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Highly Porous and Ultra-Lightweight Aero-Ga_2O_3: Enhancement of Photocatalytic Activity by Noble Metals

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Abstract: A new type of photocatalyst is proposed on the basis of aero-β-Ga_2O_3, which is a material constructed from a network of interconnected tetrapods with arms in the form of microtubes with nanometric walls. The aero-Ga_2O_3 material is obtained by annealing of aero-GaN fabricated by epitaxial growth on ZnO microtetrapods. The hybrid structures composed of aero-Ga_2O_3 functionalized with Au or Pt nanodots were tested for the photocatalytic degradation of methylene blue dye under UV or visible light illumination. The functionalization of aero-Ga_2O_3 with noble metals results in the enhancement of the photocatalytic performances of bare material, reaching the performances inherent to ZnO while gaining the advantage of the increased chemical stability. The mechanisms of enhancement of the photocatalytic properties by activating aero-Ga_2O_3 with noble metals are discussed to elucidate their potential for environmental applications.

Keywords: aeromaterial; Ga_2O_3; photocatalysis; metal-semiconductor photocatalyst; methylene blue degradation

1. Introduction

Five different polymorphs have been reported for gallium oxide (Ga_2O_3), namely, the monoclinic (β), rhombohedral (α), defective spinel (γ), cubic (σ), and orthorhombic (ε) structures [1,2]. β-polymorph Ga_2O_3 has attracted most of the attention due to its superior chemical and thermal stability, wide bandgap, high stability to breakdown voltage, and high Baliga's figure of merit (BFOM). It has been widely studied and utilized for various applications including in power electronics, solar blind UV photodetectors, solar cells, and as gas-sensing materials [3–5]. Photocatalysis is another emerging application of the β-Ga_2O_3 polymorph. Particularly, the photocatalytic activity of the Ga_2O_3 polymorphs was found to be strongly influenced by its crystal structure in the following order: β-Ga_2O_3 > α-Ga_2O_3 > γ-Ga_2O_3 [6].

Ga_2O_3-based pure phases and composites have been examined for energy and environmental applications, including the decomposition of volatile aromatic pollutants in air [6]; water purification [7–11]; solar water splitting [12–15]; photocatalytic carbon dioxide (CO_2) reduction with water to produce carbon monoxide (CO), hydrogen (H_2), and