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Single crystalline quasi aligned one dimensional P-type Cu_2O nanowire for improving Schottky barrier characteristics

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ABSTRACT

Schottky diodes usually exhibit non-ideal characteristics. The departure from an ideal junction may result from a thick interfacial layer between the semiconductor and metal, or the presence of series resistance from the bulk semiconductor below the depletion region and back side Ohmic contact resistance. In the present work an attempt was made to avoid most of these factors in order to obtain Schottky diode with better characteristics. For such purpose, single crystalline vertically aligned P-type Cu_2O nanowires are deposited on a silicon substrate using solid-vapor technique, without using a catalyst or pre-deposited buffer layers. The structure and morphology of the as-synthesized nanowires are characterized using X-ray diffraction, scanning and transmission electron microscopy. The results showed that the use of $CuCl_2$ is critical for the formation of Cu_2O nanowires. The (I–V) and (C–V) characteristic curves of Au/p-Cu_2O Schottky diode were measured. The results showed that the ideality factor, barrier height and donor state density states equal 1.05, 1.32 eV and 3.65×10^{18} cm^{-3}, respectively.

1. Introduction

Cuprous oxide (Cu_2O) is a P-type semiconductor with a direct band gap of 2.17 eV [1]. It has a unique cuprite structure (a body-centered cubic packing of oxygen atoms with copper atoms occupying one-half of the tetrahedral sites). In recent years, there is a growing interest to synthesize Cu_2O nanostructures [2–6] not only for the development of synthetic strategies, but also for the examination of their sensing, catalytic, electrical, and surface properties. Cu_2O nanostructures have been demonstrated to possess properties useful for applications in gas sensing [7], CO oxidation [8], photocatalysis [9–13], photochemical evolution of H_2 from water [14], photocurrent generation [15,16], and organic synthesis [17,18]. The electrical properties of individual Cu_2O nanowires synthesized under hydrothermal conditions in the presence of poly(2,5-dimethoxyanaline) have also been examined [19]. To construct nanowire devices, the electrical contacts should be scaled accordingly. In such manner, investigation of the transport processes at the nanometer scale is essential for an overall improvement of the device response. In case of low-dimensional systems, the Schottky barrier height depends not only on the work functions of the metal and the semiconductor nanowire, but also on the pinning of the Fermi level by surface states, image force lowering, field penetration and the existence of an interfacial insulating layer [20]. To a good approximation, all of these effects change only the absolute current value via lowering the Schottky barrier. Thus, the fabrication of Schottky nanocontact with the Cu_2O nanowire will further promote an understanding of the device physics and practical applications. In this contribution, Au/p-Cu_2O quasi aligned 1D nanowires Schottky diodes were fabricated and the junction properties were studied.

2. Experimental

2.1. Samples preparation

A schematic drawing of the experimental setup is shown in Fig. 1. Anhydrous $CuCl_2$ powder is chosen as source materials due to its low melting point ($CuCl_2$ 498 °C). One gram of the source powder was then inserted into the bottom of a cylinder one-end sealed quartz tube with a diameter of 12 mm. The aim of this cylinder quartz tube is to concentrate the source vapor, which is critical for the formation of nanowires. Before the growth, this cylinder quartz tube was put into the center area of a horizontal tube furnace with the opening facing the left. Carefully cleaned Si substrates were placed a few centimeters from the source on the left side, inside of the cylinder quartz tube. A carefully calibrated mass flow controller and meter was connected to the left end of the furnace tube. Argon mixed with 5% oxygen was used as the carrying gas with a controlled flow rate of 10 sccm (sccm denotes for standard cubic centimeter per minute). Typically, the temperature of the furnace was raised to 600 °C with a ramping rate of 50 °C/min and cooled down quickly to room temperature after 15 min

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