Palladium oxide thin films for oxidizing gas detection

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Abstract

Statement of the Problem: Three out of six common air pollutants (also called as "criteria pollutants") are oxidizing gases: nitrogen oxides, low level ozone (or tropospheric ozone), and sulfur dioxide [1]. Recently various types of binary, ternary and quaternary metal-oxide semiconductors have been used widely for oxidizing gases monitoring in ambient air [2 – 4]. In this work palladium oxide thin and ultrathin films are presented as perspective materials for detection of oxidizing gases. It is known that palladium and palladium oxide were used as effective catalysts in fabrication of gas sensors based on SnO_2 [5]. PdO films were prepared by thermal oxidation of previously formed Pd layers on different substrates: SiO_2/Si (100), Si (100), optical quality quartz, and KCl (100) with buffer layer of amorphous carbon. By X-ray analysis, reflection high-energy electron diffraction, and high resolution transmission electron microscopy investigations it has been established that homogenous polycrystalline PdO films (thickness was about 5 – 40 nm) were formed by oxidation at dry oxygen at temperatures T = 770 - 870 K. The experimental results of X-ray analysis and transmission electron microscopy have shown that the increase in oxidation temperature led to uniformity and enlargement of crystalline grains in homogeneous PdO films. The results of Hall effect measurements have shown that at room temperature PdO films prepared at T = 870 - 1070 K were characterized with p-type conductivity and hole densities of about ~ 10^{16} cm^{-3} and 10^{15} cm^{-3}, respectively. It has been found that the energy band gap values increased monotonically from ΔE_g = 2.15 eV to 2.3 eV for PdO films with p-type conductivity oxidized at T = 670 K and 1070 K, respectively. At ozone detection (concentration interval from 90 ppb to 230 ppb) PdO films fabricated on polished poly-Al_2O_3 have shown high values of sensitivity, signal stability, and reproducibility of sensor response (Figure 1). The values of sensor response have varied from S = 8.2 to S = 14.5 at ozone concentration 90 ppb and 230 ppb, respectively.

Conclusion & Significance: For fabrication of gas sensors the application of PdO thin and ultrathin films has some advantages in comparison with other materials because PdO films have shown good values of sensor functional parameters, and their synthesis procedure is rather simple and is compatible with planar processes of the microelectronic industry also.

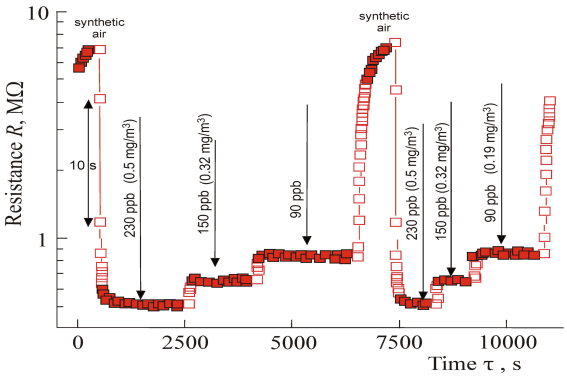


Figure 1. Time dependence of PdO sensor resistance at different ozone concentrations (operating temperature T_d = 490 K, film thickness ~ 25 nm).

Recent Publications

1. Estimating Mortality Risk Reduction and Economic Benefits from Controlling Ozone Air Pollution. Report of the US National Academies of Sciences (2008) The National Academies Press, Washington.
2. Korotcenkov G, Cho BK (2012) Ozone measuring: What can limit application of SnO_2-based conductometric gas sensors? Sensors and Actuators B.161 28–44.
3. Varenne C, Ndiaye A, Brunet J, Monier G, Spinelle L, Pauly A, Bideux L, Lauron B, Robert-Goumet C (2012) Comparison of InP Schottky diodes based on Au or Pd sensing electrodes for NO_2 and O_3 sensing, Solid-State Electronics. 72 29–37
4. Da Silva LF, Mastelaro VR, Catto AC, Escanhoela CA, Bernardini S, Zilio SC, Longo E, Aguir K (2015) Ozone and nitrogen dioxide gas sensor based on a nanostructured $SrTi_{0.85}Fe_{0.15}O_3$ thin film. J. of Alloys and Compounds. 638 174–179.
5. Ievlev VM, Kushchev SB, Sinel'nikov AA, Soldatenko SA, Ryabtsev SV, Bosykh MA, Samoilov AM (2016) Structure of heterosystems formed by a SnO_2 film and island metal (Ag, Au, or Pd) condensate. Inorganic Materials. 52 700–707.



Biography

Oleg G Kuzminykh got a bachelor degree in Material Sciences in 2016. Now he is the MA course student at Voronezh State University. Previously, his scientific interest concern was in the study of narrow-band gap semiconductors with infrared radiation sensitivity. In particular, he studied the microstructure of lead telluride thin films prepared on silicon and barium fluoride substrates by "hot wall" technique. Now he studies the wide band gap metal oxide semiconductors for gas sensors.

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Notes/Comments: