

MOCVD Grown Metal-Insulator-Semiconductor
Field-Effect Transistor (MISFET) Hydrogen Sensor

Kun-Wei Lin, Hung-Ming Chuang¹, Chun-Yuan Chen¹,
Chun-Tsen Lu¹, Yan-Ying Tsai¹, Chung-I Kao¹, and
Wen-Chau Liu^{1*}

Department of Electrical Engineering, Chien Kuo Institute
of Technology Changhua, TAIWAN, Republic of China
¹Institute of Microelectronics, Department of Electrical
Engineering, National Cheng-Kung University, 1 University
Road, Tainan, TAIWAN 70101, Republic of China
Fax: +886-6-209-4786 or +886-6-234-5482
*Corresponding author. E-mail: wcliu@mail.ncku.edu.tw

We propose a novel and high-performance Pd/oxide/GaAs metal-insulator-semiconductor field-effect transistor (MISFET) hydrogen sensor. The schematic cross-section of the studied device is depicted in Fig.1(a). Figure 1(b) illustrates the corresponding energy band diagram of the fabricated device. The dipole layer is generated by hydrogen atoms at Pd/oxide interface as indicated in Fig.1(b). The dipole layer between metal and semiconductor corresponds to a voltage drop and therefore changes the characteristics of the studied MISFET. Figure 2 shows the corresponding gate-drain current-voltage (I-V) characteristics of the studied Pd/oxide/GaAs MISFET measured under different hydrogen concentrations at room temperature.. The common source output I-V characteristics at room temperature are illustrated in Fig.3(a). As shown in this figure, the drain saturation current distinctly increases with increasing hydrogen concentration. All I-V curves show good pinch-off and cut-off behaviors.. Figure 3 shows the hydrogen transient response under the introduction and removal of 202 and 537ppm hydrogen/air gases at the reverse bias of $V_{GD} = -4V$ and $100^{\circ}C$. The reverse current shifts rapidly to the steady-state value upon hydrogen adsorption (point a) and hydrogen desorption (point b). Generally, the response time constants including the adsorption and desorption time constant τ_a and τ_b are defined as the times reach e^{-1} of the final steady-state current values. The τ_a values under 202 and 537ppm hydrogen/air gases are 2.8 and 2.6 sec, respectively. In addition, the corresponding τ_b value are 3.2 and 2.9sec, respectively. The response times (τ_a and τ_b) are decreased when the hydrogen concentration is increased. The shorter reaction time can be explained by the larger interface cover sites and more collisions induced high reaction rate.

In summary, a high-performance hydrogen sensor based on a Pd/oxide/GaAs MISFET structure is fabricated successfully and reported. The oxide layer is employed to improve the turn on voltage and hydrogen detecton sensitivity by eliminating the Fermi-level pinning effect. In addition, the studied device exhibits obvious modulation of drain current (in the degree of mA) . The short response time constants of 2.8 and 2.6 sec are observed under the 202 and 537ppm hydrogen/air condition, respectively, at $100^{\circ}C$. As mention above, the studied device shows a promise for high-speed and high-sensitivity hydrogen sensor and MISFET integrated circuit applications.

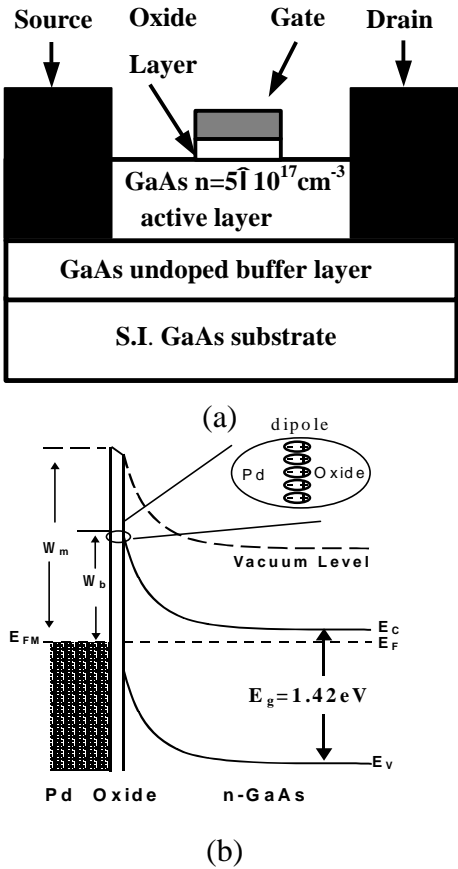


Fig.1 (a) The schematic cross-section and (b) corresponding energy band diagram of the studied device.

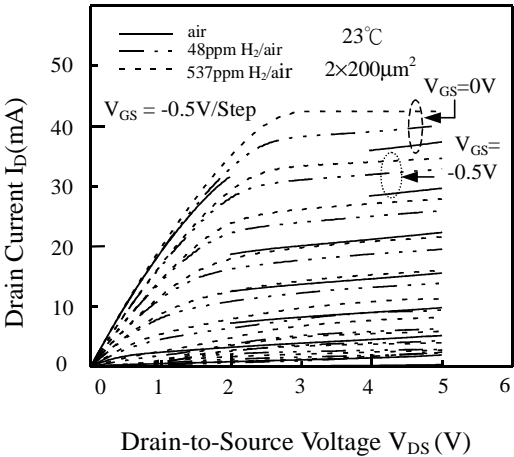


Fig.2 Output I-V characteristics of the fabricated device under different hydrogen concentrations at room temperature.

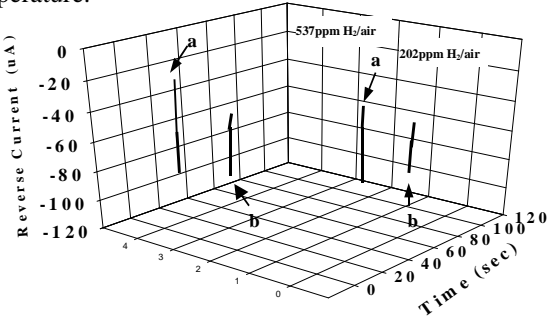


Fig. 3 Transient response curves with the introduction and removal of 202 and 537ppm hydrogen/air gases at $100^{\circ}C$.