SPR chip fabrication using silicon-on-quartz bonding

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Abstract

In this study, an Otto configuration based SPR chip is designed and fabricated using a SoQ bonding process. The measured SPR effect is compared to a FEM simulation result.

Surface plasmon resonance (SPR) is the resonant oscillation of conduction electrons at the interface between a negative and a positive permittivity material stimulated by incident light. The SPR effect is a basic tool for measuring material adsorption in planar metal surfaces, and has been used in a number of applications such as gas detection or different lab-on-a-chip sensors [1-2]. Kretschmann and Otto configurations are well known as arrangements for measuring the SPR. The Kretschmann configuration is used in most practical applications, because of its robust measurement of interactions at the metal-environment interface, in this configuration, a thin metal film is evaporated with the adhesion layer onto the glass substrate [3-4]. Thus, the quality factor of the SPR effect is decreased by the adhesion layer. In case of the Otto configuration, the metal film surface is separated from the glass substrate, eliminating the effect of the adhesion layer on the SPR quality factor [5].

A schematic view of the proposed SPR chip is shown in Fig. 1. The size of the proposed SPR chip is $30 \times 30 \times 1$ mm^3. This SPR chip consists of a glass substrate and a silicon substrate with an initial cavity (2.5 μm-depth). A 300 nm-thick gold metal film is evaporated on the silicon cavity. Fig. 2 shows the simulated SPR curve using FEM simulation (COMSOL) for the design. The simulated resonance angle and reflectance are 42.2 degree and 0.28, respectively.

The proposed Otto configuration based SPR chip is fabricated using a SoQ bonding process. First, a 2.5 μm-deep cavity is machined on a 500 μm-thick Silicon substrate using a deep reactive ion etching (DRIE) process. Then, the 300 nm-thick Au metal film is deposited over an adhesion layer (Cr, 10 nm-thick) on the silicon cavity, using the lift-off process. After RCA1 cleaning, the silicon substrate and the 500 μm-thick quartz substrate are manually bonded using oxygen plasma-assisted bonding process. Finally, the prepared bonded wafer is annealed on a hotplate under the proper condition (temperature of 200 °C) for 2 hours. Fig. 3 shows the fabricated SPR chip.

The SPR effect of the fabricated chip was measured using an automated reflectometer. The fabricated SPR chip is placed in optical contact with the top surface of a right angle coupling prism (BK7) in order to observe the SPR effect. The laser beam (wavelength of 975.1 nm) incident upon the prism is polarized at parallel to the incidence plane. The input laser beam which is reflected by the splitter is detected by the reference photodetector. The transmitted beam is detected by a photodetector. Fig. 4 shows the measured SPR curve according to the angle of incidence. The measured resonance angle and reflectance are 42.17 degree and 0.52, respectively.

In this study, the Otto configuration based SPR chip is designed and fabricated. The SPR effect was measured. The measured results agree well with the simulation results and the SoQ bonding is a feasible approach for implementation of Otto configuration based SPR chips.

[1] B. Liedberg, C. Nylander and I. Lundsrom, "Surface-plasmon resonance for gas-detection and biosensing," Sens. Actuators, vol. 4, 1983, pp. 299-304.

[2] M. T. Flanagan and R. H. Pantell, "Surface Plasmon Resonance and Immunosensors", Electr. Lett., vol. 20, 1984, pp.968-970.

[3] S. Sjolander and C. Urbanicczky, "Integrated fluid handling system for biomolecular interaction," Anal. Chem., vol. 63, 1991, pp. 2338-2345.M. T. Flanagan and R. H. Pantell, "Surface Plasmon Resonance and Immunosensors", Electr. Lett., vol. 20, 1984, pp.968-970.

[4] B. Liedberg, I. Lundsrom and E. Stenberg, "Principles of biosensing with an extended coupling matrix and surface plasmon resonance," Sens. Act B, Vol. 11, 1993, pp. 63-72.

[5] A. Otto, "Excitation of nonradiative surface plasma waves in silver by the method of frustrated total reflection," Z. Physik, Vol. 216, 1968, pp. 398-410.

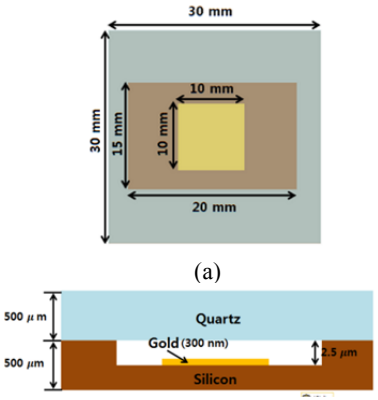

Figure 1. Schematic view of the proposed SPR chip (a) Top view (b) Cross-section view

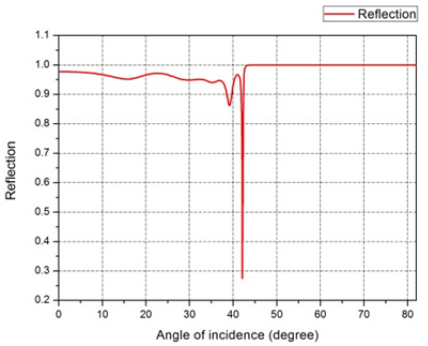

Figure 2. FEM simulation result using COMSOL

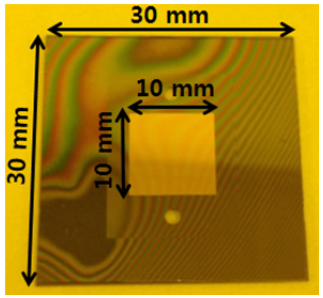

Figure 3. Fabricated SPR chip

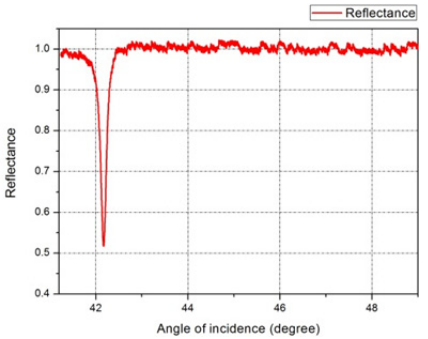

Figure 4. Measured SPR curve