Luminescent Properties, X-ray photoelectron and X-Ray Absorption Spectroscopy Study of Antimony Doped P-type ZnO Nanowires

A. M. Alsmadi[1] and B. Salameh[1]

[1]Department of Physics, Kuwait University, 13060 Safat, Kuwait

Abstract

Zinc oxide (ZnO) is an extensively studied semiconductor due to its versatile properties applicable to many technologies, including electronic and optoelectronics [1]. Research has been conducted on Sb doped ZnO thin films with the intent of achieving p-type conductivity [2]. However, the instability of the thin films, non-uniform doping and the impurity phases present in these thin films have been a barrier to performing systematic and accurate studies of photoelectrical properties. Compared to ZnO thin films, ZnO nanowires have many interesting properties, such as single crystalline and high optical quality [3]. In this study, we synthesized Sb-doped ZnO (ZnO:Sb) nanowires with varying Sb content and carried out a systematic study on their structural, optical and photoluminescent properties. The x-ray absorption spectroscopy (XAS) and x-ray photoelectron spectroscopy (XPS) results indicated the incorporation of Sb dopants into the ZnO lattice. XPS and x-ray diffraction (XRD) analysis with full structural Rietveld refinement revealed that all ZnO:Sb nanowires with different Sb doping possessed typical wurtzite structure and had no other impurity phases. The XAS and XPS results showed that Sb ions are in an oxidation state between 3+ and 5+, indicating the presence of the (Sb_{Zn}-$2V_{Zn}$) acceptor complex in the ZnO:Sb nanowires. Photoluminescence (PL) measurements confirmed the formation of shallow acceptor levels in the ZnO:Sb nanowires. Strong violet luminescence, originating from free-electron to acceptor level (FA) transitions, was identified by temperature-dependent PL measurements. The FA emission showed a slight blue shift with the increase of the temperature. As a result of Sb incorporation into the ZnO lattice, we observed a red shift in the ZnO:Sb nanowires energy gap with the increase of Sb doping. The results provide strong promise of p-type conductivity of ZnO by Sb doping.

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