Preparation and application of Wideband Gap Nanocrystalline Semiconductors Thin Films

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ABSTRACT

Transparent conducting Al-doped ZnO (AZO) thin films have been deposited by sol-gel route. Starting from an aqueous solution of zinc acetate by adding aluminum chloride as dopant, a c-axis oriented polycrystalline ZnO thin film 100nm in thickness could be spin-coated on glass substrates via a two-step annealing process under reducing atmosphere. The effects of thermal annealing and dopant concentration on the structural, electrical and optical properties of AZO thin films were investigated. The post-treated AZO films exhibited a homogenous dense microstructure with grain sizes less than 10nm as characterized by SEM photographs. The annealing atmosphere has prominent impact on the crystallinity of the films which will in turn influence the electrical conductivity. By varying the doping concentrations, the optical and electrical properties could be further adjusted. An optimal doping concentration of Al/Zn=2.25 at.% was obtained with minimum resisivity of 9.90×10-3 ohm-cm whereas the carrier concentration and mobility was 1.25×1020cm-3 and 5.04 cm2V-1S-1, respectively. In this case, the optical transmittance in the visible region is over 90%. In addition, photocatalytic removal of indoor level of toluene in the gas phase was performed in a tubular reactor by TiO2-based photocatalysts under illumination of UV and visible light, respectively. Two types of TiO2 suspensions were employed in the whole experiments: one prepared by a sol-gel route (designated as SG-TiO2) and the other by applying a commercial Degussa P25 TiO2 (designated as P25-TiO2). All photocatalysts were dip-coated on the inner surface of a Pyrex glass tube and followed by a post-annealing process. For visible-type photocatalysts, the above TiO2 films were sensitized by tetrakis (4-carboxyphenyl) porphyrin (TCPP) and designated as TCPP/SG-TiO2 and TCPP/P25-TiO2, respectively. The photocatalytic destruction of gaseous toluene by the four catalysts was evaluated. For the UV-type photocatalysts, toluene was decomposed significantly by both types of TiO2 films at lower toluene concentrations, [T] o. However, the overall removal efficiency (RE) was decreased dramatically as the initial concentration of was elevated to 6.5 ppm for P25-TiO2 and 4.0ppm for P25-TiO2, respectively. A plot of toluene elimination capacity (EC) vs. toluene loading rate indicated that the limiting EC for the SG-TiO2 and P25-TiO2 was 4.9 and 2.7 mg hr-1 m-2, respectively. In contrast, either type of dye-sensitized TiO2 photocatalysts evaluated under illumination of visible light showed relatively low toluene RE as compared to the UV-type photocatalysts under identical conditions. After pre-soaking in HCl solution, the activity of the acid-pretreated TCPP/P25-TiO2 [designated as TCPP/P25-TiO2 (ACT)] was improved considerably under the identical conditions. The kinetics of photocatalytic decomposition of gaseous toluene in our study generally would follow the Langumuir-Hinshelwood (L-H) model. The rate constant k, as fitted by L-H model, for the SG-TiO2 based catalysts is larger than that of P25-TiO2 based catalysts while the absorption constant K, on the contrary, follows the different trend. The higher activity of SG-TiO2 could be attributed to the smaller grain size (4.6~8.1 nm) of anatase crystals as evaluated in XRD diffraction pattern.

Keywords : AZO、thin film、precursor chemistry、aqueous phase deposition、Indoor air、Photocatalytic、Dye-sensitized TiO2 、Toluene、Visible light、porphyrin.

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