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Photocurrent of Single Silicon Nanowire synthesized by Thermal Chemical Vapor Deposition

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1. Introduction

The synthesis of nanostructured semiconducting materials has become one of important research issues since a notable discovery of graphitic nanotubes[1]. Among the several issues, research of the one-dimensional silicon (Si) nanowires has progress rapidly. Recently, many researchers have studied the synthesis of silicon nanowires and Si based nanodevices [2, 3, 4]. Photoconduction has been investigated by many research groups for various type of nanowires[5]. But photoconduction of silicon nanowires has not researched yet by other laboratories.

In this study, silicon nanowires were first synthesized by thermal chemical vapor deposition (Thermal CVD), and then current–voltage (I–V) characteristics, photoresponses of the single nanowire were investigated. Finally, the photoconduction mechanism is discussed in this letter.

2. General Instructions

Silicon nanowires have been grown by thermal CVD using silicon monoxide powders under controlled conditions without the catalyst. For the synthesis of Si nanowires, Al_2O_3 substrates were used. High-purity Si monoxide powders with a particle size of -325 mesh were employed as the starting material in this experiment. Prior to thermal evaporation, Si monoxide powders were ground in a mechanical ball-mill system (SPEX 8000 M) for 20 h. 20 h ball-milled Si monoxide powders were placed at the center of a Al_2O_3 tube. The tube furnace system was heated at 1380 ºC for 1h. During the synthesis of silicon nanowires, flowing a mixture of Ar(95 %) and H_2(5 %) about 500 sccm at a pressure of about 250 torr.

I-V and photoresponses were measured for the Si nanowires in vacuum at room temperature. The light sources for these measurements were the 325 nm wavelength line from a He-Cd laser and the 633 nm wavelength line from a He-Ne laser; the power density of the light was 10 mW/cm^2.

Figure 1 shows the scanning electron microscopy (SEM, HITACHI S-4700) image of silicon nanowires synthesized by thermal chemical vapor deposition. The synthesized Si nanowires were in the range of 50 ~ 100 nm in diameter and in the range of 10~50 μm in length. The Si nanowires were composed of crystalline silicon cores and amorphous SiO_2 shells.

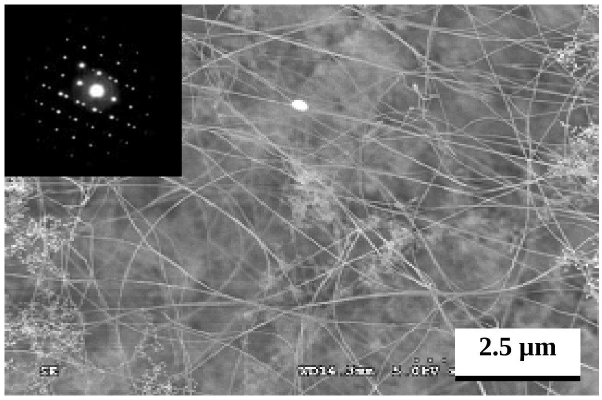

Fig. 1 SEM image of Si nanowires synthesized by thermal CVD. The inset shows their SEAD pattern.

Figure 2 shows the optical microscope image of a single Si nanowire between two Au/Ti electrodes on SiO_2/Si substrate. This nanowire has a length of about 7~8 μm and diameter of about 80 nm. In order to make two electrodes, the oxide sheath was etched out by the HF(4 %) for 90 sec. The Au/Ti electrode pattern was made by photolithography.

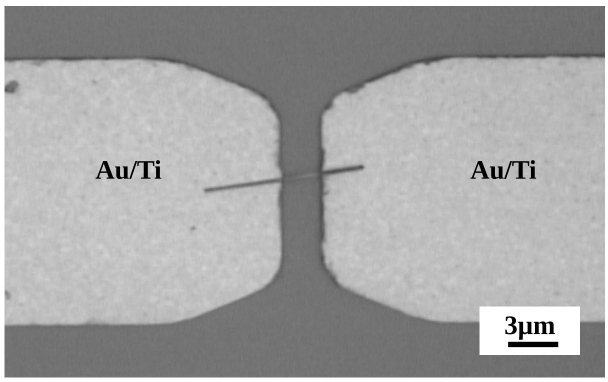

Fig. 2 Optical microscope image of a single Si nanowire between two Ti/Au electrodes on a SiO_2/Si substrate.

Figure 3 shows that I-V characteristic of a single Si nanowire. The I-V curve shown in this in figure is non-linear, indicating an existence of a schottky barrier between the nanowire and the Ti contacts. The current level is symmetric from -15 pA to 15 pA.

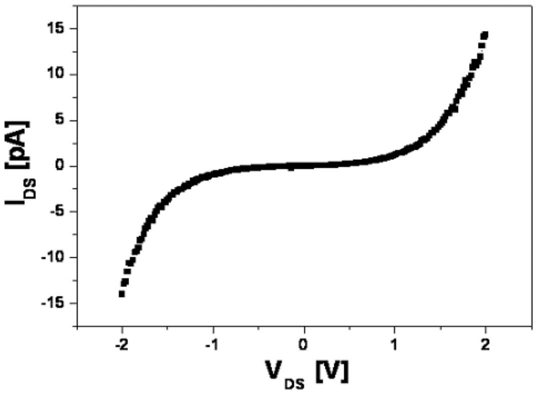

Fig. 3 I-V characteristics of a single Si nanowire.

Figure 4 shows photoresponses of single silicon nanowire under modulated illumination of the 325 nm wavelength light from a He-Cd laser(a) and the 633 nm wavelength light from a He-Ne laser(b). The light was switched on and off per 100 sec in air at room temperature at a bias voltage of 3 V. The intensity of the photoresponse is independent of illumination time. This figure shows that And rise and decay times of the photoresponses are shorter than 1 sec.

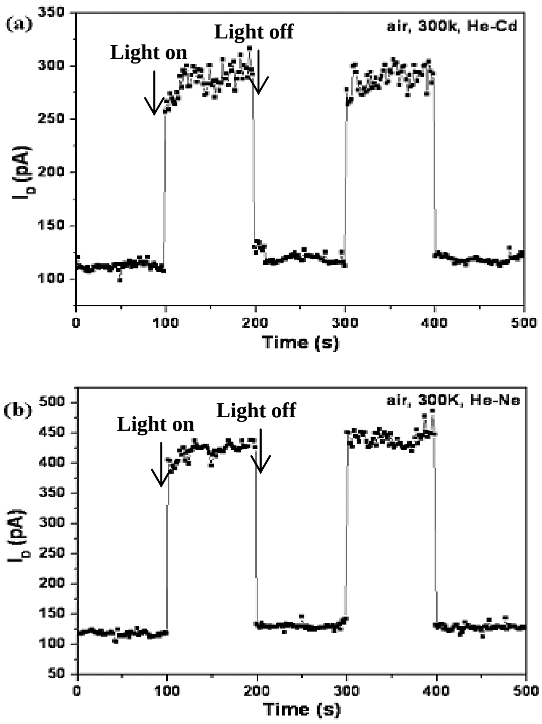

Fig. 4 The time-dependent photocurrents under the illuminations of the 325 nm wavelength light (a) and the 633 nm wavelength light (b); The light was switched on and off per 100 sec in air at room temperature at a bias voltage of 3 V.

3. Conclusions

In summary, Si nanowires have been grown by thermal CVD using the Si monoxide powders under controlled conditions without the catalyst. Two Au/Ti electrode patterns were made by photolithography on a single Si nanowire. The I-V curve is non-linear, indicating an existence of a schottky barrier between the nanowire and the Ti contacts. This single Si nanowire is allowed photoconduction. The intensity of the photoresponse is independent of the illumination time. And rise and decay times of the photoresponses are shorter than 1 sec.

Acknowledgements

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