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Poly Crystalline Silicon Nanowire Field-Effect Transistor for Real-Time Detection of Influenza Virus DNA

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1. Introduction

The applications of semiconductor nanodevice of nanowire field-effect transistor (FET) in life sciences have attracted a lot of attention [1-4]. However, the main drawback for using NW FET is the availability of the device due to difficulty in the manufacture process for its biological application. We have established a novel fabrication procedure for the preparation of poly crystalline silicon nanowire field-effect transistor (poly-SiNW FET) that can be fabricated by top down semiconductor process in a general silicon wafer for biosensing application [5-10]. Here, a real-time detection of 100 fM avian influenza H5 virus DNA using complementary captured DNA probe modified poly-SiNW FET was demonstrated. The result indicated that the poly-SiNW FET could be developed to a simple, quick, and high sensitive biosensor for diagnosis application.

2. Device performance

Schematic diagram and SEM/TEM images of the poly-SiNW FET are shown in Figs. 1 and 2, respectively. Typical characteristics of the poly-Si NW FET at room temperature are shown in Fig. 3. The I_D-V_G output characteristics with the constant V_D=0.5V exhibited excellent semiconductor FET characteristics, illustrating n-type behavior.

3. Micro-fluidic channel

A solidification PDMS micro-fluidic device to cover the NW sensing area was developed as shown in Fig.3. A mechanical gear was designed which uses a limpid blanket of acrylic to compress the PDMS structure and to make it stick to the wafer surface. Four screws are used to adjust the position of acrylics. Backside of the wafer contacts with a stainless steel, allowing a bias applied to the substrate serving as a back gate of the NW devices. Such active mode of measurements increases the feasibility of the testing, since the gate bias could be adjusted in the subthreshold region of the transfer characteristics of the NW device, so that the test device is most sensitive to the testing environment. The micro-fluidic system provided on chip easy alignment and control of the back-gate voltage, and it also prevented the liquid sample from vaporization even the volume was less than 10 μl.

4. Poly-SiNW FET response to variation of pH

Sensing of solution pH by single crystalline silicon nanowire FET has been previously reported [1]. The response of poly-SiNW FET to the variation of pH was first shown in Fig. 5. The poly-SiNW FET was modified with 3-aminopropopyltriethoxysilane (APTES) to increase its sensitivity to the variation of pH. The results indicated that, despite its cheap and easy fabrication process, poly-SiNW FET was comparable with single crystalline silicon nanowire FET as a pH sensor.

5. Electric responses from specific DNA/DNA interactions on poly-SiNW FET

Rapid diagnosis of influenza is critical for improvements in disease management and reduction of the impact of an influenza pandemic. Here, we demonstrated real-time, highly specific and sensitive biosensing of DNA/DNA interactions with functionalized poly-SiNW. DNA probes of H5 (Fig 6) were immobilized on the surface of poly-SiNW FET according procedures described in Fig. 7. The electric response of the functionalized poly-SiNW FET) were shown in Fig. 8. Decrease of drain current (expressed as conductance) was observed only when H5 complementary DNA_{target} (100fM) was introduced. The drain current remained unchanged in PBS buffer and in the presence of non-complementary DNA_{target} (H7) indicated that the change of electric property of poly-SiNW FET was specific and stable in the presence non-interacting charged molecules, which may exist in a variety of biological samples.

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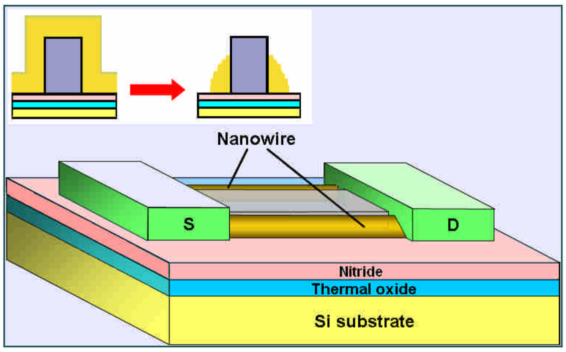

Figure 1. Side view of the poly-SiNW FET device. The inset shows that the etch step to produce the nanowire.

(a) (b)

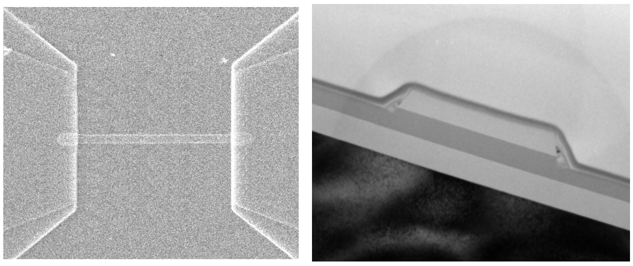

Figure 2. (a) SEM top view image of a parallel array of NW devices. (b)TEM side view image of the device.

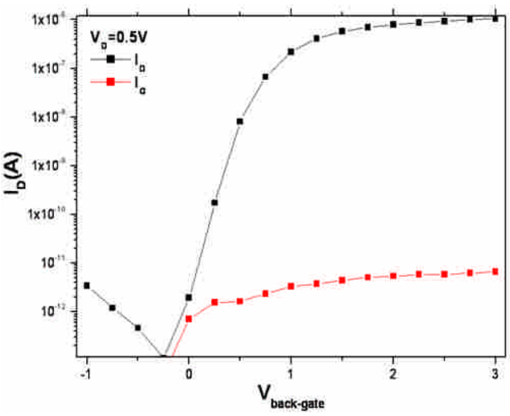

Figure 3. ID-VG curve illustrating n-type behavior of the poly-Si NW FET.

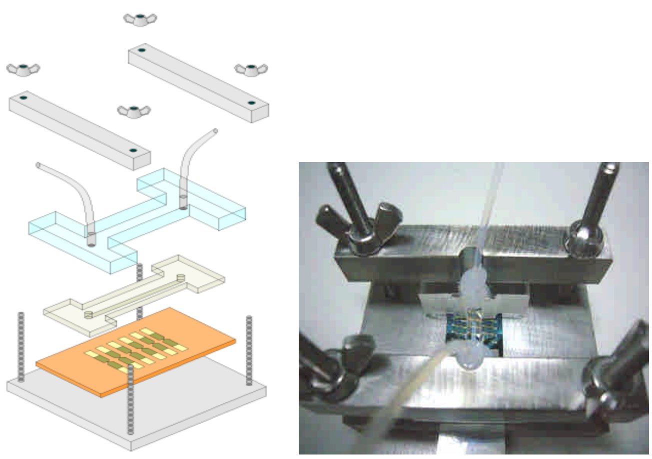

Figure 4. Picture of micro fluidic channel for the biosensing with poly-SiNW FET.

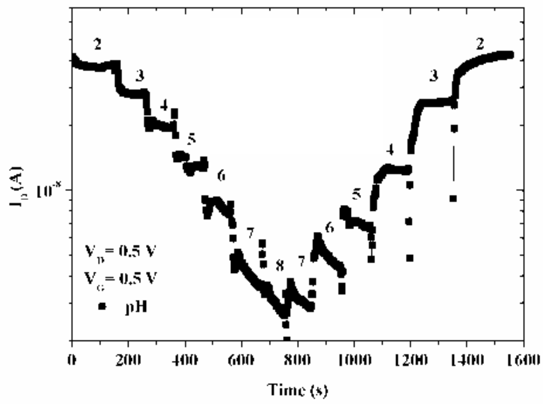

Figure 5. Real-time response of the drain current (I_D) for APTES modified poly-SiNW FET at different pH (10 mM PBS buffer).

DNA sequences (5'-3')		
	5'-H_2N C_6 modified captured DNA probe	Target DNA
H5N1	CAA ATC TGC ATT GGT TAT CA	TGA TAA CCA ATG CAG ATT TG
H7N1	CAA ATT GAC CCA GTC AAA TTG AGT A	TAC TCA ATT TGA CTG GGT CAA TTT G

Figure 6. Synthetic oligonucleotides of H5N1 and H7N1 probes and targets .

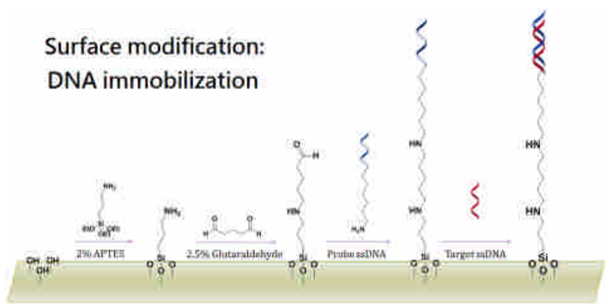

Figure7. Schematic diagram of DNA probe immobilization.

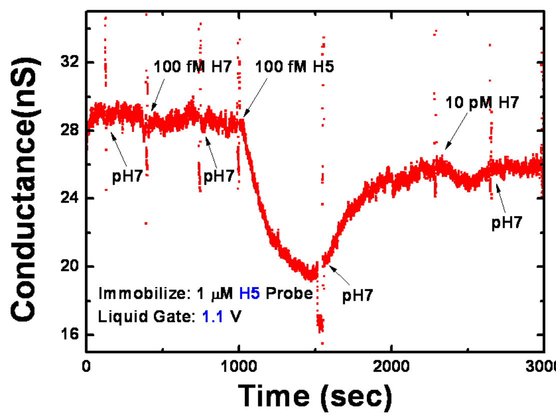

Figure 8. Real-time electric response of H5 functionalized poly-SiNW FET device following addition of pH 7 buffer, $H7_{target}$ and $H5_{target}$.