Study of ultrathin TiO_2 metal oxide gas sensor deposited by atomic layer deposition for environmental monitoring

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Summary

Functional nanosized metal oxide thin film structures produced by Atomic Layer Deposition (ALD) are promising for low power consumption gas sensing. The film thickness control and conformal coating offered by ALD enable tailoring of film thickness to the Debye length, a function of temperature, for enhancing depletion region effects and high surface to volume ratios for enhanced sensitivity. Here we have demonstrated the sensing ability of ALD TiO_2 toward NO_2 in the low ppm range and will explore the effect of film thickness and operating temperature on gas sensor performance. Impact of crystal phase, modified through post deposition anneals and evaluated through X-ray diffraction, will also be reported.

Motivation

Nitrogen oxides have been identified as a deep lung irritant and exposure has been associated with health problems such as decreased respiratory defense mechanisms, increased susceptibility to respiratory pathogens, chronic cough, chronic wheeze, shortness of breath and chest colds with phlegm[1]. Individuals, especially children, suffering from respiratory diseases such as asthma and chronic pulmonary obstructive disease are particularly sensitive to NO_2 and both short and long term exposures can induce undesirable effects on the human condition[2]. TiO_2 has been shown to be sensitive toward NO_2 in a variety of papers[3,4,5] and with an opposite response toward CO, another target gas of interest but ALD of TiO_2 for gas sensing has not yet been explored.

Results

TiO_2 films of varying thicknesses were deposited on alumina hotplate substrates with Pt electrodes, resistive thermal detector (RTD) on the device side and Pt meander heaters on the reverse as shown in Figure 1. A custom flow through chamber shown in Figure 2 was constructed for sensor testing. NO_2 was diluted in zero grade air to low concentrations and the film conductance change was measured with gas exposure. The results from 12 nm thick films are shown in the sensor response graphs in Figure 3 and 4. Clear and reversible response in the form of resistance change was demonstrated for concentrations from 1 to 50 ppm.

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References

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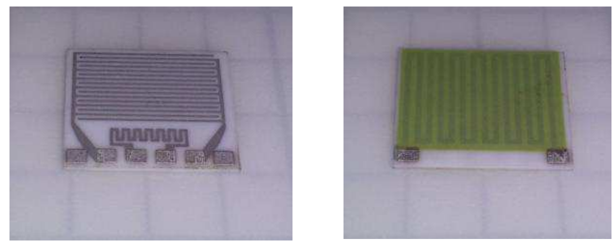

Fig. 1: Sensing substrate (left) Interdigitated Pt electrode with Pt RTD and (right) Pt meander heater on reverse

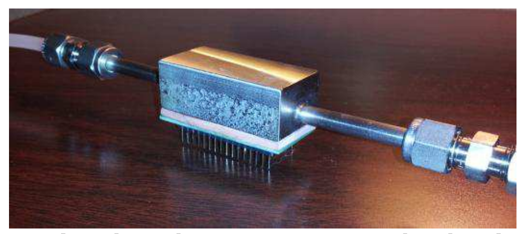

Fig. 2: Flow through gas sensor testing chamber design

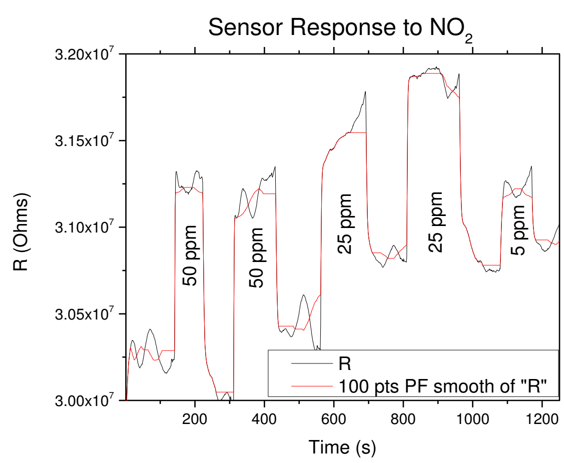

Fig. 3: TiO_2 Sensor response to 50, 25 and 5 ppm NO_2

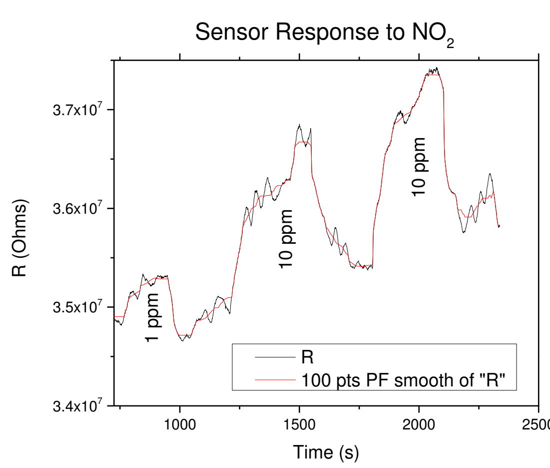

Fig. 4: TiO_2 Sensor response to 1 and 10 ppm NO_2