Fabrication of the α–Fe_2O_3 nanowires and application of the photodetector/optical switching

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ABSTRACT

In this study, we demonstrate a rapid and easy method to synthesis α-Fe_2O_3 nanowires (NWs). The density of the α-Fe_2O_3 NWs were successfully control by different thickness of Fe thin film within 10 hours by thermal oxidation at 350 ^oC in the oven. Iron films with different thicknesses (50 nm and 150 nm) were coated on the indium tin oxide (ITO) glass by direct current (DC) sputtering. In addition, the amount of α-Fe_2O_3 NWs increased with the increase of the film thickness. The photocurrents of the α-Fe_2O_3 NWs were investigated with the illumination of the simulation solar power. Photocurrents were measured between two electrodes (Pt and ITO) when the sample was irradiated without or with the light under a bias. The I-V curves of the various densities of the α-Fe_2O_3 NWs with/without illumination. The higher density of the NWs, the photocurrent was higher with the same bias. Therefore, the on/off ratio would be measured by the high density of the NWs.

Keywords: α-Fe_2O_3 nanowires, photodector

1 INTRODUCTION

Recently, the development of nanowires (NWs) devices, such as field emission displays (FED)[1,2],field effect transistors (FET)[3], light emission diodes (LED)[4], photoswitches[5-7], and gas/photo sensors[5,8], have been studied rapidly. Photodetector is a device which converts light into electricity though the photoelectric effect. The conductivity of photodetector was depended on the illumination light. Under the illumination of light, the electorn-hole pairs were photo-generated. Therefore, the conductivity was increased with the light. With the light-induced conductivity was increased, the NW can reversibly switch between "ON" and "OFF" states. [9,10] In the dark, oxygen molecules adsorb on the surface of NW by capturing free electron from the n-type semiconductor. Upon expose to visible or ultraviolet (UV) light, the electron-hole pairs was photo-generated. The hole migrated to the surface and discharges the adsorbed oxygen ions [11]. Therefore, the photogenerated electrons significantly decrease the response time of the NW. Because of small surface-to-volume, the response time of thin film photodetector was not very fast (1s to few minutes) [12-14].

Hematite (α-Fe_2O_3) is a direct, narrow band gap (E_g=2.1 eV), and n-type semiconductor with the unique magnetic properties[15], stable chemical state[16], and thermal stability. Due to the band gap of 2.1 eV, α-Fe_2O_3 NWs were applied in water splitting [17] and solar cell [18].

In this study, we demonstrate a rapid and easy method to synthesis α-Fe_2O_3 nanowires (NWs). The density of the α-Fe_2O_3 NWs were successfully control by different thickness of Fe thin film within 10 hours by thermal oxidation at 350 ^oC in the oven. Iron films with different thicknesses (50 nm and 150 nm) were coated on the indium tin oxide (ITO) glass by direct current (DC) sputtering. The photocurrents of the α-Fe_2O_3 NWs were investigated with the illumination of the simulation solar power.

2 EXPREIMENTAL

The indium tin oxide (ITO) glasses were used as the substrate for the growth of the α-Fe_2O_3 NWs. The two thin films of iron were deposited on the wafer by the direct current (DC) sputter technology. The Fe was coated 50nm and 150nm, and then placed in an oven. The experiment started with increasing the temperature to 350 ^oC using a ramping rate of 10 ^oC/min and kept for 10 hours. After the process, the surface morphology of the substrate and the crystalline structure of as–grown NWs were observed by field emission scanning electron microscopy (FE–SEM, HITACH S–4800). For the photocurrent properties, the spectroscopic photocurrent of the α-Fe_2O_3 NWs were measured by illumination using a Oriel class a solar simulators (Model: 91160A, 1000W/m^2 and AM1.5G).

3 RESULTS AND DISCUSSION

After the thermal process, the as-product was shown in the Figure 1. In previous study [15], the as-product was α-Fe_2O_3 NWs. Figures 1(a) and 1(b) show the top views of the sample A (50nm) and sample B (150nm), respectively. As can be seen, the amount of α-Fe_2O_3 NWs increased with the increase of the film thickness. It can be seen that the thicknesses of the 50 nm and 150 nm with average density of 7.8×10^8 cm^{-2}/NWs and 1.83×10^9 cm^{-2}/NWs.

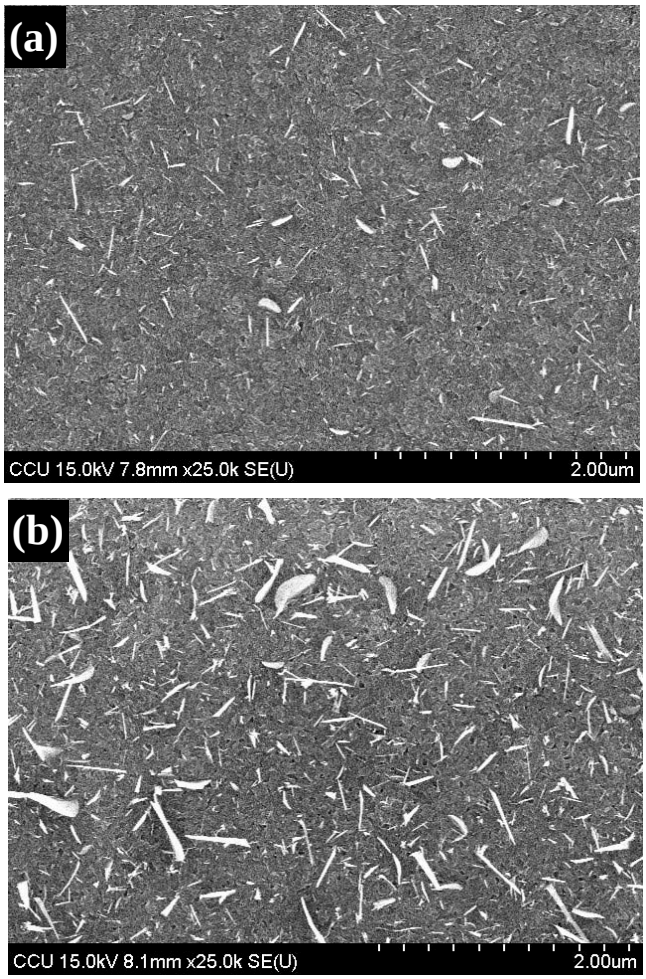

Figure 1. FE-SEM images of the α-Fe_2O_3 NWs grown from (a) 50nm and (b) 150nm iron films.

In order to measure the photocurrent properties of the NWs, Figure 2 shows the illustration of photocurrent measurements setup. The photoresist (PR) was spin coated on the as–grown NWs. The NWs were embedded in PR and only the tips of the NWs were exposed. A 20nm Pt thin film was then sputtered on the surface of the PR as an electrode. The simulation solar power would illuminate the ITO face.

Photocurrents were measured between two electrodes when the sample was irradiated without or with the light under a bias. Figure 3(a) shows the I-V curves of the α-Fe_2O_3 NWs with/without the illumination. The voltage was swept from -2 V to 2 V. It was indicated that the conductivity were increased significantly with the amount of the NWs. With the illumination, the conductivity was increased.

Because of the density effect, the on/off ratio will be measured by the high density NWs (Figure 3(b)). The on/off ratio is defined as the photocurrent over the dark current. The NWs device would be measured the current with/without the light in a period of the 60s. As can be seen in Figure 3(b), the photocurrent was not stable in 60s. After the 60s, the current was not decreased to the initial state in the dark. Because of the photocurrent of the each NW was different, the response time was longer than individual nanobridge (NB)[11]. The on/off ratio was 1.42, the value was smaller than NB.

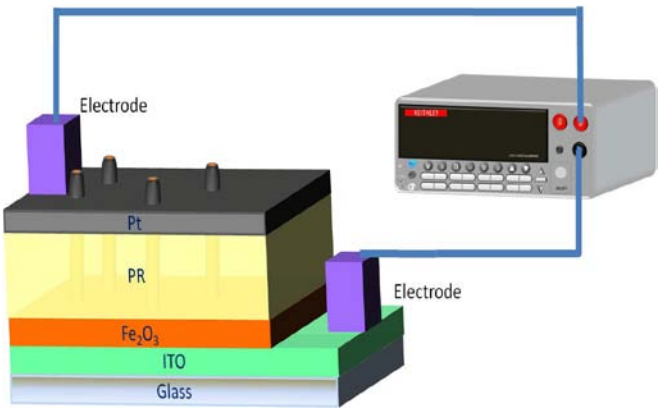

Figure 2. Schematic illustration of photocurrent measurement.

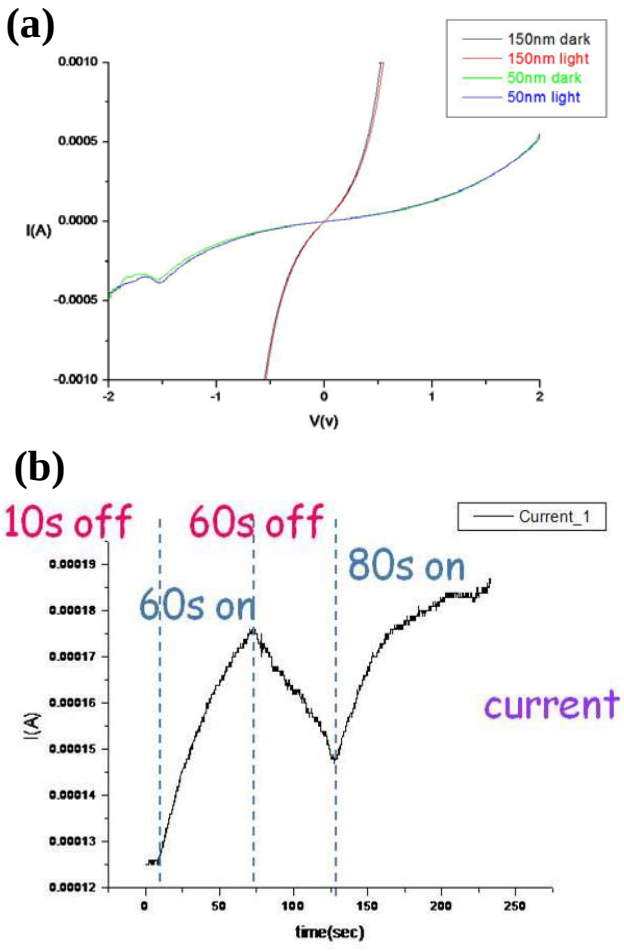

Figure 3 (a) I-V curves of the various densities of the α-Fe_2O_3 NWs with/without illumination, and (b) the on/off ratio of the high density NWs.

4 CONCLUCTIONS

In summary, two densities of the α-Fe_2O_3 NWs were fabricated on the ITO glass by the thermal oxidation. By increasing the iron film thickness, the density could be increased. A simple method to fabricate a photodetector was introduced. The conductivity was increased significantly with the amount of the NWs, the photocurrent would be generated more under the illumination. The response time of the photodector was dominated by the electric transport rate of each α-Fe_2O_3 NWs.

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