Porous Silicon Sensors with Membrane Structure for Organic Vapor Sensing

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Since porous silicon (PS) was suggested as a potential optical material using photoluminescence phenomena[1], it has invoked much interest for the development of new silicon light emitting diodes. In addition to it, PS has also received attention as an increasingly important sensitive material in chemical sensors[2-3].

In this work, the conductive property of PS layer (p^+-type) was investigated for organic vapor sensing. To do this, a gas sensor was fabricated by applying the technologies of silicon membrane formation by anisotropic etching and PS layer by anodization. The backside etching for the membrane formation was done in 20% TMAH solution for 14 hours in 85℃, and the anodization for formation of PS layer was done in 25% HF solution under the current density of $120mA/cm^2$ for 2 minutes. In our fabrication process, the formation of PS layer was done to the final step to maintain PS layer purely without the accumulation of any extra-settled layer on it.

From fabricated sensors, current-voltage (I-V) curves were measured from 0 to 5V against ethanol, methanol and acetone vapors from 0.1 to 0.5% concentrations. While I-V curves showed quite a little slope below the applied voltage of 2V or below the electric field of $1x10^4V/m$, they increased rapidly as the applied voltage approaches to 5V. Consequently, the sensitivity was enhanced considerably at high voltage.

Fig. 1 indicates schematic diagram of the sensor suggested in this work. 25 (5x5) samples per wafer were fabricated, and 4 wafers were used. A fabricated sensor which is finished up to wire bonding is shown in Fig. 2. The size of samples is 3.5 x 3.5 mm^2. We examined the surface of PS layer with SEM. Fig.3 shows a photograph taken from the surface. Typically, pores formed in heavily doped p-type wafers showed irregular shape, and it was found that the distribution of pore diameter spreads from sub-micron to tens of nano scale with a mercury porous meter. Fig.4 shows I-V curves depends on ethanol vapor concentrations. A rectifying behavior is supposed to be due to a diode structure between Si and PS. The relative current changes by vapor exposure were shown largely at 5V. The change of the conductivity in PS layer may be caused by the amount of adsorbed gases, which lead to various electrical charges at PS layer. From the experiment of other methanol and acetone vapors, it was concluded that the conductive properties of PS layer are dependent strongly on their dipole moment and hydrophile property or adhesion against silicon.

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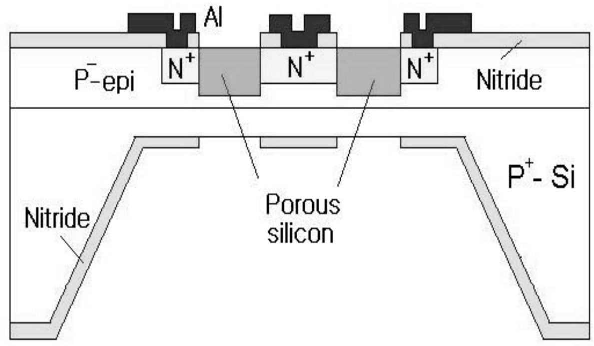

Fig. 1 Schematic structure of our sensors

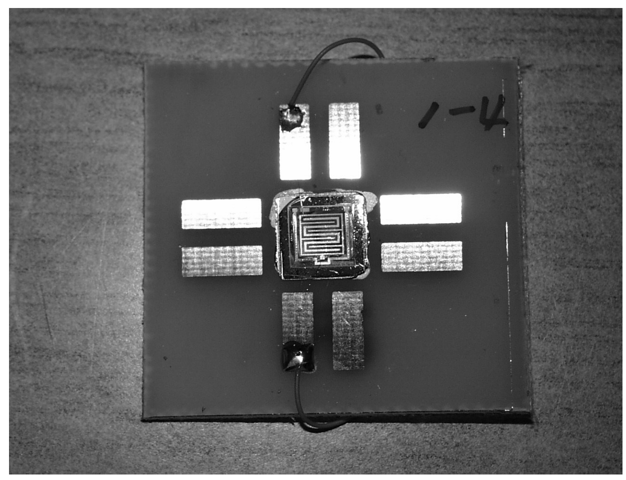

Fig. 2 Photograph of a fabricated sensor

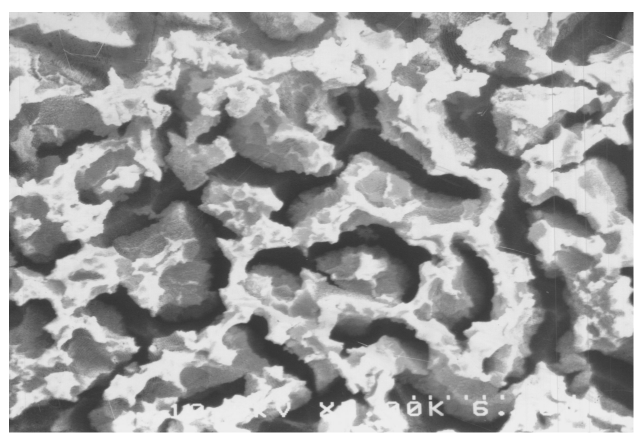

Fig. 3 SEM photograph of PS layer taken from the top view

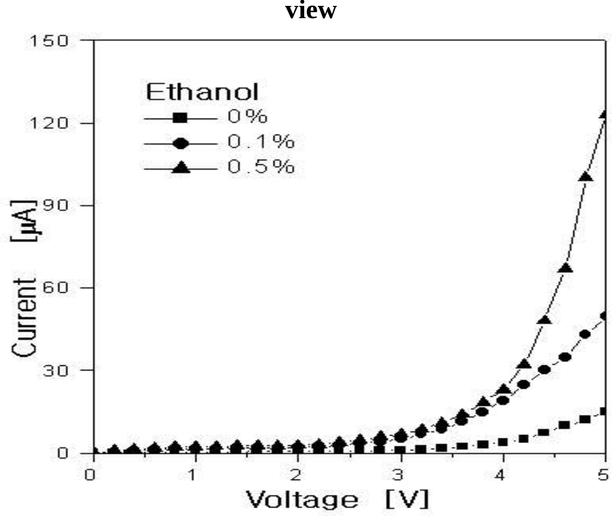

Fig. 4 I-V curves measured from ethanol vapor