Atomic Layer Deposition of Metal Oxide Inverse Opals: A Tailorable Platform for Unprecedented Photocatalytic Performance

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Abstract : Metal oxide inverse opals are a unique class of photocatalysts with a hierarchical structure that mimics the natural opal gemstone. They are composed of a network of interconnected pores, which provides a large surface area and efficient pathways for the transport of light and reactants. Atomic layer deposition (ALD) is a versatile technique for the synthesis of high-precision metal oxide thin films, including inverse opals. ALD allows for precise control over the thickness, composition, and morphology of the synthesized films, making it an ideal technique for the fabrication of photocatalysts with tailored properties. In this study, we report the synthesis of TiO2, ZnO, and Al2O3 inverse opal photocatalysts using thermal or plasma-enhanced ALD. The synthesized photocatalysts were characterized using a variety of techniques, including scanning electron microscopy (SEM)-energy dispersive X-ray spectroscopy (EDX), X-ray diffraction (XRD), Raman spectroscopy, photoluminescence (PL), ellipsometry, and UV-visible spectroscopy. The results showed that the ALD-synthesized metal oxide inverse opals had a highly ordered structure and a tunable pore size. The PL spectroscopy results showed low recombination rates of photogenerated electron-hole pairs, while the ellipsometry and UV-visible spectroscopy results showed tunable optical properties and band gap energies. The photocatalytic activity of the samples was evaluated by the degradation of methylene blue under visible light irradiation. The results showed that the ALD-synthesized metal oxide inverse opals exhibited high photocatalytic activity, even under visible light irradiation. The composites photocatalysts showed even higher activity than the individual metal oxide inverse opals. The enhanced photocatalytic activity of the composites can be attributed to the synergistic effect between the different metal oxides. For example, Al2O3 can act as a charge carrier scavenger, which can reduce the recombination of photogenerated electron-hole pairs. The ALD-synthesized metal oxide inverse opals and their composites are promising photocatalysts for a variety of applications, such as wastewater treatment, air purification, and energy production. For example, they can be used to remove organic pollutants from wastewater, decompose harmful gases in the air, and produce hydrogen fuel from water.

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