Nanowire Sensors

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Abstract

The approach for growing nanowires (NWs) used here was the step-and-grow method, which combines the NW synthesizing and positioning step in an economic and safe way [1]. Template molds containing growth-controlling nanochannels were created with polydimethylsiloxane (PDMS) by using a master mold and placed over electrodes pre-positioned on a substrate. Polyaniline (PANI) NWs were then synthesized electrochemically in growth channels positioned between a biased anode and grounded cathode electrodes. The template molds could be stepped and the process repeated. After the synthesis of PANI NWs, they were tested for their sensitivity to humidity as a function of their surface to volume ratio. PANI NWs (110 nm) showed a linear response to humidity and could potentially function as a humidity sensor.

Introduction

Nanowires possess a high surface to volume ratio. This makes them excellent candidates for sensing applications, since a high surface to volume ratio improves detection sensitivity and response time due to more reaction area per volume and reduced diffusion time [2,3]. Most current approaches to growing nanowires require a synthesizing step, as well as a positioning step [4-6]. The overall approach for growth of the nanowires used here for sensing is the step-and-grow method, a novel approach that combines the two steps and eliminates the production of excess nanostructures [1].

Experimental Procedure

The first step was to create PDMS template molds using a previously created master mold. The master mold was made from a silicon wafer coated with 1 μm silicon dioxide, and was a positive image in relationship to the nanochannels, which would be created in the template mold. The template molds were created by spinning h-PDMS onto the master mold, curing at 65°C for 30 minutes, and adding s-PDMS mixture. They were then placed under vacuum, followed by a cure at 65°C for 3 hours. The template molds were then separated from the master molds and cut into rectangular slices with nanochannels located in the center of each piece.

The creation of the substrate began with patterning the electrodes onto a 2000Å silicon oxide coated Si wafer. The top surface of silicon oxide contained trenches patterned by dry etching and filled with platinum, with a titanium adhesion layer, deposited level with between the surface of the wafer.

In the synthesis of nanowires, the PDMS template molds were laid across the surface of the electrodes. An aniline monomer solution was then introduced to the opening of the nanochannels. 1V was applied to the anode by HP 4284a. PANI started to grow from the anode and filled the nanochannels until it reached to the grounded cathode. After carefully removing the PDMS template from the electrodes, PANI NWs are characterized by field emission scanning electron microscope (FESEM) and atomic force microscope (AFM). Figure 1 shows FESEM image of 111.6 nm PANI NW, and Figure 2 shows AFM image of the surface of PANI NW. Finally, PANI NW was tested for sensitivity to humidity, the results of which can be seen in Figure 3.

Results and Conclusions

Nanowire synthesis using the step-and-grow method is effective for synthesizing and positioning nanowires in a potentially economic manner. The PANI NWs were responsive to humidity and could potentially function as a humidity sensor.

Future Work

The step-and-grow approach can be used for synthesizing nanowires of many different materials. This opens up the opportunity for different types of nanowire sensors, as well as nanowire array structures.

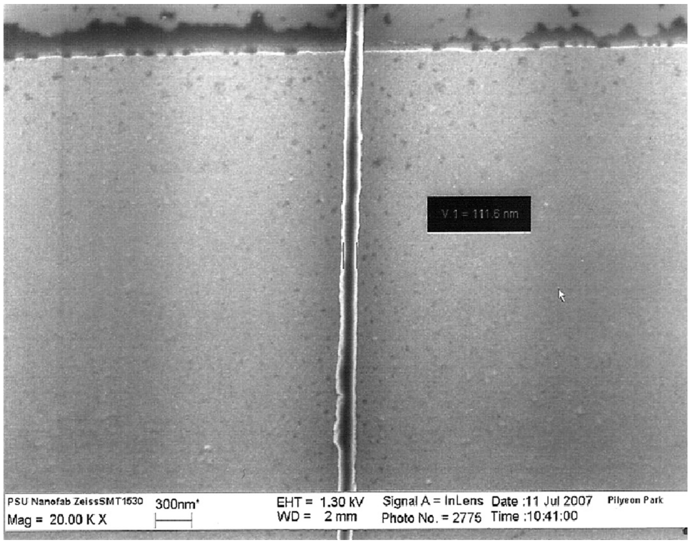

Figure 1: FESEM image of 111.6 nm polyaniline nanowire at 20.00 K X.

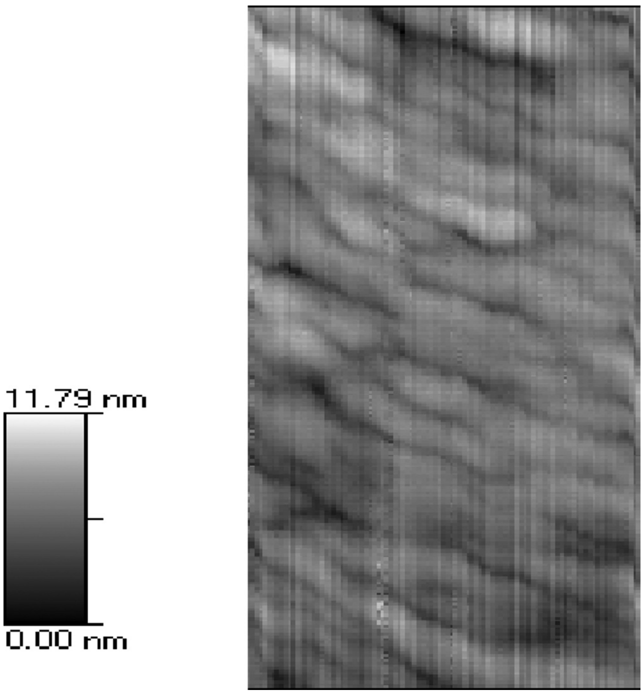

Figure 2: AFM image of polyaniline nanowire topology.

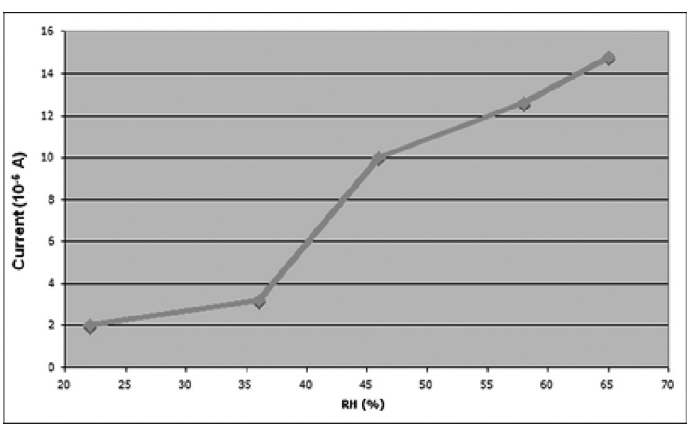

Figure 3: Relative humidity versus current when I V of electrical bias was applied to the device.

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References

[1] Nam, W. J, Carrion, H., Park, P., Garg, P., Joshi, S., Fonash, S. J., Proceedings of the 2007 International Manufacturing Science And Engineering Conference, 2007, Atlanta, Georgia, USA.

[2] J. Huang, S. Virji, B. H. Weiller, and R. B. Kaner, Chem. Eur. J. 10, 1314 (2004).

[3] D. Xie, Y. Jiang, W. Pan, D. Li, Z. Wu, and Y. Li, Sens. Actuators B, 81, 158 (2002).

[4] L. Roschier, J. Pentilla, M. Martin, P. Hakonen, M. Paalanen, U. Tapper, E. I. Kauppinen, C. Journet, and P. Bernier, Appl. Phys. Lett. 75, 728 (1999).

[5] Y. Huang, X. Duan, Q. Wei, and C. M. Lieber, Science, 291, 630 (2001).

[6] P.A. Smith, C.D. Nordquist, T. N. Jackson, T. S. Mayer, B. R. Martin, J. Mbindyo, and T. E. Mallouk, Appl. Phys. Lett. 77, 1399 (2000).