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G-8-3

Direct Ultrasensitive DNA Sensors Based on Carbon Nanotube Field-Effect Transistors

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1. Introduction

Recently, high-sensitive detections of DNA hybridization have attracted great attention to a lot of fields such as genomics, clinical diagnosis, practical pharmacy, and so forth. Optical detection methods have commonly been used for detections of DNA hybridization, which are highly sensitive and specific methods. However, they need professional knowledge and techniques, and are very difficult to miniaturize. Therefore, alternative methods have been required, which are suitable to use for medical diagnostics at home.

In this study, DNA hybridization has sensitively been detected using carbon nanotube field-effect transistors (CNTFETs) without any labeling and in real time, as shown in Fig. 1.

2. Experimental

Figure 2 shows a chemical modification scheme of the back gate at CNTFETs. Amino modified peptide nucleic acid (PNA) oligonucleotides at 5′ end were covalently immobilized onto the Au surface of the back gate. A schematic diagram of the micro-flow chip is also shown in Fig. 3, which was developed for the introduction of DNA samples to the CNTFETs.

3. Results and Discussion

Figure 4 shows the drain current-drain bias characteristics at the gate bias of 0 V after target full-complementary DNA introduction with 20 fmol/L at the PNA probe-modified Au back-gate surfaces. The current increased, while monitoring in real time for about 60 min. Figure 5 shows the time dependence of the source-drain current of CNTFETs at the source-drain bias of 1 V and the gate bias of 0 V after the introduction of target full-complementary DNA with 20 fmol/L. The increase in conductance for the *p*-type CNTFET device was consistent with an increase in negative surface charge density associated with binding of negatively charged oligonucleotides at the surfaces. Figure 6 shows a plot for the net source-drain current dependence on target full-complementary DNA concentration. Net source-drain current value was determined as the difference of the source-drain current value measured before DNA introduction and after 60 min of hybridization. The result reveals that amount of net source-drain current linearly increases as a function of DNA concentration. Therefore, full-complementary DNA with concentration as low as 1 fmol/L could be effectively detected with CNTFETs without any labeling and in real time.

4. Conclusions

Ultrasensitive real-time DNA hybridization detection has been performed using CNTFETs functionalized with PNA probes on Au back-gate surfaces of the devices. For 11-mer PNA oligonucletide probe, full-complementary DNA with concentration as low as 1 fmol/L solution could be effectively detected. Our CNTFET-based biochip is a promising candidate for the development of an integrated, high-throughput, multiplexed DNA biosensor for medical, forensic and environmental diagnostics.

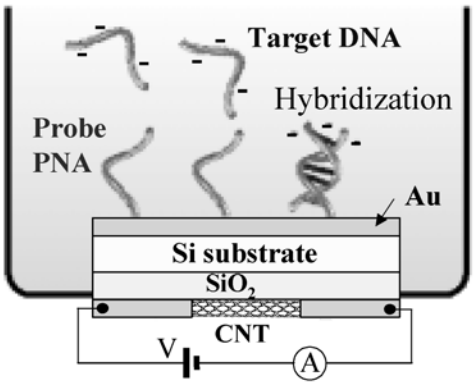

Fig.1. Schematic diagram for the electrical detection of DNA hybridization using CNTFET.

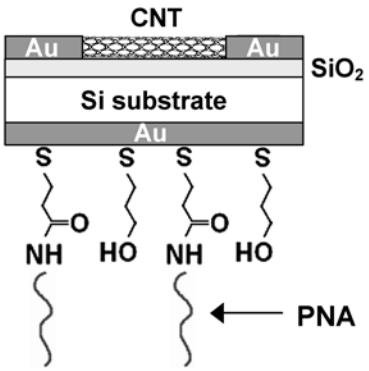

Fig. 2. Chemical modification scheme of the back gate at CNTFETs.

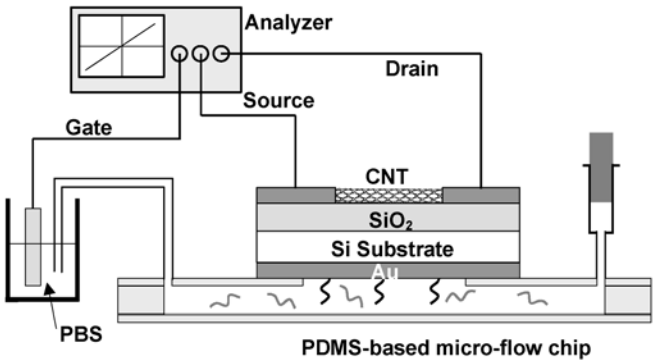

Fig. 3. Schematic diagram for the integration of the micro-flow chip and the electrical detection system.

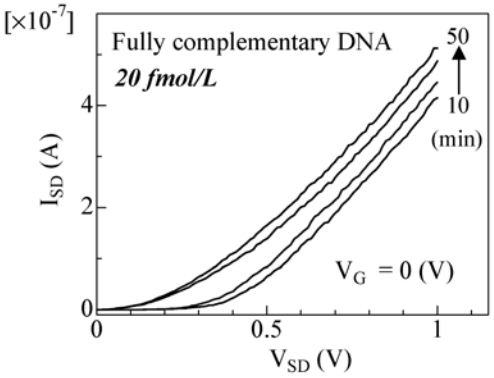

Fig. 4. Drain current - drain bias characteristics after the introduction of full-complementary target DNA at 20 fmol/L.

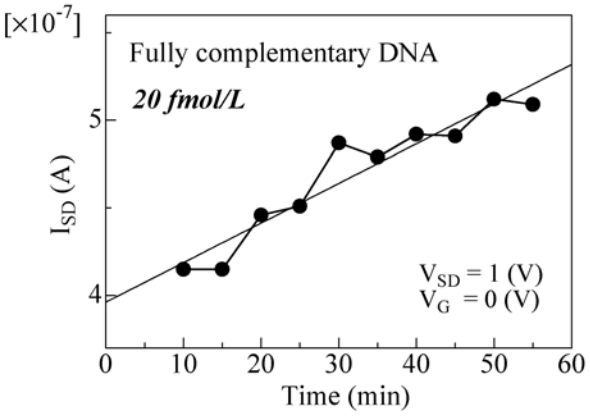

Fig. 5. Time dependence of the source-drain current of CNTFETs at the source-drain bias after the introduction of full-complementary target DNA at 20 fmol/L.

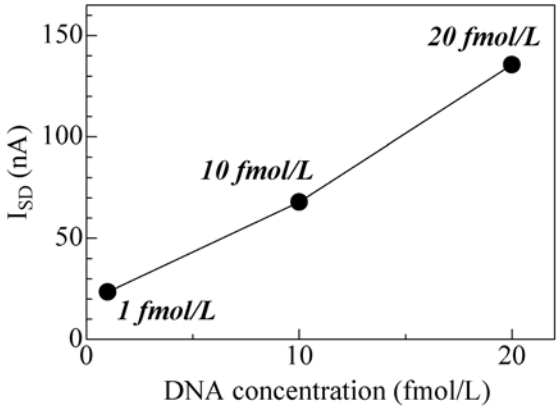

Fig. 6. Plot for the net source-drain current dependence on target DNA concentration.