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Effect of noble metal functionalization and film thickness on sensing properties of sprayed TiO_2 ultra-thin films

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Abstract

In this paper, the effect of the thickness of nano-structured TiO_2 thin films (12–40 nm) and successive deposition of different noble metal nanoparticles on the performances of propanol vapor and H_2 gas sensors was investigated. The obtained titania thin films were integrated into a device for UV, gas, and gas/vapor sensing studies at different operating temperatures. Qualitative analysis revealed that the sensor selectivity and its response could be altered by film thickness and type of noble metal nanoparticles. The results indicate that the sensor with 40 nm TiO_2 film has the highest response to H_2 gas (~ 650%). The fastest response time and the most rapid recovery however were achieved by the sensors made of 12 nm sprayed TiO_2 ultra-thin films, which also offered the highest selectivity to H_2 gas.

The best UV detection performances were demonstrated by films functionalized with Au nanoparticles (the $I_{UV}/I_{dark} \approx 80$). The structural, chemical, electrical, UV, and gas sensing properties of such films were investigated using SEM, AFM, Raman spectroscopy, electrical characterization, and sensing experiments. It has been clearly demonstrated that films are nanostructured and have mixed phases that contain mostly anatase (annealed at 450 °C) and small amounts of rutile after thermal annealing at higher temperatures (more than 600 °C), as improved materials for sensor applications. Our combined study analyzes the relationship between thickness, electrical properties and the gas/vapor sensing performance of such thin film based TiO_2 gas sensors as well as the effect of different types of noble metal nanoparticles (Au, Ag, Ag-Au and Ag-Pt) deposited on the surface. The enhanced response was attributed to the involvement of noble nanoalloy or nanoparticle interface to titania forming nano-junctions in the gas sensing mechanism. Highly selective and sensitive sensors towards specific gas or vapor molecules are essential for environmental monitoring, and for health and safety issues.