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Abstract

Title	Formation of Zinc Oxide Nanostructures and Their Photo-Electrochemical Application

(800 words)

Nowadays, low-temperature and environmentally conservative methods of functional oxides formation have been the main motivation for many researchers. By using low temperature synthesis techniques, flexible device fabrication utilizing substrates with low thermal stability such as organic polymer substrates are envisaged. Initial investigations on the formation of ZnO nanostructures were performed using rapid thermal oxidation of Zn foils as a function time, temperature and atmosphere. One-dimensional (1-D) ZnO nanorods and two-dimensional (2-D) ZnO nanosheets were reported; the formation mechanism of the ZnO nanostructures and the photocatalytic properties were also documented. Subsequently, surface oxidation of Zn foils via hot-water treatment (HWT) was investigated at 90°C from 4 to 24 h. Chemical etching of Zn foils' surface was found to affect the morphologies of ZnO nanostructures generated due different diffusion route of Zn ions from the substrate to the surface of the foils; ZnO nanowires and nanorods were obtained on the surface of chemically etched Zn foils while ZnO nanosheets were formed on untreated Zn foils. However, the ZnO nanostructures formed exhibited good crystallinity and optical properties as indicated by photoluminescence, Raman spectra, and high-resolution transmission electron microscope (HR-TEM) observations. Moreover, HWT was performed on sol-gel derived coatings in order to study the formation mechanism of ZnO nanostructures. The effect of an external direct current (D.C.) electric field induction during HWT on sol-gel derived ZnO coatings for controlled formation of good crystalline ZnO films was investigated. The electric field induced hot-water treatment (EF-HWT) was found to influence the formation of crystalline ZnO nanostructures on the ZnO gel films at low-temperature of 50°C for 3 h. The effects of time, voltage and substrates used during the EF-HWT were investigated. Flower-like precipitates of hexagonal zinc oxide were generated from the zinc acetate derived ZnO gel film on a silicon single crystal substrate at the negative electrode by applying an electric field.

Ce-doped ZnO nanostructured films were also prepared via HWT of Ce-doped ZnO sol-gel coatings. Rod-like undoped and Ce-doped ZnO nanostructures have been formed using hot-water treatment of the undoped and Ce-doped sol-gel derived layer at low temperature of 60°C for 30 min on glass substrates. The concentration of Ce doping was varied from 2 to 20 at %. Morphological structures and optical properties of the hot-water treated ZnO films were investigated and compared with those of the conventional, annealed ZnO films. The resultant undoped and Ce-doped ZnO nanostructures showed ultraviolet (UV) and strong blue emissions which can be used for the fabrication of optoelectronics devices. Besides that, well-aligned ZnO nanorod arrays were grown on seeded substrates via low-temperature hydrothermal process. The oriented ZnO nanorod arrays were used as the photo-electrode for dye sensitized solar cells (DSSCs). The formation mechanism of the oriented ZnO nanorods arrays was investigated as a function of time systematically. The maximum conversion efficiency of DSSCs obtained after a prolonged hydrothermal growth time of 24 h was 0.22 %. In addition, ZnO composite films consisting of ZnO nanorods and nanosheets were prepared by low-temperature hydrothermal at 80°C on seeded glass substrates. The seed layer was coated on glass substrates by sol-gel dip-coating and pre-heated at 300°C for 10 min prior to hydrothermal growth. The formation of composite one-dimensional ZnO nanorod arrays and two-dimensional ZnO nanosheet films using seeded substrates in a single low-temperature hydrothermal step would be beneficial for realization of device applications with properties exhibited in this unique morphology. The ZnO nanorods and nanosheets composite structure demonstrated higher photocatalytic activity during degradation of aqueous methylene blue under visible-light irradiation compared to only one-dimensional ZnO nanorod arrays. Based on all the studies, it can be concluded that the multi-dimensional and multi-functional ZnO nanostructures can be prepared at low-temperature using various low temperature methods. HWT is also a promising method to form ZnO nanostructures without any catalyst and specimen contamination.