C-V Characteristics and Photoluminescence of Porous Silicon Sensors for Alcohol Sensing

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Since drinking alcohol affects one's ability to safely operate equipment such as automobiles and industrial equipment, various test meters to measure the level of alcohol in blood have been developed to check drinking driving.

In this work, C-V and photoluminescence properties of porous silicon sensors were investigated for alcohol sensing. Porous silicon (PS) was first suggested as a potential optical material using photoluminescence phenomena[1], and later on, it has received attention as sensitive material in chemical sensors due to its large effective surface area[2]. In this work, PS layer was prepared by anodization of a (100) p-type, boron-doped Si wafer with resistivity of 20 Ωcm in a 1:1 volume solution of HF (49% in water)-ethanol. The etch current density was 100mA/cm^2. The anodization time was about 4 minutes. For capacitance-voltage measurements, semi-transparently thin Au/Cr (300nm thickness) contacts were evaporated on top of the porous silicon layer, and photoresist was patterned with 2.56 mm squares over the gold film to open the center of the porous silicon layer into the air and were connected to metal wires. Fig. 1 is a photograph of a completed sensor mounted on an insulation board.

We measured small-signal capacitance with high frequency of 1MHz under the bias of 0 to 2V. We used different ethanol solutions mixed with pure water, which were diluted from 0 to 0.2%. Here, to adjust our experiment with conditions of breath alcohol measurement, alcohol vapors evaporated at 36°C close to human body's temperature were injected to the sensor surface with a carrier gas of N_2.

Fig. 2 shows C-V curves which were measured in air with no vapor, and under exposure of alcohol gases vaporized from 0, 0.1 and 0.2 % ethanol solutions at 36°C, respectively. The C-V curves were shaped like those of a MOS capacitor with a p-type substrate. Generally PS layer can be regarded as a complicated dielectric material, where its dielectric constant is affected by various components such as air, water and alcohol vapors impregnated in pores. As the result, the capacitance of the sensors increased with alcohol concentration which dielectric constant is 25. Alcohol is volatile, so it becomes strongly vaporized even at low temperature of 36°C. Therefore, the capacitance was largely changed for the small variation of alcohol concentration.

Photoluminescence (PL) spectra of PS layer in the sensor were observed for different alcohol concentrations from 0 to 0.5%. In PS layer, it has been known that variation of both peak position and emission intensity is accompanied by the adsorption of gases into the porous structure[3]. In our experiment, as the substitution of air with alcohol vapor in the pores causes the value of refractive index of the PS layers to be increased, it resulted in a red-shift of the peak and a quenching effect in the PL line as shown in Fig. 3.

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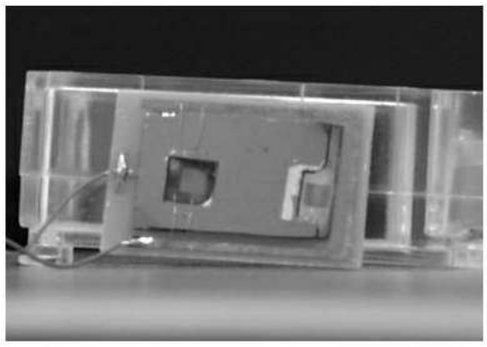

Fig. 1 Photograph of a completed sensor

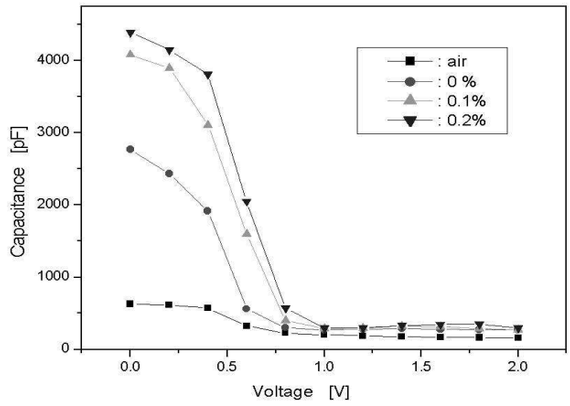

Fig. 2 C-V curves of a sensor in different alcohol concentrations

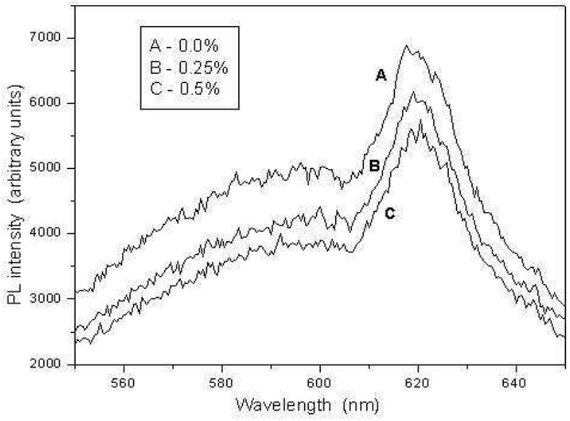

Fig. 3 PL spectra of a PS layer in different alcohol concentrations