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Coupling of semiconductors for photocatalytic oxidation and CO2 reduction reactions under visible-light

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Removal of environmental pollutants through photocatalytic reaction has drawn increasing attention over the last few decades. Photocatalysts have also been designed and investigated for the purpose of water splitting and CO_2 reduction to generate clean energies. We fabricated several heterojunction structures between TiO_2 and other visible-light absorbing semiconductors, and found that relative energy band locations between TiO_2 and sensitizer are a crucial factor in determining the efficiency of the photocatalytic reactions. First, we investigated several coupled structures of TiO_2 and sensitizers, whose VB are lower than that of TiO_2 (denoted to "type-B heterojunction"). With visible light irradiation, the electrons in the VB of the semiconductor are excited to its CB. Thereby, its VB is rendered partially vacant, and the electrons in the VB of TiO_2 can be transferred to that of the semiconductor, since its VB is located at lower level. As a result, the holes generated in the VB of TiO_2 have sufficient lifetime to initiate the photocatalytic oxidation reactions. Some of the coupled systems exhibited significantly higher photocatalytic efficiency than the typical N-doped TiO_2 in decomposing gaseous 2-propanol and several organic pollutants in aqueous solution. For further enhancement of visible-light catalytic efficiency, we doubly combined the two different sensitizers with TiO_2. That is, sensitizer-B with lower VB position than that of TiO_2 was designed to be located in the core of the TiO_2 structure, whereas sensitizer-A with higher CB was loaded onto the TiO_2 surface. Under visible-light irradiation, both the electrons and holes are generated in CB and VB of TiO_2, and these active species induces remarkably high photocatalytic efficiency in evolving CO_2. Second, we also found that some of the coupled photocatalytic systems can be used for the reduction of CO_2 under visible-light irradiation. We monitored the evolution of methanol and carbon monoxide, and it was also found that relative energy band positions between two semiconductors were critical for the photocatalytic CO_2 reduction reactions.