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Anti-Bacterial and Photocatalytic Activities of $(Mo_{0.5}, W_{0.5})O_3$ with $Cu(Mo_{0.5}, W_{0.5})O_4$ Prepared by Impregnation Method and Mechanochemical Processing

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Abstract

A tungsten–molybdenum solid solution oxide ($(Mo_{0.5}, W_{0.5})O_3$) powder hybridized with $Cu(Mo_{0.5}, W_{0.5})O_4$ was prepared using impregnation method and mechanochemical processing. The powder prepared through the impregnation method exhibited antibacterial effects both in the dark and under visible light. The contribution of MoO_3 in the powder surface was inferred for activity in the dark. The phase transition temperature of $(Mo_{0.5}, W_{0.5})O_3$ was decreased more than 50°C by planetary ball milling. The powder produced through mechanochemical processing also exhibited photocatalytic decomposition activity on the gaseous 2-propanol under visible light.

***Key-words**: Mo, W, Cu, Photocatalyst*

1. Introduction

Molybdenum trioxide (MoO_3), the most stable oxide of molybdenum, comprises layers of edge-shared MoO_6 octahedra in an orthorhombic crystal[1]. This material is commonly applied to catalysts[2-5], photochromic or electrochromic materials[6,7], and anti-bacterial agents[8,9].

This oxide forms a solid solution ($(Mo, W)O_3$) with WO_3. Its crystal structure is the same as that of WO_3[1], a well-known photocatalyst material[10]. An earlier study revealed that the particles of $(Mo, W)O_3$ powder prepared using hydrothermal processing are smaller than particles of pure MoO_3[11]. Its bandgap is smaller than pure WO_3. These characteristics indicate that $(Mo, W)O_3$ is a candidate photocatalyst material for use in visible light. However, the reduction power of $(Mo, W)O_3$ is insufficient for its use as photocatalyst by itself because the conduction band (CB) of WO_3 decreases (becomes positive) with dissolution of Mo[11,12]. Based on the reported value of the CB level of $(Mo, W)O_3$, multi-electron reduction of oxygen is infeasible by the modification of Cu-clusters onto the powder surface, which is effective for provision of visible light photocatalytic activity to WO_3 by the interface charge transfer[13].

By contrast, Cu reacts with WO_3 and MoO_3 and forms $CuWO_4$ and $CuMoO_4$ at 500–800°C in ambient air atmosphere[14,15]. Recent reports have revealed that $Cu(W_{1-x}, Mo_x)O_4$ is an n-type semiconductor with a bandgap of 2.1–2.3 eV. Its valence band (VB) level is located in the bandgap of $(Mo, W)O_3$[16,17]. Very recently, we provided visible light photocatalytic activity to $(Mo, W)O_3$ powder by modification of $Cu(W_{1-x}, Mo_x)O_4$ on the surface[18]. Detailed analysis revealed that the Hedvall effect[19] at the phase transition of $(Mo, W)O_3$ from orthorhombic to monoclinic at 400–450°C during heating hastens $Cu(W_{1-x}, Mo_x)O_4$ formation, and revealed that the resultant construction of Z-scheme between $(Mo, W)O_3$ and $Cu(W_{1-x}, Mo_x)O_4$ provides visible light photocatalytic activity.

Although this material might exhibit antibacterial effects not only under visible light but also in the dark because of MoO_3 in the surface, this activity has not been examined to date. Moreover, the controllable surface concentration ratio between $(Mo, W)O_3$ and $Cu(W_{1-x}, Mo_x)O_4$ is limited in the previous process because of impregnation of a $CuCl_2$ solution and subsequent one-time heat treatment for the Hedvall effect. It is important to develop a different processing route to evaluate the potential of this material in a wide chemical composition range. Based on this background, we first examined antibacterial activity both in the dark and under visible light using the $(Mo_{0.5}, W_{0.5})O_3$ powder with $Cu(W_{0.5}, Mo_{0.5})O_4$ prepared in our previous study. Secondly, mechanochemical processing[20,21] was investigated to hybridize $Cu(Mo_{0.5}, W_{0.5})O_4$ with $(Mo_{0.5}, W_{0.5})O_3$. The photocatalytic activity of the powders prepared through this process was evaluated using decomposition of gaseous 2-propanol (IPA) under visible light[22].