Silicon Nanodevices and Their Bio Application

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Introduction

Recent super aging society requires the medical treatment to be of quick response and cost effective. The state-of-the-art silicon nanotechnologies will help to solve these problems. In this paper our current research results concerning silicon nanodevices and their application to bio devices such as cancer sensors and antigen-antibody reaction biosensors are demonstrated.

1. Cancer sensor using silicon radar technology

Because the dielectric constant of cancer cells is different from that of the normal cells, the electromagnetic waves are reflected. Thus the radar technology is applicable to detect the cancer cells when very short pulse is used. We are developing such system using silicon LSI technologies. Figure 1 shows the principle of the cancer detection, where many antennas are arranged and the position of the cancer cells is calculated from the arrival times of the each pulse emitted from the one transmit (TX) antenna to another receive (RX) antenna. Figure 2 shows the sample image detected from the dummy cancer (Al foil chip) [1].

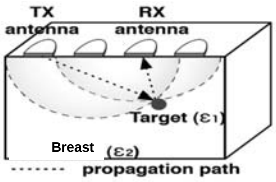

Fig. 1 Structure of the cancer detection system using radar principle.

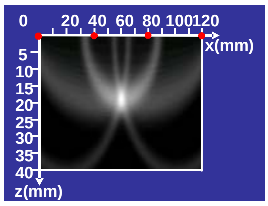

Fig. 2 Example of the detection image of the dummy cancer (Al foil chip).

2. Charged biomaterial sensor using nanowire transistor

Almost of all the biomaterials are electrically charged positively or negatively. Therefore, they are detected by using the high sensitive nanoscale transistors. In order to improve the sensitivity the nanowire transistor (shown in Fig. 3) is used [2]. Figure 4 shows an example for detection of pH of the solution. It is possible to detect a single base of the DNA [3].

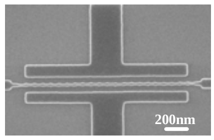

Fig. 3 Scanning electron microscope image of nanowire transistor.

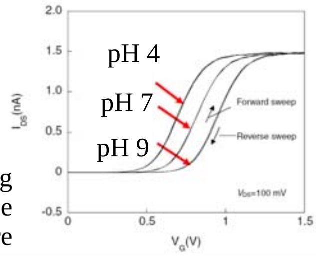

Fig. 4 Electric characteristics of the nanowire transistor at various pH of sample solution.

3. Si optical-ring-resonator biosensor

Biosensing using optical signal is low noise compared with the other methods. The Si ring resonators are very sensitive to the change in the refractive index of the surrounding ambient and compact, which is suitable for the integrated biosensors. Newly developed silicon binding protein binds to Si and aligns the direction of the bio-receptors, therefore enhances the sensitivity (Fig. 5(a), (b)). We have succeeded in high sensitive detection of biomaterials such as D-dimer (Fig. 6), which is used for diagnosis and treatment of thrombotic diseases, prostate specific allergen (PSA), anti-allergen antibody in serum and so on [4,5].

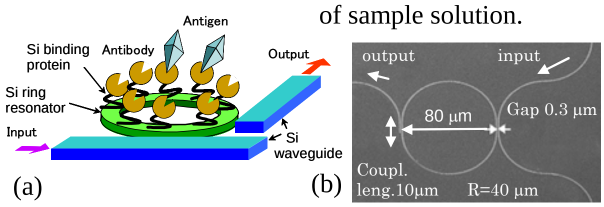

Fig. 5 (a) Schematic of Si ring biosensor and (b) microphotograph.

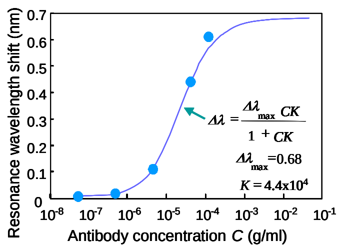

Fig. 6 Resonance-wavelength shift versus antibody (D-dimer) concentration.

References

[1] S. Kubota *et al.*: Jpn. J. Appl. Phys. **48** (2009) 09700. [2] T. Kudo *et al.*: ibid. **48** (2009) 06FJ04. [3] T. Sakata and Y. Miyahara: Biosensors and Bioelectronics: **21** (2005) 827. [4] S. Yamatogi *et al.*: Jpn. J. Appl. Phys. **48** (2009) 04C188. [5] M. Fukuyama *et al.*: ibid. **49** (2010) 04DL09.