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SnO_2-Pd as a Gate Material for the Capacitor Type Gas Sensor †

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Abstract: The article describes the result of the use SnO_2-Pd thin films as a gate for structure measured ppb range of NO_2 gas by the capacitive method. The technological aspects of fabrication SnO_2-Pd gate and one comparison by metrological parameters with the classical Pd gate field effect sensor are discussed. The use of SnO_2-Pd material allows improvement in sensitivity of NO_2 by an order of magnitude compare the classical Pd based gate field effect sensors.

Keywords: field-effect sensor; metal oxide sensor; gas sensitivity

1. Introduction

Using of SnO_2 material for fabrication field effect gas sensors based on Schottky diode effect firstly describing in work [1], somewhat later, a study of the sensitivity of field-effect sensors to NO_2 began [2]. But still remains an important issue measurement of sub-ppb concentrations of NO_2 in such areas as medicine, environmental control and explosives detection. Materials based on SnO_2 are widely used to measure NO_2 by resistive type MOX sensors, but MOX sensors margin of stable sensitivity is limited by sub-ppm range. The further increase in sensitivity to NO_2 is possible in the technological combination of well proven material using nowadays in MOX sensors and high sensitivity of field-effect sensors.

2. Experimental

In [3] was shown that the characteristics of field-effect sensors strongly depend on the composition metal-dielectric transition layer, which is determined by the materials of metal gate and insulator dielectric and methods of their deposition. For a new capacity type sensor manufacturing n-type silicon substrate with a 0.1 μm SiO_2 layer thickness was used. Layer of SnO_2 is additionally deposited through the shadow mask on the SiO_2 film by the method of magnetron sputtering. This method of deposition allows you to form films with a high effective surface area. The Pd film with a thickness of 100 nm was coated SnO_2 film through the shadow mask by pulse laser deposition method. The Pd-SnO_2-SiO_2-Si structure was basis of capacitor type gas sensor which photo present on Figure 1 and cross-section scheme of structure on Figure 2, respectively. In parallel with the SnO_2-Pd based sensor, a similar series of capacity sensors without SnO_2 layer, only with a 100 nm Pd gate, was made for comparing changes of gas-sensitive characteristics.

Figure 3 presents the capacitance-voltage characteristic for Pd gate sensor at different heating temperatures. The capacitance-voltage characteristics for SnO_2-Pd and Pd base sensors at temperatures of 170 °C, 140 °C and 100 °C was study and present in Figure 4. Also sensitivity to NO_2 at different temperatures present on Figures 5 and 6. On Figure 4 and Figure 5 can be seen that the slope of the characteristic decreases with increasing temperature, therefore, the sensitivity of the sensor should decrease; this effect is explained by the shift of C-V characteristic during exposed to gas. The Figure 5 shows the time responding capacity sensor with SnO_2-Pd gate to 108 ppb NO_2 at different temperature and possible to see decreasing response time and sensitivity during increasing working temperature of sensor. This behavior is standard for the field effect sensor.

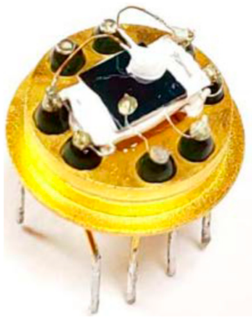

Figure 1. Capacitor sensor's photo assembled with film resistive heater and thermistor. Package type is TO-8 (11 mm in diameter).

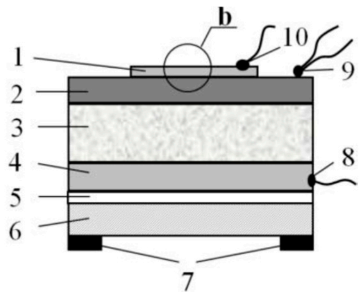

Figure 2. Capacitor sensor: 1—SnO_2/Pd gate; 2—SiO_2 film; 3—Si substrate; 4—Al electrode; 5—insulator; 6—heater; 7, 8, 10—the electric contacts; 9—thermistor.

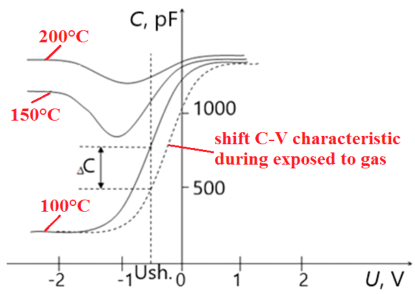

Figure 3. Scheme of capacitance-voltage characteristic for Pd gate sensor at different heating temperatures and shift C-V characteristic during exposed to gas.

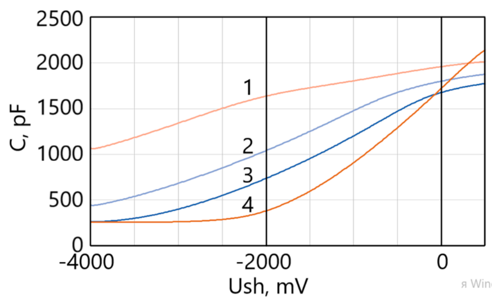

Figure 4. The capacitance-voltage characteristics for capacity sensor at temperatures: 1—170 °C, 2—140 °C, 3—100 °C, 4—pure Pd gate at 100 °C.

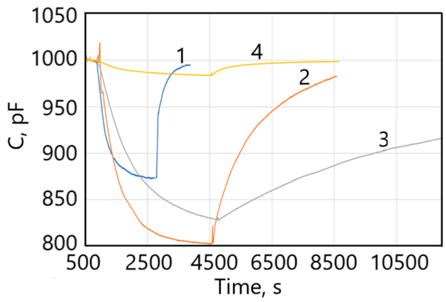

Figure 5. Responses capacitor sensor to 108 ppb NO_2 concentration at temperatures: 1—170 °C, 2—140 °C, 3—100 °C, 4—pure Pd gate at 100 °C.

Figure 6. The response of capacity sensors to108 ppb NO_2 concentration at different temperatures.

T, °C	Gate Structure	
	Pd-SnO_2	Pd
	Response, pF	
100	172	20
140	195	-
170	130	-

The using of the new type SnO_2-Pd gate in capacity type sensor gives possible to raise sensitivity by almost ten times but disadvantage for such approach is increasing response and relaxation times of the sensor. Possible approach for improving response and relaxation times is using pulse temperature mode increasing diffusion rate through the gate present in work [4]. Extrapolation of present measurement results suggests stable detection NO_2 concentrations by the Pd-SnO_2-SiO_2-Si structure in the region of 1 ppb and less.

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Conflicts of Interest: The authors declare no conflict of interest.

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