Self-ordered nanoporous silica films applied to surface photo voltage type NO_x gas sensor

Haoshen Zhou, Takeo Yamada, and Itaru Honma

Energy Electronics Institute, National Institute of Advanced Industrial Science and Technology (AIST), Umezono, Tsukuba, 305-8568, Japan.
E-mail: hs.zhou@aist.go.jp

Nitrogen oxides (NO_x) generated by combustion are harmful to human's health, and all the nations have regulated their concentrations in the environment. Therefore, development of a highly sensitive, highly responsive, and portable device for monitoring these gases are urgently required. The surface photo voltage (SPV) semiconductor characterization technique has great potential for satisfying the requirements of such gas sensors. The SPV system sensitively detects variation in surface voltage, which is effected by physical adsorption and chemical interaction between the target gases and the sensitive layer. The capacitance of the insulator layer depends on the gas adsorption performance, and improvement of gas adsorption performance leads directly to enhancement of SPV gas sensor characteristics.

The large surface area created by nanosize pores in self-order nanoporous materials enables improvement in the gas adsorption properties of SPV devices. This paper reports possible application of the self-ordered hexagonal and cubic-like self-order nanoporous silica films to SPV type NO_x gas sensor, the film being synthesized by the spin coating method and by use of nonionictype triblock copolymer (PEO-PPO-PEO) surfactant as a template. The NO_x gas sensors are based on the SPV characterization system. The self-order nanoporous silica film is assembled as a gas adsorption insulator layer of the MIS structure based on the SPV characterization system.

The SPV sensor system is fabricated from the MIS structure of semiconductors. Specifically, n-Si with SiO_2 and Si_3N_4 layers is used as a substrate. Hexagonal silica film by P123 (EO_{20}-PO_{70}-EO_{20}) or cubic-like silica film by F127 (EO_{100}-PO_{65}-EO_{100}) is prepared on the Si_3N_4 layer of the substrate as a gas adsorption insulator layer. Consequently, the self-order nanoporous silica combined MIS structure of the SPV sensor is constituted of Au/ hexagonal or cubic-like self-order nanoporous silica/ Si_3N_4/ SiO_2/ n-Si/ Al (SPV-hex or SPV-cub). The sensing properties of each SPV device were estimated under NO (100ppm, 100sccm) and NO_2 (50ppm, 100sccm) gas exposure conditions.

Figure 1 shows the Current-Bias voltage curves (CB curve) of SPV-hex and SPV-cub measured at room temperature under standard air (100sccm) conditions and under NO conditions. These SPV samples exhibit clear bias shift by NO gas adsorption in self-order nanoporous films and also indicate the gas accessibility dependence on nano-structures. The bias shift resulted from changes in the dielectric constant and charge in the insulator layer, which in turn were caused by physical adsorption and chemical interaction between the detected gases and the gas-sensitive film.

Figure 2 shows the CB curve of SPV-hex and SPV-cub measured at room temperature under standard air conditions and under NO_2 conditions. These SPV samples also exhibit clear bias shit and by NO_2 adsorption in nanoporous films and indicate the dependence on nano-structures. The bias shift differences between exposure gases in each device are also observed in each figure. This result is strongly influenced dielectric constants of exposure gases.

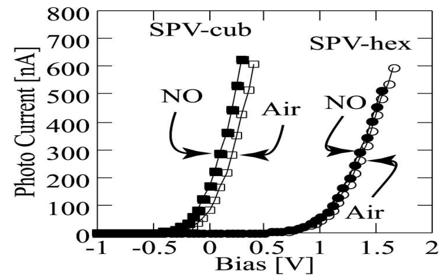

Figure 1. Current-Bias Voltage Curve of SPV-hex and SPV-cub under air and NO condition.

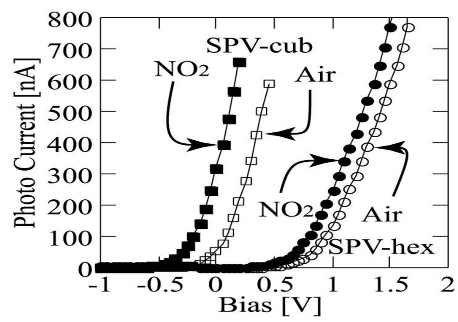

Figure 2. Current-Bias Voltage Curve of SPV-hex and SPV-cub under air and NO_2 condition.