Electric Field Assisted-Assembly of Perpendicular Oriented ZnO Nanorods on Si Substrate

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ABSTRACT

In this work, we report a new electric-field assisted assembly technique used to vertically-align ZnO nanorods on the Si substrate during their growth. In the assembly process, the forces that induce the alignment are a result of the polarization of the electric field. The synthesis was carried out at near-room temperature (90° C). Novel measurements on these structures show encouraging characteristics for future applications.

The phase purity, composition and morphology of the synthesized products by the assembly method were examined by XRD, TEM, and SEM. Room-temperature micro-Raman spectroscopy was performed to examine the properties of the self-assembly ZnO nanorods on Si substrate structures. Such highly oriented and ordered ZnO nanorods could be beneficial for field emission, solar cells, LEDs and spintronic applications.

Keywords: ZnO nanorod, self-assembly, nanorod arrays, nanowires, silicon

1 INTRODUCTION

ZnO is of importance for fundamental research as well as relevant to industrial and high-technology applications. ZnO can also be considered as an alternative wide band gap semiconductor for photonic devices [1]. ZnO nanorods/nanowires are becoming common building blocks for the next generation electronic devices [2].

In this context, self - assembly and assisted - assembly of nano-architectures has attracted high interest driven by the demands of technology and engineering. The large interest is motivated by necessity in development of new fabrication tools for novel electronic, optoelectronic and magnetic properties for versatile applications in nanotechnology. Chemical and electric field assisted-assembly offer a new opportunity to create heterostructures in multicomponent systems and to manufacture of nanodevices. They include nanorods-based ultra-violet lasers [3], nanosensors [2] and light emitting diodes [4, 5] with higher performances and significantly lower cost in comparison to the traditional lithographic fabrication. Thus, it is important to study the novel fabrication techniques of semiconducting nanorods-nanowires for future applications.

At the same time, from a fundamental point of view, it is crucial to study the structure and assembly of such novel materials to enable tailoring their properties for novel and improved nanodevices fabrication. Efficient manipulation, positioning and alignment of one-dimensional (1-D) ZnO nanowires present key challenges toward the integration of nanostructures with larger scale systems.

The presence of a direct current (DC) electric field during synthesis yields a better organized growth, because nanorods will align with electric-field lines. This behavior can be attributed to the polarizability of 1-D nanorods and the electrophoretic effect [6].

ZnO nanoarchitectures can be assembled on different types of substrates (e.g. glass, silicon, sapphire) by patterning the seed or catalyst layer, and usually the ZnO nanorods are well-aligned with their *c*-axis perpendicular to the substrate surface [3]. In this respect, typically gold is used to catalyze the growth of nanorods from vapor–liquid–solid (VLS) method and silver is used to facilitate the assembly of ZnO nanorods from solution [7, 8].

In this paper, we demonstrate electric field assisted-assembly of perpendicularly oriented ZnO nanorods on a Si substrate during growth from aqueous solution. We demonstrate the flexibility to order ZnO nanorods on substrates through the strength of the electric field.

2 EXPERIMENTAL

The starting materials, zinc sulfate ($Zn(SO_4)\cdot 7H_2O$, 99.9 % purity) and ammonia NH_4OH (29.6%) were used as received without further purification.

The hydrothermal synthesis of vertically-aligned ZnO nanorod arrays was carried out by dissolving $Zn(SO_4)\cdot 7H_2O$ and ammonia NH_4OH (29.6%) in 20 mL of deionized water (18.2 MΩ·cm). The complex solution was then transferred to a reactor [9]. A DC electric field was applied during growth. The substrates, Si or glass slides were placed in