Development of the New Photocatalysts for Environment and Energy Applications

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Photocatalysts are active materials based on solar energy, an infinite resource that can be easily obtained, and have optimal conditions for solving environmental problems such as solar energy conversion (Hydrogen Evolution) and eco-friendly decomposition of pollutants (Water and Air Treatment). Violet phosphorus (VP), also known as Hittorf's phosphorus, is promised a next-generation two-dimensional (2D) material with black phosphorus (BP). It is an intermediate in the process of synthesizing BP starting with red phosphorus (RP), and has a unique activity.

In our group, synthesis and characterization of the new photocatalysts were studied by establishing synthetic parameters under mild conditions, and presented as follows. First, a **Ti-based peroxo (Ti-OOH) complex** was successfully synthesized by oxidizing the surface of a metallic titanium hydride (TiH_2) precursor using hydrogen peroxide (H_2O_2), which is easy to react even under mild oxidizing conditions as a green oxidizing agent. Second, we synthesized the VP by a high energy mechanical milling method using RP powder. This fabricated partially oxidized VP, named as **2D-POVP**, does not show up characteristics in both RP and BP, and has an abnormal catalytic reduction performance. The 2D-POVP had 2D amorphous structure with a very strong negative charge and the P=O structure acted as a redox functional group. However, since BP has proved problematic in the photocatalyst field, due to rapid recombination of electrons and holes. Third, to overcome this, we used a nanocomposite with MoS_2 to prevent the recombination of electrons and holes and to have a broad range of optical absorption from visible light to near IR light. The nanocomposite material of BP and MoS_2, named by **MoS_2@BP 2D-nanocomposite**, shows a remarkable increase in photocatalytic decomposition ability of both organic dyes and VOCs. It has also many cycles of catalytic ability, which is advantageous in terms of stability. Finally, we designed and synthesized a new type of **Ti-OOH/RP heterojunction 2D-nanocomposite** for energy application. For the heterojunction composite photocatalyst, the contact interface contributes to charge separated carrier conditions, resulting that the photo-induced charge carrier life time of the 2D-nanocomposite increased by up to 60%. A photocatalytic hydrogen evolution test was performed under visible-light irradiation and it was confirmed that the efficiency improved as the amount of RP added from 7.97 to 17.05 μmol/h.