High Aspect-Ratio ZnO Nanowires Based Nanoscale Field Effect Transistors (Nano-FETs)

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High aspect-ratio ZnO nanowires were grown onto the copper foil, in a large-quantity, by non-catalytic thermal evaporation method. The detailed morphological observations revealed that the diameters and lengths of as-grown nanowires are in the range of 60–100 nm and 10–30 μm, respectively exhibiting a very high-aspect ratio. Detailed structural characterizations confirmed that the as-grown nanowires are well crystalline, possesses a wurtzite hexagonal phase and grown along the c-axis direction in preference. The presence of a sharp and strong UV emission at 381 nm in the room temperature photoluminescence (PL) spectrum affirmed that the obtained nanowires have good optical properties. The electrical transport properties of the as-grown nanowires was explored by fabricating the field effect transistors (FETs) using a single ZnO nanowire. From the fabricated single ZnO nanowire based FET, the electron carrier density and field effect mobility were estimated to be \( \sim 6.7 \times 10^{13} \) cm\(^{-2} \) and \( \sim 3.8 \) cm\(^2\)/Vs, respectively.

Keywords:

1. INTRODUCTION

The II–VI semiconductor ZnO presents itself as an exciting material with versatile properties and vast applications.\(^1\)--\(^15\) It is one of the most attractive material for ultraviolet optoelectronic devices and lasers operating at room-temperature due to its unique properties such as direct band gap (3.37 eV), a larger exciton binding energy (60 meV), strong emission and high break down voltage. Owing to its non-centrosymmetric crystal structure, it exhibits the piezoelectric and pyroelectric properties which stimulate itself as a promising material for the fabrication of electromechanical coupled sensors and actuators.\(^8\) Among diverse morphologies of ZnO, the 1D nanostructures are the ideal system for studying the transport process in one-dimensionally confined objects which are not important only to understand the basic prodigy in the low dimensional systems but also for the development of high performance nanodevices. Moreover, the high surface to volume ratio of these nanostructures makes them a promising candidate for the fabrication of novel and efficient nanodevices from electro-optical devices to sensors. Various research groups claimed the successful synthesis of ZnO nanowires but the growth of high aspect-ratio with good properties of these nanowire are still desirable to explore the possibility for their use in the fabrication of efficient nanodevices.\(^1\)--\(^10\) Previously, Geng et al. presented the synthesis of ZnO nanowires on silicon substrate using the mixture of ZnO and graphite powders via thermal evaporation technique at 1200 °C.\(^16\) Banerjee et al. also reported the formation of free-standing ZnO nanowires by thermal evaporation process using the ZnO and graphite powders at 1000–1200 °C.\(^17\) Jo et al. demonstrated the synthesis of ZnO nanowires by thermal evaporation using the Au-coated gold nano particles at 950–1000 °C.\(^18\) Dai et al. also reported the formation of large-scale ZnO nanowires by thermal evaporation of metallic zinc powder in the presence of water at high-temperature of about 1000 °C.\(^19\) In all the above-mentioned results, either high temperature or metal catalysts are required for the growth of ZnO nanowires. Moreover, nanowires are also exhibit deep level emission in room-temperature photoluminescence which is directly related with the structural defects and impurities in the deposited nanowires.

In this paper, a simple, cost effective, non-catalytic and low-temperature method is presented for the growth of single-crystalline high aspect-ratio straight ZnO nanowires in a large quantity. The as-grown nanowires were characterized in terms of their structural, optical and electrical properties. Since, it is important to realize the transport properties of the 1D ZnO nanowires in utilizing them for the construction of high-performance electronic...