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Suppression of Drift in FET-type Gas Sensor Having WS_2 Nanoparticles Using Pulse Measurement

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Abstract:
In this paper, sensing characteristics of the FET-type gas sensor having WS_2 nanoparticles as a sensing layer deposited using ink-jet printer are analyzed with various measurement conditions. In case of using DC measurement method, the transfer curve has a large hysteresis gap due to charge trapping in the sensing layer. For this reason, we adopt a pulse measurement. Transient response of the FET-type gas sensor is measured with NO_2 concentrations using DC and pulse measurement methods. Through adopting pulse measurement, drift characteristics of the gas sensor are suppressed and recovery characteristics are improved. As NO_2 concentration increases, response rate of the gas sensor increases. As a result, the gas sensing characteristics of the FET-type sensor having WS_2 sensing layer are improved effectively by using pulse measurement method.

Key words: TMDCs, WS_2, NO_2 sensor, MOSFET, pulse measurement

Experimental Preparation

Fig. 1. (a) is a microscopic image of the fabricated field effect transistor(FET)-type gas sensor having horizontally formed floating-gate (FG). The fabrication process of the gas sensor has been reported in our previous work [1]. Before forming the sensing layer, SU-8 patterning is performed to protect metal electrodes since metal electrodes can be damaged by ink solutions. In final steps, WS_2 nanoparticles as a sensing layer is printed using ink-jet printer using WS_2 solution. The solution having WS_2 nanoparticles is produced through exfoliation method from WS_2 micro powder mixed in solvent. Fig. 1. (b) shows that a SEM image of ink-jet printed WS_2 nanoparticles on a sensing area. After WS_2 sensing layer is printed, H_2 annealing is performed at 300℃ to remove surfactant of WS_2 solution.

Experimental Results

The characteristics of the synthesized WS_2 nanoparticles are measured by XPS spectrum analysis. As shown in Fig. 2, which is XPS spectrum of the synthesized WS_2 nanoparticles, 1T-phase WS_2 nanoparticles are well-synthesized. Fig. 3 shows that hysteresis gap of transfer curve(I_D-V_{CG}) is a relatively large when the curve is measured using DC measurement. A hysteresis gap of the FET-type gas sensor with a WS_2 sensing layer is attributed to the charge trapping in the WS_2 nanoparticles and the interface between the WS_2 sensing layer and the O/N/O stack [2]. Especially in case of DC measurement, more charges are trapped since a constant bias is applied to the control-gate (CG) of the gas sensor for a long time. Fig. 4 shows that time response of the gas sensor with different NO_2 concentrations ranging from 2.5 ppm to 10 ppm using DC measurement at 100 ℃. As shown in Fig. 4, the recovery characteristics of the gas sensor are degraded by the drift effect originated from the charge trapping. To solve this problem, we adopt a pulse measurement. The pulse measurement is carried out using the pulse scheme in the inset of Fig. 3, which has an on-time of 200μs, off-time of 0.01s. In the pulse measurement, control gate is biased for a short on-time, and biased to 0V for off-time. Therefore, much less charge is trapped, and then the drift of the gas sensor is suppressed. Fig. 5 shows that NO_2 response of the gas sensor with different NO_2

concentrations using pulse measurement at 100℃. Contrary to transient curves using DC measurement method, drift characteristics of the gas sensor is suppressed by using a V_{CG} pulse of -0.9 V. Thus, as shown in Fig. 5, gas response and recovery characteristics are improved.

References

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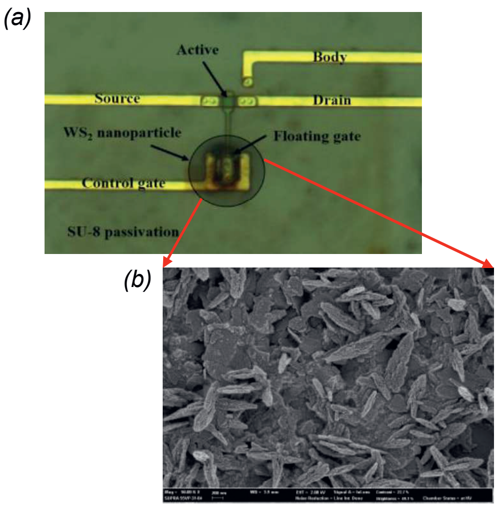

Fig.1. (a) The optical top view of FET-type gas sensor having horizontal floating-gate and ink-jet printed WS_2 sensing layer. (b) A SEM image of Ink-jet printed WS_2 nanoparticles.

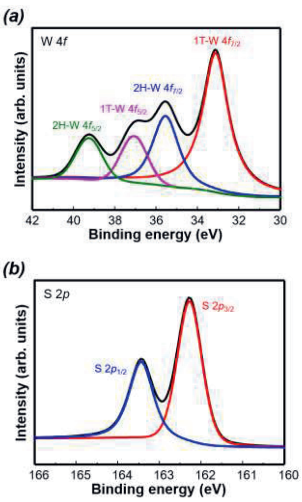

Fig.2. XPS spectrum of the synthesized WS_2 nanoparticles.: (a) W 4f region, (b) S 2p region.

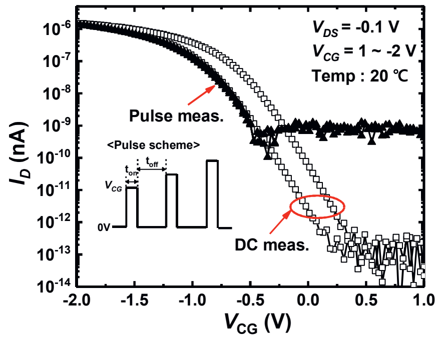

Fig.3. Transfer characteristics (I_D-V_{CG}) of the WS_2 gas sensor at 20℃ using DC measurement and Pulse measurement. The pulse scheme in the inset is used for pulse measurement.

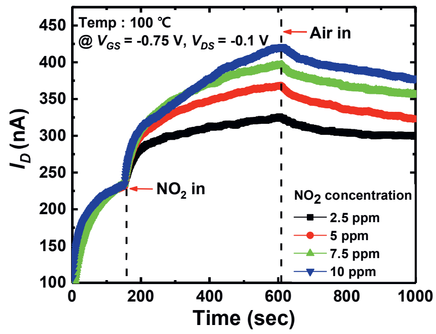

Fig.4. Transient response of FET-type gas sensor having WS_2 nanoparticles using DC measurement at 100℃ as a parameter of NO_2 concentration from 2.5 to 10 ppm.

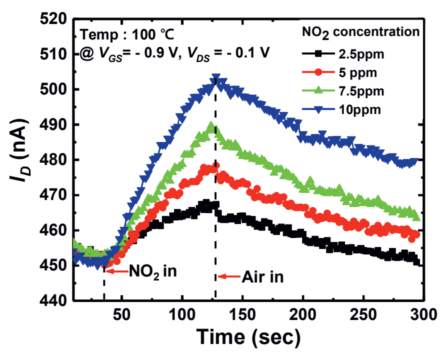

Fig.5. Transient response of FET-type gas sensor having WS_2 nanoparticles using pulse measurement at 100℃ as a parameter of NO_2 concentration from 2.5 to 10 ppm.

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