Photocatalytic Degradation of Methylene Blue by Innovative $BiVO_4/TiO_2$ Composite Films under Visible Light Irradiation

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Bismuth vanadate and titanium dioxide ($BiVO_4/TiO_2$) composites used as visible-light-driven photocatalysts were successfully synthesized with different mole ratio by coupling of a co-precipitation method with a sol-gel method. The phase transitions of the as-prepared $BiVO_4/TiO_2$ composites were carried out by X-ray diffraction (XRD). The results clearly indicated that the as-synthesized $BiVO_4/TiO_2$ composites presented in two crystalline phases, which were monoclinic $BiVO_4$ and tetragonal TiO_2 (anatase) structures. Raman spectroscopy provided further structural evidence as to the composition of the $BiVO_4/TiO_2$ composites. In order to investigate the effect of TiO_2 on the $BiVO_4$ photocatalyst, X-ray photoelectron spectroscopy (XPS) and transmission electron microscopy (TEM) were used to consider the $BiVO_4/TiO_2$ composite as comparison with the pure TiO_2 and $BiVO_4$. It was found that the $BiVO_4/TiO_2$ composite was formed by coupling TiO_2 nanoparticles on surface of $BiVO_4$ particles, rather than a doped material. Light absorption of the $BiVO_4/TiO_2$ composites across the UV-visible spectrum and band gap energy were also investigated by UV-vis diffuse reflectance (UV-vis DR) spectroscopy. Furthermore, the $BiVO_4/TiO_2$ composites were fabricated in film form by a doctor blading technique on glass substrates to solve the catalysts separation issue for studying their photocatalytic activities evaluated via degradation of methylene blue (MB) dye in aqueous solution under visible light irradiation. Photocatalytic results showed that the composite photocatalysts showing a higher photocatalytic activity (with pseudo-first order kinetics) than the pure $BiVO_4$ and TiO_2 do individually, which the $BiVO_4/TiO_2$ composite with mole ratio of 1:1 exhibited the highest of the apparent MB degradation rate constant of 1.568 h^{-1}. Since electronic interaction between $BiVO_4$ and TiO_2 leads to an improved charge separation of the coupled $BiVO_4/TiO_2$ system, that is responsible for the enhancement in the rate of photocatalytic degradation. Additionally, the MB degradation efficiency over the $BiVO_4/TiO_2$ composite films had no significant changes after five reuse cycles, indicating the long-term stability of the films. $BiVO_4/TiO_2$ composite films are intended to be used in photocatalytic degradation of organic pollutants in wastewater, especially those from the textile and the photographic industries.