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Hydrothermal synthesis and optical properties of Ni doped ZnO hexagonal nanodiscs

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ABSTRACT

Single crystalline Ni-doped ZnO hexagonal nanodiscs are successfully synthesized. Zinc acetate, nickel nitrate, sodium hydroxide and poly (vinyl pyrrolidone) (PVP) were mixed together and transferred to a 100 ml Teflon-lined stainless steel autoclave which kept at 150 °C for 24 h. The morphology and microstructure were determined by field emission scanning electron microscopy (FE-SEM), X-ray diffraction transmission electron microscopy (TEM), energy-dispersive X-ray spectroscopy (EDX) and photoluminescence (PL) spectroscopy. The investigation confirmed that the products were of the wurtzite structure of ZnO. The doped hexagonal nanodiscs have edge length 30 nm and thickness of 45 nm. EDX result showed that the amount of Ni in the product is about 12%. Photoluminescence of these doped hexagonal nanodiscs exhibits a blue shift and weak ultraviolet (UV) emission peak, compared with pure ZnO, which may be induced by the Ni-doping. The growth mechanism of the doped hexagonal nanodiscs was also discussed.

1. Introduction

Synthesis of size and shape controlled metal oxide nanostructures is very important in controlling their physical and chemical properties, and crucial for their potential uses. Recently, considering the properties of the materials are greatly affected by their morphologies, wide range of metal oxide with different morphologies providing great opportunities for the discovery of new properties and potential uses have been synthesized via different methods. Among these methods, hydrothermal approach [1,2] has great advantages in synthesizing metal oxide crystals through relative low temperature and simple equipment, which makes the method more suitable and economic for large-scale production. In order to control the morphology of ZnO crystals, organic additives: such as PVP, PEG, SDS and CTAB [3–5], were commonly introduced into the reaction system to manipulate the nucleation and growth in hydrothermal reactions. However, it still remains a challenge to understand their precise working mechanism in directing the growth of ZnO.

As an important II–VI semiconductor, ZnO has a wide band gap (3.37 eV) and large exciton binding energy of 60 meV [6]. Therefore, it is a promising material for the fabrication of optoelectronic devices operating in the blue and ultraviolet (UV) region [7]. Moreover, due to its superior conducting properties, ZnO has also been investigated as a transparent conducting and piezoelectric material for use as electrodes, catalysts and sensors [8]. Recently, various doped ZnO nanostructures with different elements have been achieved to improve the electrical, optical and magnetic properties [9].

Nanosized nickel oxide has demonstrated excellent properties such as catalytic [10], magnetic [11], electrochromic [12], optical and electrochemical properties [13]. Furthermore, nickel oxides can be used as a transparent p-type semiconducting layer [14] and are being studied for applications in smart windows, electrochemical supercapacitors [15] and dye sensitized photocathodes [16].

The aim of the present contribution is the investigation of structures and optical properties of Ni-doped ZnO hexagonal nanodiscs, which is very important for both fundamental and applied points of view.

2. Experimental work

For the synthesis of Ni doped ZnO nanopowders, analytical grade zinc acetate dehydrate [$Zn(O_2CCH_3)_2(H_2O)_2$], nickel nitrate [$Ni(NO_3)_3{\cdot}6H_2O$], sodium hydroxide (NaOH) and poly vinyl alcohol (PVA) were used. All the reagents were used as received (Fluka and Aldrich) without further purification. In a typical reaction process for the growth of hexagonal nano-discs Ni doped ZnO, 1.975 g zinc acetate dehydrate, 0.305 g of nickel nitrate and 3.0 g of PVP were dissolved in 100 ml deionized water and stirred for 30 min. Simultaneously, a 10 ml NaOH (10 M) was added drop wise into this aqueous zinc acetates, nickel nitrate and PVP solution under vigorous stirring. During the addition of NaOH into aqueous solution, the solution was heated at 80 °C to avoid the immediate precipitation of zinc and nickel ions. At last, the final solution was transferred into a 100 ml Teflon-lined stainless steel autoclave. The autoclave was sealed and maintained at 150 °C for 24 h, and then allowed to cool to room temperature naturally. After terminating the reaction in desired

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