Periodic Structures Consisting of Germanium Nanoparticles in Buried Channel Waveguides

NISHIYAMA Hiroaki and HIRATA Yoshinori
(Graduate School of Engineering)

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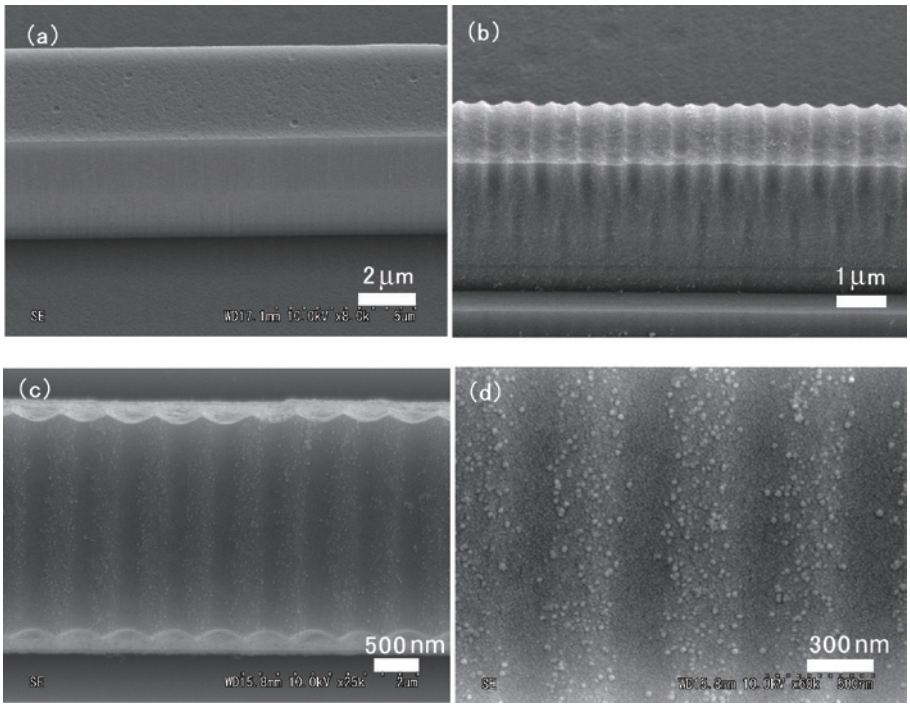

Periodic structures consisting of Ge nanoparticles were formed in buried channel waveguides. Such periodic structures were created in GeO_2-B_2O_3-SiO_2 thin glass films by the combination of exposure to interference patterns of ultraviolet laser light and thermally induced phase changes of the glasses. Figures 1(a) and 1(b) respectively show scanning electron microscope images of the channel structure before and after HF etching. The images of the structures from above and with an enlarged view are shown respectively in Figs. 1(c) and 1(d). Figure 1(a) shows that surfaces of the channel structure were rather smooth in spite of the precipitation of Ge nanoparticles. In particular, the sidewall surface roughness was almost not observed. It is readily apparent from Figs 1(b) and 1(c) that periodic relief patterns appeared on the channel surfaces after HF etching. The nanoparticles are visible in the convex regions. These periodic structures in the channels served as the Bragg gratings with high diffraction efficiencies in the optical communication wavelength. Transmission spectra measurements show the depths and positions of the diffraction peaks as 37.77 dB at 1536.2 nm and 38. 72 dB at 1537.6 nm, respectively, for TE-like and TM-like modes. The diffraction efficiencies remain unchanged even after further annealing at temperature as high as 500°C.

Fig. 1 Scanning electron microscope images of the channel structure (a) before and (b) after HF etching, and images (c) from above and (d) of the enlarged one.

Isolated Electrodeless High-Frequency Quartz Crystal Microbalance for Immunosensors

OGI Hirotsugu and MOTOHISA Kazuma
(Graduate School of Engineering Science)

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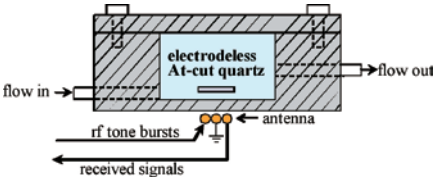

Fig. 1 Side view of the isolated electrodess QCM cell. The line antenna is placed near the bottom of the cell, which radiates the quasistatic electric field to generate the shearing vibrations and receives the vibrational signals through the piezoelectric effect.

Various immunosensors have been studied because of two principal purposes. First, they are used to detect specific protein markers that are excreted by corresponding disorders, such as, glypican-3 protein for hepatocellular carcinomas and amyloid-β peptide for Alzheimer's disease. Early detection of such protein markers increases the probability of their permanent cure. Second, they are expected to determine the kinetic constants related to biochemical reactions, yielding affinity between biomolecules, which significantly contributes to the development of an effective antibody for a specific antigen, that is, to the drug discovery. Among many immunosensors, the quartz-crystal microbalance (QCM) technique has been extensively studied because it allows absolute and quantitative measurement of the affinity. However, it shows lower sensitivity for proteins with smaller molecular masses.

This paper then proposes an ultrahigh-sensitive QCM immunosensor with the wireless-electrodeless technique. The shear bulk wave resonance frequencies of the isolated quartz crystal were measured in a flow cell with the noncontacting manner by the line antenna placed outside the cell (Fig. 1). Exact vibrational analysis predicts higher frequency sensitivity to the adsorbed material at higher modes when the electrode layer is removed. The 13th overtone (72-MHz resonance frequency) was used to detect human immunoglobulin G with concentrations between 0.1 and 20 μg/mL captured by Staphylococcus-aureus protein A immobilized on one side of the crystal (Fig. 2). The real-time monitoring of the binding and dissociating reactions was made via the frequency response (Fig. 3), which yielded the equilibrium constant K_A of 5.21×10^7 M^{-1}. The much higher sensitivity was confirmed by this novel technique.

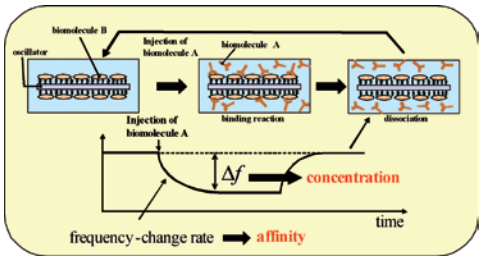

Fig. 2 Principle of the real-time monitoring of the binding and dissociating reactions between biomolecules A and B by the isolated oscillator immunosensor. The amount of the frequency change indicates the concentration of the injected protein and the frequency change rate yields their affinity.

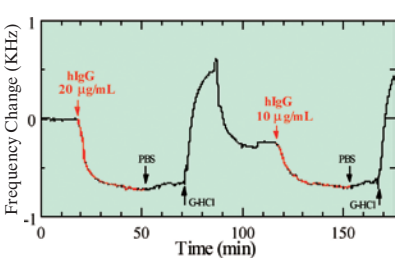

Fig. 3 Typical response of the 13th overtone resonance frequency observed during the injection sequence. IgG, PBS, and G-HCl denote the arrival times of the human IgG, phosphate-buffer solution, and glycine-HCl buffer solution, respectively.