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Electrodeposition and characterization of ZnO thin films for gas sensing

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The gas sensor is a sensing device that measures target gas molecules in a given atmosphere specially in the monitoring of environmental contaminants in air, water, and soil. Sensors based on semiconducting metal oxides are being widely used for gas or vapour sensing owing to their properties such as non-toxicity, biocompatibility, compact device structure, high sensitivity and stability and ease of syntheses. The most popular semiconducting metal oxides-based gas sensing materials are ZnO, SnO_2, WO_3 and TiO_2. Among them, ZnO is attracted more due to its other properties such as chemical and photochemical stability and high-electron mobility. Hence, ZnO is one of the most propitious materials in developing sensors in electronic and optical technologies. In this study, characterization and fabrication of ZnO for gas sensing applications using a simple and cost-effective electrodeposition method is discussed. Aqueous electrolytic solutions of Zn $(NO_3)_2$ and $ZnSO_4$ were used as the Zn precursors to find the best suited precursor to electrodeposit ZnO. The deposition was performed under a three-electrode electrochemical cell consisted of FTO coated glass (1×3 cm^2, 7 Ω/m^2), graphite rod (99.995%) and a saturated Ag/AgCl electrode as the working, counter, and reference electrodes respectively. The gas sensing ability of the ZnO films, developed under different deposition parameters (cathodic deposition potential, pH of the electrolyte, precursor concentration), was studied. By obtaining the workable cathodic deposition potentials (CDP) by cyclic voltammetry, the k best suited bath pH and the temperature to develop uniform ZnO thin films were found to be 3.5 - 4.5 and 55 ℃ respectively. Subsequently, the heat treated (425 ℃ for 1 hour) samples were characterized with UV/Vis spectroscopy, X-ray diffraction, scanning electron microscopy and energy dispersive X-ray techniques to investigate the bandgap energy, crystal structure, surface morphology and the material's composition respectively. The band gap energy of the material grown was fallen within 3.00 – 3.30 eV, while the crystals were found to be preferably grown along the [101] or [002] planes possessing hexagonal wurtzite structure in samples grown using two Zn precursors. SEM micrographs evidenced compact morphology with coral/rod-shaped appearance. According to the EDX analysis, Zn:O atomic ratio was revealed to be 1:1. The gas sensing ability of deposited films was examined against NO_2 and H_2S gases that causes due to electronic interactions between the crystallographic plane and the subjected gas molecules. The samples grown in 0.10 mol/L $ZnSO_4$ at CDP 1.00 V in pH 4.50 at 55 ℃ was found to have an average sensitivity of 5% and 11% while the samples grown in 0.10 mol /L Zn $(NO_3)_2$ at CDP 1.10 V in pH 3.70 at 55 ℃ were found to have an average sensitivity of 2% and 5% after exposing to NO_2 and H_2S gases respectively for 5 minutes at 30 ℃.

Keywords: Zinc oxide, Electrodeposition, Thin films, Three electrode system, Gas sensing

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