AN OPTICAL IMMUNOSENSOR USING CARBON NANOTUBE (CNT) COATED WITH PHOTOVOLTAIC POLYMER

Joon S. Shim, Andrew W. Browne and Chong H. Ahn
Microsystems and BioMEMS Laboratory
Department of Electrical and Computer Engineering
University of Cincinnati, Cincinnati, Ohio, 45221 USA

ABSTRACT

An on-chip optical immunosensor using carbon nanotube (CNT) with a photovoltaic polymer coating has been developed, characterized and applied for the detection of a cardiac biomarker in this work. Individual CNT was assembled on titanium (Ti) electrode and coated with a photovoltaic polymer, and then insulated by Parylene. Under an incident light, the photovoltaic polymer generated electrons which changed the conductivity of CNT. On-chip chemiluminescent immunoassay was directly performed on the CNT photodetector for the detection of cardiac biomarker (cTnT) with the concentration of 12 pg/ml.

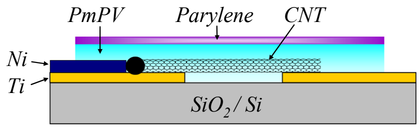
KEYWORDS: Carbon nanotube, Optical immunosensor, CNT biosensor

INTRODUCTION

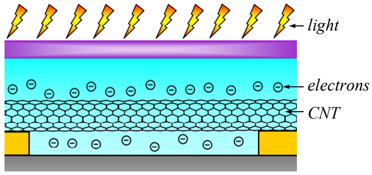
CNTs have been widely used as field effect transistor (FET) biosensors by functionalizing its surface with capture antibodies [1, 2]. In spite of extremely high sensitivity of this type of biosensor, its specificity is very low because the electrical property of CNT is also affected by surrounding ions or non-specifically bound proteins [3]. So, there has been a large demand for the development of new CNT-based immunosensor with better selectivity. In this work, the CNT coated with a photovoltaic polymer has been fabricated and characterized as a new immunosensor using chemiluminescence optical detection. Since the signal transmitted optically, a high specificity as well as sensitivity was achieved, which is very desirable for the point-of-care (POC) clinical diagnostics of protein biomarkers from whole blood.

PRINCIPLE

Due to the extremely large surface-to-volume ratio, the CNT FET responds to surrounding media with a high sensitivity. When the CNT is coated with the photovoltaic polymer, the photovoltaic polymer generates electric dipoles under the incident light as described in Figure 1. In these dipoles, the holes are injected



(a) CNT Field Effect Transistor (FET) with PmPV coating and Parylene insulation



(b) Charge generation in photovoltaic polymer under light irradiation

Figure 1. Schematic illustrations of CNT photodetector and its principle.

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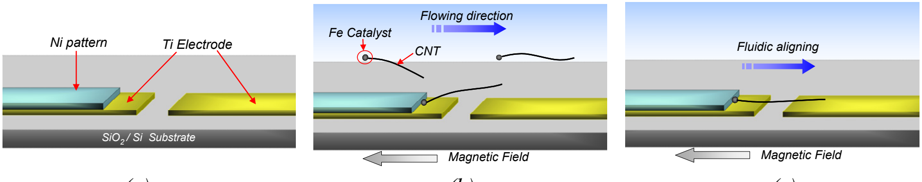


(a) *(b)* *(c)*

Figure 2: Microfluidic self-assembly procedure of CNT. (a) Self-aligned Ni pattern on Ti electrode fabricated by CUM, (b) Magnetic capturing Fe catalyst at the end of SWNT and (c) Fluidic alignment of CNT parallel to flow direction.

into the CNT by the alignment of valence band between the CNT and the photovoltaic polymer [4]. As a result, the surrounded electrons provide a gate potential, changing the electrical response of CNTFET.

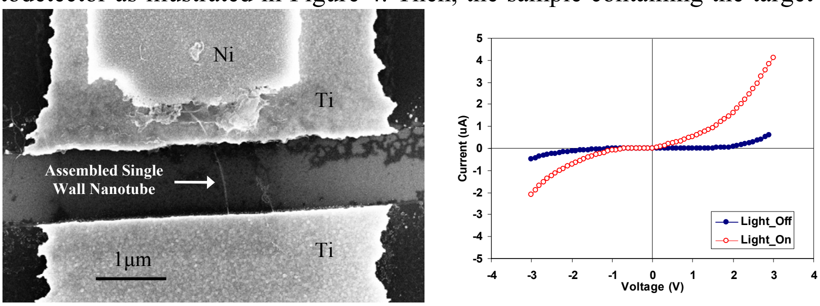
FABRICATION

A self-aligned nickel (Ni) and titanium (Ti) electrode with nano gap was fabricated by optical lithography with the technique of controlled undercut and metallization (CUM) [5]. On the fabricated electrode, individual CNTs were microfluidically assembled by magnetically capturing an iron (Fe) catalyst at the end of the CNT as depicted in Figure 2 [6]. The assembled nanotubes were coated with poly{(mphenylenevinylene)-co-[(2,5-dioctyloxy-p-phenylene)vinylene]} (PmPV) by drop-casting 1 µl of PmPV solution (1 wt% in chloroform ($CHCl_3$)) [4]. After drying the $CHCl_3$, 200 nm thick parylene film was deposited on the PmPV-coated CNT.

Figure 3 (a) shows a SEM image of the individually assembled single-wall carbon nanotube (SWNT) (FirstNano Inc.) on the self-aligned Ni and Ti electrodes with nano scale gap. The PmPV-coated SWNT was electrically characterized as plotted in Figure 3 (b). The SWNTs showed a schottky contact behavior, indicating the assembled SWNT had a semiconducting property. When the light is incident on the fabricated device, the PmPV provides electrons to change the electrical response of the assembled SWNT. The fabricated device showed a fast and stable optical performance for the irradiated light on the device.

EXPERIMENTAL

For the detection of cardiac Troponin-T (cTnT) protein, the capture antibody was functionalized inside the microchannel attached on the parylene-insulated CNT photodetector as illustrated in Figure 4. Then, the sample containing the target anti-



(a) *(b)*

Figure 3. Assembled SWNT: (a) SEM image and (b) I-V curve under the incident light

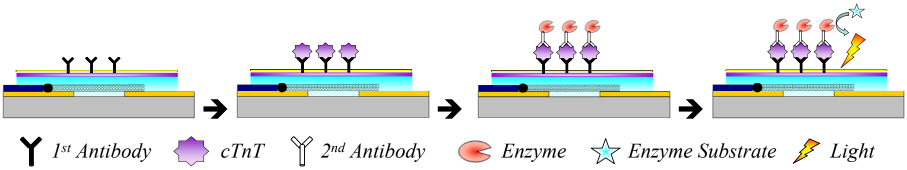
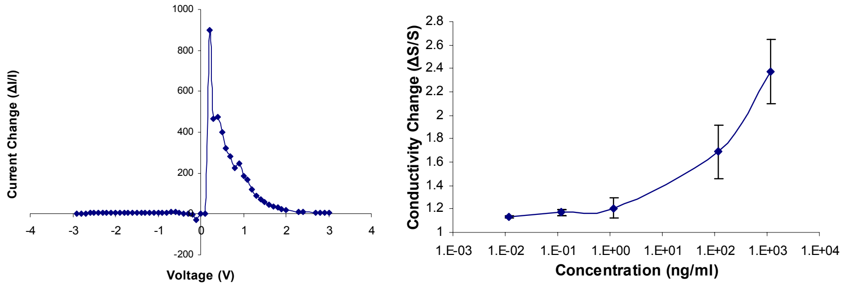


Figure 4. Sequences for on-chip chemiluminescent immunoassay with CNT photodetector

gen was applied, then followed by solutions of the HRP conjugated secondary antibody and the HRP substrate. Between each step, DI water was used as a buffer solution to remove non-immobilized proteins. While the different concentrations of cTnT were tested, the intensity of chemiluminescent light was measured by the fabricated device.

To reduce the loss of chemiluminescent light, the immunoassay was directly performed on the CNT photodetector. Also, drain-source voltage (V_{ds}) was characterized to increase the signal change ($\Delta I/I = (I_{on} - I_{off})/I_{off}$) from the device as plotted in Figure 5 (a). Considering signal conditioning, 0.5 V of V_{ds} was selected to maximize the output signal. Under these configurations, 12 pg/ml of cTnT has been successfully detected by the fabricated device as shown in Figure 5 (b).



(a) *(b)*

Figure 5. (a) Characterization of V_{ds} for maximum output and (b) conductivity change of photovoltaic polymer coated SWNT according to the concentration of cTnT

CONCLUSIONS

In this work, a highly sensitive and selective optical biosensor was developed using the photovoltaic polymer coated CNT and successfully detected 12 pg/ml of cTnT. The fabricated device was electrically insulated by the parylene and directly contacted to the site of chemiluminescent assay, which reduces electrical noise and light scattering through the substrate. This biosensor can be applied to low-cost POCT devices achieving highly specific and sensitive optical detection.

REFERENCES

[1] S. N. Kim et al., *Adv. Mater.*, 19, 3214 (2007).
[2] G. Gruner, *Anal. Bioanal. Chem.*, 384, 322, (2006).
[3] A. Star et al., *Nano Lett.*, 3, 459 (2003).
[4] D. W. Steuerman et al., *J. Phys. Chem. B*, 106, 3124 (2002).
[5] Joon S. Shim and Chong H. Ahn et al., *NSTI Nanotech* 2009, TX, USA.
[6] Joon S. Shim and Chong H. Ahn et al., *Nanotechnology* (In press) (2009).