulk or nanoscale material, quantum sized semiconductor may have the most potential to realize this great target. First, quantum sized semiconductor has high surface areas to provide more reactive sites. Moreover, the redox potential of photogenerated charge carriers in quantum sized semiconductor usually can be improved by quantum confinement effect to sufficiently drive photochemical reactions. Besides, due to a multiple exciton generation in quantum sized semiconductor, the concentration of photogenerated charge carriers are largely increased when comparing with that in their ordinary material. However, quantum sized semiconductors also have a disadvantage that the space charge layers are not effective for separating electron-hole pairs, which is one of the main reasons that quantum sized semiconductor for efficient water splitting or CO_2 reduction has been rarely reported up to the present.

Herein, we synthesized series of quantum sized transition metal oxide semiconductors to study the possibility of efficient solar fuels production by affording abundant different active sites, increased electron-hole separation, and superior solar light absorption.

2. Experimental (or Theoretical)

Quantum sized transition metal oxide semiconductors were synthesized by facile hydrothermal synthesis method under the temperature between 100-180℃.

3. Results and discussion

We found many quantum sized oxide semiconductors such as $BiVO_4$, Bi_2WO_6, Bi_2O_3, WO_3 etc. exhibited excellent activity for pure water splitting or N_2, CO_2 reduction under simulated solar light irradiation. We also studied the photocatalytic mechanism by compositing DFT calculation and comparative studies. Figure 1 is the microstructure of quantum sized $BiVO_4$ and its pure water splitting performance. Figure 2 shows the microstructure of quantum sized bismuth oxide and its N_2 reduction performance.

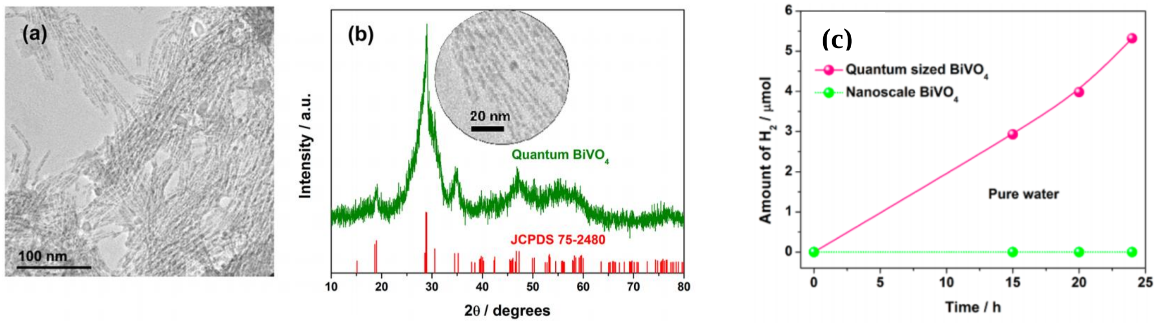

Figure 1 (a) TEM image and (b) XRD pattern of $BiVO_4$ quantum tube. (c) pure water splitting performance of $BiVO_4$ quantum dots.

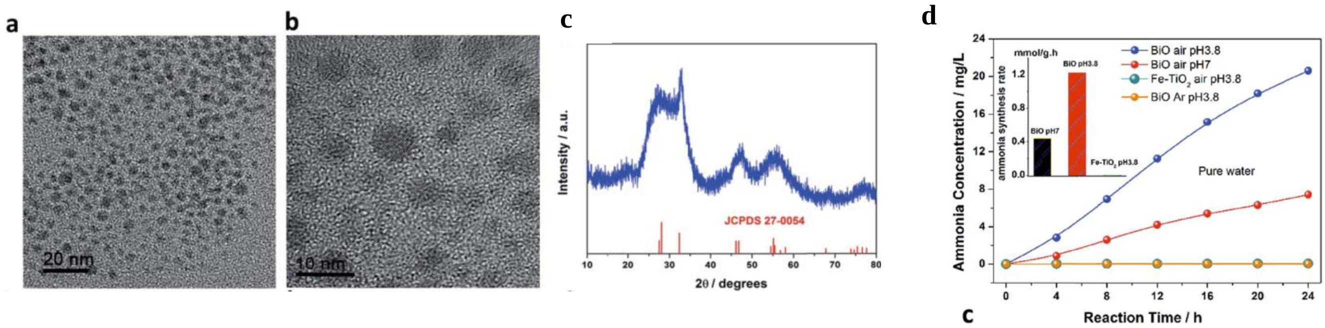

Figure 2 (a,b) TEM image of bismuth oxide quantum dots, (c) XRD of bismuth oxide quantum dots, (d) N_2 reduction to ammonia by bismuth oxide quantum dots in pure water under simulated solar light.

4. Conclusions

By our studies on series of quantum sized oxide semiconductor photocatalyst, it can be proved that the photocatalytic performance for solar fuels production can be largely improved by quantum confinement effect.

References