Optical and field emission properties of single-crystalline aligned ZnO nanorods grown on aluminium substrate

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Abstract
Optical and field emission (FE) properties of aligned single-crystalline ZnO nanorods, grown on aluminium substrate at 550 °C by the non-catalytic thermal evaporation process, have been examined. Raman-scattering and room-temperature PL spectra exhibit a strong and sharp optical phonon E₂ mode at 437 cm⁻¹ and a strong ultraviolet emission at 381 nm, respectively. The FE characterization shows that a turn-on field for the vertically aligned nanorods was 5.8 V μm⁻¹ and the emission current density reached to 0.061 mA cm⁻² at an applied electrical field of 9.0 V μm⁻¹ and shows no saturation. The field enhancement factor β was estimated, from the F-N plot, to be about ~2.081 x 10⁹.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Field emission (FE), one of the most fascinating properties of 1D nanostructured materials for practical application in vacuum microelectronic devices such as FE displays, x-ray sources and microwaves devices, has been studied extensively in the past few decades [1–3]. Since the last decade, carbon-based materials, especially carbon nanotubes, have been used as a promising material for field emitters due to their high mechanical stability, good conductivity, low turn-on field and large emission currents [1, 2]. Importantly, it was seen that compared with CNTs, metal oxide nanostructure emitters are more stable in harsh environments and have controllable electrical properties [3]. Among the various metal oxide nanostructures, the nanostructures of zinc oxide (ZnO) present themselves as a promising material for the fabrication of effective nanodevices due to its exceptional properties. The properties of ZnO include its wide band gap (3.37 eV), high exciton binding energy (60 meV) at room temperature, negative electron affinity, high mechanical strength and chemical and thermal stability. Hitherto, a variety of ZnO nano- and microstructures have been synthesized using various fabrication techniques and their optical and FE properties have been checked and demonstrated in the literature [4–13]. It was observed that morphologies and density and alignment of the nanostructures have a strong influence on the FE and optical properties of nanostructures [5(a)]. Among the various kinds of ZnO nanostructures, the 1D nanostructures of ZnO are of particular interest for producing good FE properties. Han et al. grew aligned ZnO nanowires at 600 °C by thermal evaporation and observed a suppressed green emission (that appeared due to structural defects and impurities) in the photoluminescence (PL) spectrum but the FE properties of these nanowires showed the turn-on field of 6.2 V μm⁻¹ [13(a)]. Shen et al. demonstrated the synthesis, FE and optical properties of aligned ZnO nanopencils and nanoballs by the modified thermal evaporation process. They observed a broad green emission in the PL spectra for both the structures, while FE characterizations show the turn-on fields for nanosols and nanoballs are 7.9 V μm⁻¹ and 7.2 V μm⁻¹, respectively [4]. In addition to these, some other reports on the aligned growth, optical and FE properties of ZnO nanostructures are reported.