Bismuth-Based Visible-Light-Active Photocatalytic Nanomaterials for Environmental Remediation

Mirabbos Hojamberdiev[1], Gangqiang Zhu[2], Zukhra Kadirova[3], Masashi Hasegawa[1]

[1]*Department of Materials Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan*
[2]*School of Physics and Information Technology, Shaanxi Normal University, Xi'an 710062, PR China*
[3]*Uzbekistan-Japan Innovation Center of Youth, University Str 2B, Tashkent 100095, Uzbekistan*

E-mail: *hmirabbos@gmail.com*

Bismuth-based semiconductors are regarded as a promising new candidate of advanced photocatalytic nanomaterials due to their suitable optical band gap energy for visible light absorption, an increased mobility of photogenerated charge carriers because of well-dispersed Bi 6s orbital, non-toxicity, and easy tailoring of their morphologies owing to their layered structure [1]. In this study, we have explored a wide variety of bismuth-based semiconductors, namely Bi_2O_3, Bi_2MO_6 (*M* = Mo, W), $BiVO_4$, BiO*X* (*X* = Cl, Br, and I) and $(BiO)_2CO_3$ for environmental remediation. As a narrow band gap semiconductor, Bi_2O_3 has four polymorphs: α-Bi_2O_3, β-Bi_2O_3, γ-Bi_2O_3, and δ-Bi_2O_3. Among them, β-Bi_2O_3 has the strongest absorption in the visible light region with a smaller band gap (E_g = 2.0–2.4 eV) and demonstrated a good photocatalytic performance than other polymorphs under visible light irradiation, and is inexpensive, nontoxic, and stable in acidic conditions. To further enhance its photocatalytic performance, β-Bi_2O_3 was composited with MoS_2 quantum dots and Pd/PdO nanoparticles, and doped with Gd^{3+} ions. Bi_2WO_6 is one of the simplest members of the Aurivillius oxide family of layered perovskites, which are structurally composed of alternating perovskite-like and fluorite-like blocks. Having an optical band gap of 2.80 eV, Bi_2WO_6 was composited with BiOI (or $CeVO_4$) and allophane to enhance its photocatalytic performance. As expected, the Bi_2WO_6/0.5BiOI/allophane and Bi_2WO_6/$CeVO_4$/allophane composites showed high adsorption capacity, excellent photocatalytic performance and stability for degradation of gaseous acetaldehyde thanks to their large specific surface area, greater number of easily accessible active sites, facilitated diffusion of reactants, multiple scattering of incident light, and *p*–*n* heterojunction. $(BiO)_2CO_3$ is the only well-established solid carbonate in the Bi_2O_3-CO_2-H_2O system and has an optical band gap of 3.4 eV. We have synthesized $(BiO)_2CO_3$/Fe_3O_4, $(BiO)_2CO_3$/Bi_2O_3, and $(BiO)_2CO_3$/Ag/AgBr composites to enhance its visible light absorption and improve photocatalytic performance for the degradation of various organic pollutants under visible light. Furthermore, $BiVO_4$ and BiO*X* (*X* = Cl, Br, and I) with different morphologies and dopants were synthesized, and the effects of morphology and dopant amount on photocatalytic degradation efficiency of various organic pollutants were investigated. In summary, the bismuth-based photocatalytic nanomaterials have potential to be applied in wastewater treatment and air purification systems in the future.

[1] X. Meng and Z. Zhang, *Journal of Molecular Catalysis A*, 2016, **423**, 533–549.