Optical and Electrical Sensing Application of High-Aspect-Ratio Nanoholes Formed by Etching of Latent Tracks

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We have developed a waveguide-mode sensor that utilizes a sensing plate having a multilayer structure consisting of a SiO_2 glass waveguide, a single crystalline Si layer, and a SiO_2 glass substrate.[1] We have reported that the sensitivity can be enhanced by forming nanoholes in the SiO_2 glass waveguide layer. As for the perforation, selective etching of latent tracks formed by swift heavy ion irradiation is desirable, since this method can create nanoholes with an aspect ratio of more than 40. In the present research, we found that electro-chemical reaction can be carried out in the nanoholes and that the reaction can be used for material detection.

The substrate used was a silicon-on-quartz substrate having a 286-nm single crystalline Si layer on a 1.2-mm SiO_2 glass substrate. The surface of the Si layer was oxidized to form a 530-nm SiO_2 layer. The Si layer thickness became 45 nm after the oxidization. For perforating the SiO_2 layer, 450-MeV Xe ions were irradiated to the SiO_2 layer and 5% hydrofluoric acid etching following the irradiation was applied. The total ion fluence was 1×10^{10} cm^{-2}. Figure 1 shows a SEM image of the surface perforated by 2-min etching. A droplet of a mixed solution of 5-mM sulfuric acid with a surfactant was attached on the perforated surface and a gold needle was put in the droplet as an anode. The Si layer was used as a cathode. Figure 2 shows a correlation between the etching time and the current measured between the electrodes with applying a voltage of 1 V. The current started to increase at an etching time of 70 s, indicating that the nanoholes reached to the Si layer, whereas the current was saturated with an etching longer than 135 s, indicating that the nanoholes completely penetrated the SiO_2 layer. By using the perforated plate as a sensing plate of the waveguide-mode sensor and by applying voltage, we have succeeded in the detection of Pb-ion reduction in water.

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[1] M. Fujimaki *et al.*, Opt. Express 16, 6408 (2008).

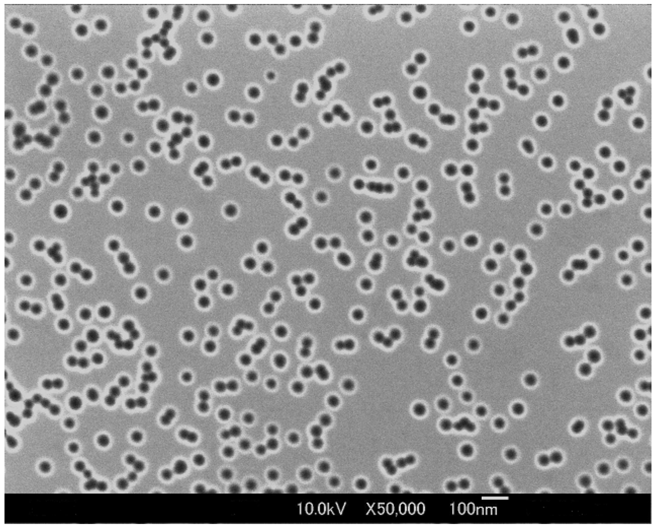

Figure 1: The SEM Image of the perforated SiO_2 surface: On the surface, nanoholes with diameters of around 50 nm are observed.

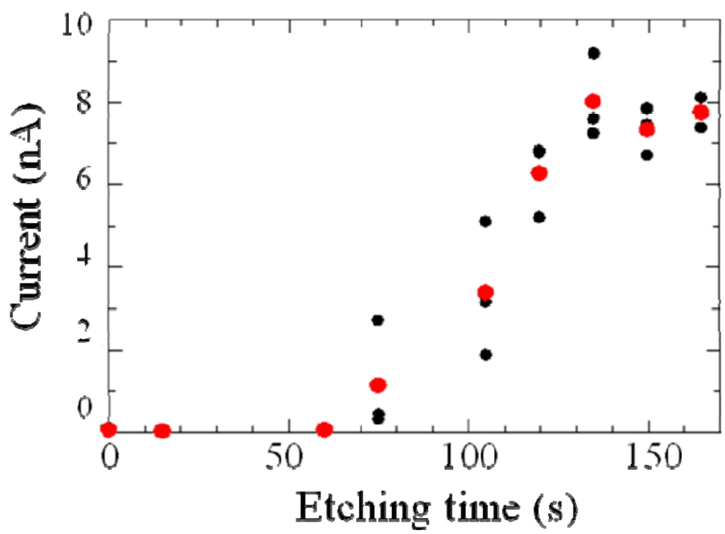

Figure 2: The correlation between the etching time and the current measured on the perforated plates: The current started to increase at the etching time of 70 s, and was saturated with the etching longer than 135 s. The black and red dots indicate the experimental values and averages, respectively.