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MOCVD Growth of ZnO Nanowires Through Colloidal and Sputtered Au Seed Via $Zn[TMHD]_2$ Precursor

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Abstract

Zinc oxide (ZnO) nanowire (NW) arrays were grown on Si (100) substrate by metal-organic chemical vapor deposition (MOCVD) via $Zn[TMHD]_2$ as precursor. Here we adopted two different procedures to grow ZnO NWs namely, colloid and sputtered Au pre-deposition on Si (100) substrate. Comparative studies based on the morphology and growth behavior of ZnO NWs were performed. The grown ZnO NWs were characterized by field-emission scanning electron microscopy (FE-SEM), Atomic Force Microscopy (AFM), Co-focal laser scanning microscopy (CLSM), and Raman spectroscopy.

Keywords: Nanowires; MOCVD; colloidal-solution; Zinc Oxide; $Zn[TMHD]_2$

1. Introduction

Nanotubes, nanorods, and nanowires (NWs) of various semi- conductor materials have drawn much attention in recent years due to their novel physical properties and new promising application in nanodevices [1–4]. A one-dimensional (1D) structure has been demonstrated to be a promising building block in high electron mobility transistors [5], solar cells [6], and biosensors [7]. Among them, ZnO NWs are of great interest due to their wide band-gap, which allows the possibility to tune the optoelectronic devices working from infrared to ultraviolet range. Alignment with high optical quality NW configuration would potentially offer higher performance in nanodevices [8–11]. The high surface-to-volume ratio of

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NWs makes the material properties of NWs extremely sensitive to the diameter. Reducing the NW diameter is an important issue for applications with controllable device performance [12–20]. Various methods have been developed for controlling the NW diameter, which include electron beam lithography (EBL), porous alumina membrane, photolithography, and etching process [21–25].

Alternatives techniques to synthesis of NWs implicate chemical vapour deposition using both halide and metalorganic precursor, and metal catalysis growth via the vapor – solid – liquid (VLS) mechanism [26-30]. According to the VLS growth mechanism, a small eutectic particle acts as a catalyst for decomposing and dissolving the gas phase reaction species, and after super saturation, it precipitates out the precursors to assist NW growth at a lower temperature [31]. The catalyst –assisted ZnO NW growth method is still the most widely exploited approach. On the other hand, some groups have reported the ZnS NWs growth without external catalyst [32-34]. Nevertheless, for commercial device application in the future, fabrication of well-ordered nanostructures with high density is very important because they can be effectually incorporated into devices. In the synthesis of semiconductors NWs, the control of the diameter size is very important, otherwise, if the scale of the materials is much larger than the Bohr radius, the materials will behave similar to the bulk materials, and no quantum confinement effects can be expected [35]. To investigate what controls the NWs growth direction, the information about the NW nucleation is necessary. Therefore, preparation of ZnO NWs array with high alignment has been attracting considerable interest, and various approaches have been developed.

In addition, the well-defined Au colloids could be exploited as catalysts for the growth of ZnO NWs with diameter distributions defined by the droplet catalysts. How to grow uniform, well controlled, and perfectly aligned NW arrays from desired materials is the ultimate goal of NW synthesis. However, in reality, the size of NWs may not be always determined by the size of catalyst. Diffusion kinetics and thermodynamic equilibrium may not be sufficient to predict all the NW epitaxial growth phenomena, such as the automatic formation of a buffer layer beneath NW arrays under certain circumstance.

The present study focuses on both sputtered and colloid Au seed particle and the vapor–liquid–solid (VLS) growth mechanism to performer the ZnO NWs growth by metal organic chemical vapour deposition (MOCVD) on the silicon [100] substrate. MOCVD conditions were determined into a reactor to decomposition of Bis(2,2,6,6-tetramethyl-3,5-heptanedionato)zinc II (Zn $[TMHD]_2$) precursor at priori not yet exploited to grow ZnO nanowires. The design of a heating system to obtain an improved control of the process and to obtain homogenous deposition is presented. Silicon (100) substrates were carried out to a process of cleaning and impregnated with gold seed separate from a colloidal-solution and sputtering process. ZnO nanowires were successfully growth by simple MOCVD technique from ZnO precursor. Field emission scanning electron microscope (FESEM) (JEOL Joel-JSM 6700F) was employed for examination of the morphology and microstructure of grown structures via both sputtered and colloid gold seed. X ray diffraction (XRD) was used to analysis the nanowires crystallinity. Atomic Force Microscopy (AFM) was used for analysis root-mean-square (MRS) surface. Micro-Raman and Confocal Laser Scanning Microscopy (CLSM) measurements were carried out to explore wavelength emission of the nanowires.

2. Experimental

2.1. Seed preparation

Steps by steps all Si (100) substrates were carried out a procedure of cleaning at priori before to depot Au seed; ultrasonically cleaning with acetone and de-ionized water for 5 minutes. After cleaning into isopropyl alcohol by 3 minutes, drying and chemical etching of substrate surface with HF 1 M. To follow of permeated at Poly-lysine in a beaker and drying with N_2. Finally, gold (Au) seed was deposited in