論　文　の　要　旨

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論 文 題 目　Research on Two Dimensional Silicon Photonic Resonators for Label Free Detection of Biomaterials
（非標識生体物質検出のための二次元シリコン光共振器の研究）

Early detection as well as identification of biomolecules is very important for the medical diagnosis of many diseases. The mostly used biomaterial detection methods are fluorescence based detection and label-free detection. Fluorescence based detection is quite sensitive and able to detect down to a single molecule and usually use fluorescence tag to identify the target presence. But most complexity is the labeling steps beyond the isolation of target analyses. In contrast, the label free detection performs the detection of biomolecules in their original form also able to easier and cheaper bio detection. In contrast, biosensors such as enzyme-linked immunosorbent assay (ELISA) and surface-plasmon-resonator (SPR), which are already in commercially available label free detection method. However, the advantages of ELISA method need large volume of analytes, expensive and long measurements time. On the other hand the size of SPR is quite large.

Our research focused on Si photonic crystal resonator based biosensor which is compact and highly sensitive because the light of certain frequencies is confined in resonator and takes interaction with biomaterial many times. Thus it has the advantages of being very high sensitive even though the very small volume of analytes.

To confirm our device performance we first used sucrose solution (solution of sugar and water) because of there is no need any extra binding method between device surface and sucrose solution and it is easy to remove them from the device surface. We were able to detect the resonance wavelength shift by changing the sucrose concentration. We reported Q and sensitivity are 10^5 (Q is defined as λ_{res}/FWHM, where λ_{res} is the resonance wavelength and FWHM is full width at half maximum of resonance peak), 1570 nm/RIU

(Refractive Index Unit) (sensitivity is the ration of $\Delta\lambda_{res}/\Delta n$, where $\Delta\lambda_{res}$ is a resonance wavelength shift and Δn is a change in refractive index) respectively.

We also made double nanocavity type photonic crystal resonators where surrounding air hole radius were modulated and we got the highest Q of $\sim 2 \times 10^5$, sensitivity of 1571 nm/RIU (s) and minimum detection limit of $< 10^{-6}$ RIU (detection limit is defined as λ_{res}/QS, where Q is the Quality factor and S is the sensitivity).

To detect prostate specific antigen (PSA) we used a very special feature called Si binding protein (Si-tag) which has been developed by Professor Akio Kuroda, Department of Molecular Biotechnology, Hiroshima University, Japan. Si-tag immobilizes the receptor anaytes on the device surface (on Si / SiO_2) with a same aligned orientation. Due to the receptor analytes, antigen-antibody is attached on the device surface in an aligned manner and light-matter interaction improves more, as results resonant peak shift even though the concentration is very low. We successfully detected PSA concentration as low as 0.01 ng/mL that is twice greater sensitivity than the practical sensitivity (1 ng/mL).

We describe the mechanism and solution for dominating temperature effects on refractive index based Si optical resonator sensor such as ring resonator and photonic crystal resonator sensors. The temperature change affects the silicon refractive index and affects resonator mechanical shape also. As a result, it is reported that the refractive index change is dominating whereas the mechanical deformation effect is negligible. We also demonstrated that the differential operation is effective to suppress the temperature effect for Si ring resonator sensor.