Solar Fuel Production from CO_2 and H_2O by Brookite-Containing Mixed-Phase TiO_2 Photocatalysts

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Photocatalytic reduction of CO_2 to fuels (CO, methane, methanol, etc) by sunlight is potentially a promising sustainable energy technology that not only reduces greenhouse gas emissions but also produces renewable fuels. TiO_2 has been widely used as a photocatalyst due to its low cost, high stability, and non-toxicity. TiO_2 naturally occurs as three polymorphs: anatase, brookite and rutile. Among them, only TiO_2 anatase, rutile or anatase-rutile mixed phase (P25) have been studied for CO_2 photoreduction. Brookite phase is much less studied as a photocatalyst and has not been studied for CO_2 photoreduction so far. In this work, brookite containing mixed-phase (e.g., anatase-brookite, anatase-brookite-rutile) TiO_2 nanocrystals have been synthesized through a hydrothermal method with a good control in brookite phase fraction. The catalysts were well characterized by UV-vis, XRD, SEM, TEM, BET, and FTIR analysis. The experiments of photocatalytic CO_2 reduction with water vapor using the prepared catalysts were conducted under simulated sunlight irradiation. CO and CH_4 were the major reduction products measured by a gas chromatograph (GC) equipped with thermal conductivity detector (TCD) and flame ionization detector (FID). Mixed-phase anatase-brookite TiO_2 demonstrated higher catalytic activity than single phase anatase or brookite. Mechanistic studies including the effects of surface defect sites and interfacial charge transfer between different crystal phases were also investigated.