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Short communication

Tailoring ZnO nanostructures by spray pyrolysis and thermal annealing

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Abstract

We report a novel synthesis of ZnO nanorods with hexagonal pyramid-like heads by a simple and low cost technique of spray pyrolysis with the help of zinc acetate and tin (IV) chloride pentahydrate precursors. In the present study, the growth of ZnO nanorods is optimized by varying a number of sprays and annealing temperatures in the synthesis process. FESEM analysis reveals that ZnO nanorods are observed when the number of sprays exceeds 150 and film-like structure is observed below 150 sprays. Nanorods are formed when the molar ratio of zinc acetate to tin (IV) chloride pentahydrate in the solution mixture is 3:1. The optimum annealed temperature for the growth of nanorods is determined to be 350 °C. The length and diameter of the vertically aligned nanorods are in the range of 1–3 μm and 80 nm, respectively. XRD diffraction patterns and HRTEM analysis confirm that the ZnO nanorods are single crystals with a preferred growth direction of [0 0 0 1]. The effect of various growth parameters including molar ratio of zinc acetate to tin (IV) chloride pentahydrate in the mixture, number of sprays and annealing temperatures on the growth of ZnO nanorods are systematically studied. A plausible growth mechanism for hexagonal pyramidal heads of ZnO nanorods is discussed. These ZnO nanorods with hexagonal pyramid tips have potential application in photovoltaic devices.

Keywords: Nanorod; ZnO; Spray pyrolysis; Thermal annealing; Structural properties

1. Introduction

Zinc oxide (ZnO) is a technologically and fundamentally important material with a direct band gap in the near UV region (E_g ~ 3.37 eV at 300 K) [1], high electron mobility and large exciton binding energy (~60 meV) at room temperature [2]. Hence, ZnO exhibits interesting properties such as electro-optic [3], piezoelectric [4], electromechanical and magnetic [5,6]. Due to their interesting properties, a variety of ZnO nanostructures including nanowires [7], nanobelts [8], nanorods [9], nanofibers [10] and nanotubes [11] have been developed. Among these, ZnO nanorods or nanowires are being considered for applications in gas sensors [12], dye-sensitized solar cells [13], light emitting diodes [14], water splitting [15], piezoelectric energy harvesting [16] and photocatalysts [17]. Further, it is used for bio-applications including bio imaging and cancer detection due to being an environmentally friendly material [18].

Given the high technological potential of ZnO, several growth methods have been investigated for their fabrication. Among these, solution-based processes such as spray pyrolysis and hydrothermal growth have the technological benefits of low cost, high-yield and ease of scaling up [19]. Since solution-grown ZnO nanorods show relatively poor crystallinity and high defect structure, post-annealing is commonly required to optimize the nanorod performance [20]. Over the past few years, ZnO nanorods have been typically achieved using different synthetic routes developed by two-step fabrication processes [9,21–24]. Prior to the synthesis of ZnO nanorod, a ZnO seed layer is deposited by different methods such as dip- or spin-coating, spray pyrolysis and sputtering. Small grains in the seed layer act as centers of nucleation and induce an aligned growth of ZnO nanorods [25].

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