Formation of a junction between TiO_2 and β-Bi_2O_3 to enable efficient visible-light harvesting in advanced oxidation processes for waste water treatment

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Heterogeneous photocatalysis is a type of advanced oxidation processes (AOPs) where external radiation (either UV or visible light) is used to trigger the catalytic activity of a catalyst, which produces reactive oxygen species (ROS). ROS are able to destroy a wide range of organic compounds dissolved in water. Although TiO_2 [1] is one of the most promising photocatalytic materials for waste water treatment, it has two major drawbacks: (i) the band gap of TiO_2 is 3-3.2 eV, and (ii) a fast electron (e^-) - hole (h^+) recombination. The drawbacks could be, for instance, overcome by combining TiO_2 with another low band gap semiconductor [2].
In our work a combustion synthesis procedure was used to form a junction between TiO_2 and a narrow band gap semiconductor β-Bi_2O_3 (2.4 eV) .The role of β-Bi_2O_3 in the composite is to act as a visible light photosensitizer for TiO_2. The junction between TiO_2 and β-Bi_2O_3 enables the transfer of photo-generated charge carriers. Structural, surface and electronic properties of the obtained catalysts were analyzed and correlated to their performance in the photocatalytic oxidation of aqueous bisphenol A (BPA) solution conducted in a batch reactor under visible light illumination. Bisphenol A (BPA) is an endocrine disrupting compound, which is in widespread use in the production of most packaging materials used every day [3].
Results of XRD, TEM and XPS measurements performed on composites reveal that TiO_2 is present as anatase and Bi_2O_3 as β-Bi_2O_3. UV-Vis DR spectra of the composites show that the light adsorption of the composites was shifted into the visible range. This indicates that Bi_2O_3 acts as a visible light photosensitizer for TiO_2. Based on the XPS spectra we conclude that if the Ti:Bi ratio is over 1:0.4 a separate Bi phase is formed, which results in a decreasing association of Bi_2O_3 and TiO_2. Results of EIS and EPR measurements illustrate that there is a junction between TiO_2 and Bi_2O_3 resulting in efficient charge carrier separation, which decreases when the Ti:Bi ratio is higher than 1:0.4. The results of BPA degradation runs are in good agreement with these findings: the catalytic activity of the composite drops if the Ti:Bi ratio exceeds the value of 1:0.4. A heterojunction between TiO_2 and Bi_2O_3 in the composites supports the transfer of visible-light generated h^+ from the valence band (VB) of Bi_2O_3 to the upper lying VB of TiO_2. In addition, a p-n junction between TiO_2 and Bi_2O_3 can be formed, which enables the transfer of visible light photo-generated e^- in the conduction band (CB) of Bi_2O_3 to the CB of TiO_2. Under visible light illumination the role of TiO_2 is to act as a sink for visible-light photo-generated charge carriers in Bi_2O_3 and doing so, prolonging the lifetime of visible-light generated e^- and h^+ [4].

References

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