Doping Effects on Optical Properties of Low Temperature Grown ZnO Nanorod Arrays

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ABSTRACT

In this work, we explore the influence of Ag dopant concentration on the structural and optical properties of ZnO nanorods synthesized by hydrothermal technique. We present original results of a systematic investigation of crystal quality, morphology and photoluminescence properties by using X-ray diffraction (XRD), energy dispersive X-ray spectroscopy (EDX), scanning electron microscopy (SEM) and photoluminescence (PL). Strong effects of doping in Ag-doped ZnO nanorod arrays on optical properties are observed. The main advantage of the proposed synthesis is its simplicity and fast growth rates. The strength of the proposed nanotechnology is that any substrate can be used to grow doped ZnO nanorods and transferable nanorods.

Keywords: ZnO, nanorods, doping

1 INTRODUCTION

Over the last few years, ZnO nanorod arrays have been extensively investigated due to their potential for the development of novel nanodevices [1-3]. Usually undoped ZnO exhibits *n*-type conductivity ascribed to asymmetric doping limitations [4] and propensity to defects or impurities [5]. *P*-type conductivity of ZnO films has been achieved as a result of doping by N, As, Li, P, Sb, and Ag [4-7]. It is common that doping of zinc oxide often induces dramatic changes in its electrical and optical properties, which can be used in different useful applications. Some of these applications require both *p*- and *n*-type high quality nanostructures of ZnO.

The main motivation of this work is the absence of systematic studies of impurity doping using aqueous solution method. Even though, the solubility product constant of a chemical reaction usually ensures a stoichiometric product. Under suitable chemical environment, impurity doping through aqueous solution is possible. The improvement of the doped ZnO nanorods quality and the simplification of growth techniques are also important reasons to investigate aqueous solution method for doping ZnO. It is well known that *p*-type doping in ZnO is very difficult to achieve. Most of the proposed techniques employ catalysts or templates which may bring additional impurities into final nanomaterials, which will influence the purity, electrical and optical properties. Thus, the synthesis of ZnO nanorods at low-cost requires facile and low-temperature approaches which is important for nanodevice applications.

Here, we report on the influence of Ag dopant concentration on the structural, chemical, and optical properties of ZnO nanorods synthesized by hydrothermal technique. Strong effects of doping in Ag-doped ZnO nanorod arrays on optical properties will be presented. The experimental results are compared with theoretical data. In particular, the width of the band tails and the dependence of the FWHM of the PL band on carrier concentration were calculated using the model for broadening of impurity bands in heavily doped semiconductors developed by Morgan [8].

2 EXPERIMENTAL

2.1 Synthesis

All the chemical reagents used in our experiments were of analytical grade and without further purification. Si (100) wafers were used as a substrate for the fabrication of the ZnO nanorods. Substrates were cleaned as reported before [6,9]. In a typical procedure, zinc sulfate [$Zn(SO_4)\cdot 7H_2O$] was first dissolved into 50 ml of deionized water and then 25 ml (29.32%) of ammonia (NH_4OH) was added and stirred for 10 min to mix completely at room temperature. First set of pure ZnO nanorods (#1) samples was synthesized using 0.1-0.25 M of $Zn(SO_4)\cdot 7H_2O$. Second set of samples (#2) was prepared using 0.1-0.25 M of $Zn(SO_4)\cdot 7H_2O$ and 0.001-0.005 M of silver nitrate $Ag(NO_3)$ (99.7%) which was dissolved in 50 ml DI–water. An ammonia solution (29.6%) was added.