

Fabrication and NO₂ Surface Photo Voltage Sensor
Properties of Nanoporous Tin-Silica Film

Brian Yulianto^{1,2}, HaoShen Zhou^{1*}, Takeo Yamada¹,
Itaru Honma¹, Keisuke Asai²

¹Energy Electronics Institute, National Institute of
Advanced Industrial Science and Technology (AIST),
Tsukuba, 305-8568 JAPAN

²Department of Quantum Engineering and System
Science, Graduate School of Engineering, The University
of Tokyo, Tokyo 113-8656, JAPAN

*E-mail: hs.zhou@aist.go.jp

Among of the pollutant of nitrogen oxides, NO₂ is the most dangerous gases related to the health and environmental damage. This factor has forced to develop trustworthy and reliable gas sensor to monitor and control NO₂ gas emission.

Nanoporous materials have attracted considerable attention because of their large surface area and porosity, uniform pore size distribution, order pore arrangement, and possible surface engineering.¹ The use of nanoporous material as separation and sensor devices has been increased rapidly. The key point for sensor application of nanoporous material is represented by large surface area of nanoporous material, which can produce good accessibility from the external environment. In addition it is well known that the surface photo voltage (SPV) technique has become a powerful method to detect the gas pollutant.² This study observes the performance of nanoporous tin-silica film for 1 ppm NO₂ gas using SPV technique.

Self-ordered and structure controlled nanoporous tin-silica film was prepared by a molecule surfactant template method using spin coating. The X-ray diffraction pattern of the calcined of nanoporous tin-silica film and its TEM image are shown in Fig. 1. The nanoporous tin-silica film was then fabricated as SPV NO₂ gas sensor. The sensor consists of Metal-Insulator-Semiconductor (MIS) structure of Au/ tin-silica nanoporous/ Si₃N₄/ SiO₂/ Si/ Al.³⁻⁴ The cross sectional sample of SPV NO₂ gas sensor and the band diagram structure is shown in Fig. 2. The clear characteristics of this sensor were obtained at the NO₂ gas concentration as low as 1 ppm at room temperature. The changes in the value and phase of the AC photocurrent, and the responsibility have been observed after exposure of 1 ppm NO₂ gas to the film sample. Compared with those of the pure nanoporous silica film, nanoporous tin-silica film showed enhanced sensitivity for NO₂ gas sensor as shown in Fig. 3. The gas sensor sensitivity, is defined as:

$$S = \frac{(I_{NO2} - I_{N2})}{I_{N2}} \times 100\%$$

where I is average photocurrents. Therefore, from the calculation in Fig. 3, the sensitivity of nanoporous tin-silica gas sensor is 268.18%, which is much higher than the sensitivity of pure nanoporous silica sensor that is only 99%.

References

1. C.T. Kresge, M.E. Leonowicz, W.J. Roth, J.C. Vartulli, and J.S. Beck, *Nature* **359**, 710 (1992).
2. D.K. Schroder, *Meas. Sci. Technol.* **12**, R16 (2001).
3. H.S. Zhou, T. Yamada, K. Asai, I. Honma, H. Uchida, and T. Katsube, *Jpn. J. Apl. Phys.* **40**, 7098 (2001).
4. T. Yamada, H.S. Zhou, H. Uchida, M. Tomita, Y. Ueno, I. Honma, K.Asai, and T. Katsube, *Microporous and Mesoporous Mater.* **54**. 269

(2002).

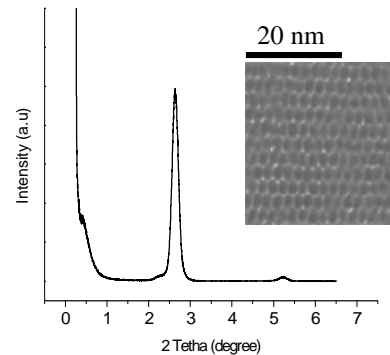


Fig. 1 The XRD patterns of the calcined of nanoporous tin-silica film, with its TEM images of a self ordered hexagonal structure film.

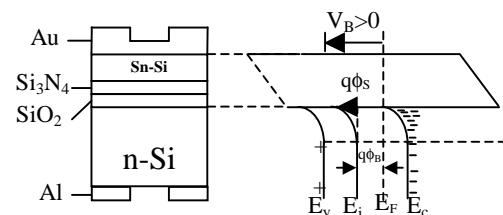


Fig. 2. The cross section of SPV sample and its band diagram (b) where: ϕ_s , ϕ_B , V_B , E_F , E_i , E_c , and E_v correspond to surface potential, potential difference between Fermi level and intrinsic Fermi level, bias voltage, Fermi level, intrinsic Fermi level, conduction band level, and valence band level, respectively.

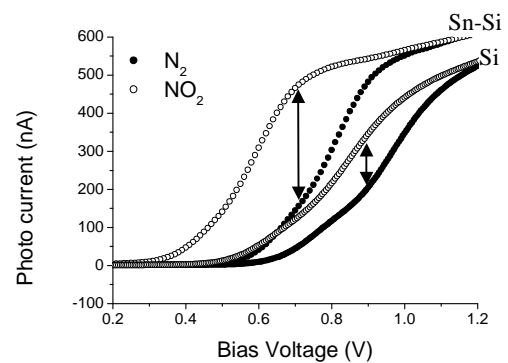


Fig. 3. The comparison of I_{PH} - V_{Bias} curve of nanoporous tin-silica SPV sensor (Sn-Si) and pure nanoporous silica SPV sensor (Si). The lines correspond to the photocurrents value used to determine sensitivity (S).