$\frac{Ro - Rg}{Rg}$

The effect of Au and Pt nanoclusters on the structural and hydrogen sensing properties of SnO_2 thin films

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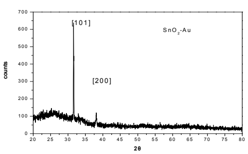
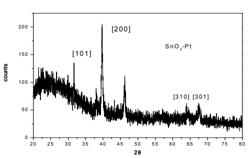
Abstract:Au and Pt nanoparticle modified SnO_2 thin films were prepared by the sol-gel method on glass substrates targeting sensing applications. Structural and morphological properties of these films were studied using X-Ray Diffraction and Scanning Electron Microscopy. It was proved that the films crystallized in tetragonal rutile SnO_2 crystalline structure. Scanning Electron Microscopy observations showed that the metallic clusters dimensions and geometry depends on the kind of the metal (Au or Pt) while SnO_2 films surface remain almost the same: nanostructured granular very smooth. Optical properties of the films were studied using UV-visible spectroscopy. The modified SnO_2 films were tested as hydrogen sensors. The response of SnO_2, SnO_2-Au and SnO_2-Pt thin films against hydrogen was investigated at different operating temperatures and for different gas concentrations. The addition of metal nanoparticles was found to decrease the detection limit and the operating temperature (from 180° C to 85° C), while increasing the sensing response signal. Au and Pt nanoparticle modified SnO_2 thin films were prepared by the sol-gel method on glass substrates targeting sensing applications. The modified SnO_2 films were tested as hydrogen sensors. The response of SnO_2, SnO_2-Au and SnO_2-Pt thin films against hydrogen was investigated at different operating temperatures and for different gas concentrations.

Structural, morphological and optical properties of SnO_2 thin films

XRD characterization



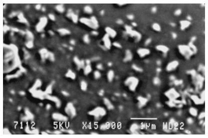
SnO_2-Au



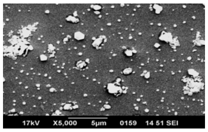
SnO_2-Pt

- The SnO_2-Au film is polycrystalline with a clear tendency of texturing in the [101] and [200] crystalline directions of the tetragonal rutile structure.
- SnO_2-Pt film has shown a weaker tendency for texturing with a preferred orientation towards the [200].
- This is a clear indication of the catalytic effect that these two metals have on the growth structure of the SnO_2 films.

SEM characterization



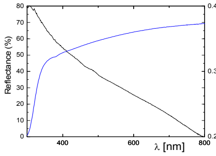
SnO_2-Au



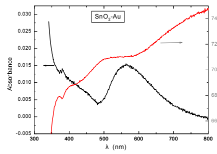
SnO_2-Pt

- All samples show the presence of a granular structured film of SnO_2 with randomly distributed shaped particles on the surface.
- The sample SnO_2-Au, ignoring the quite big features of few μm dimensions, the top particles are the most irregular shaped with dimensions of few hundreds nanometers.
- In the SnO_2-Pt thin film, the top features are clearly hexagonal faceted. The dimensional distribution seems to be more homogeneous.

Transmittance and Reflection spectra



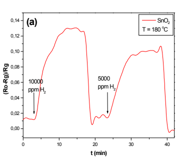
SnO_2-Pt

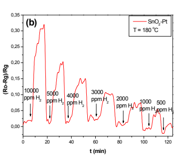


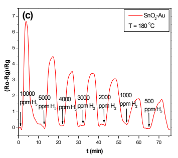
The surface plasmon resonance (SPR) shows a peak at 560 nm in the absorption spectrum.

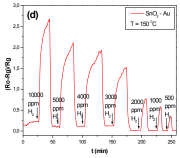
Hydrogen sensing properties

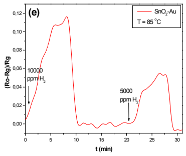
Results and Discussion



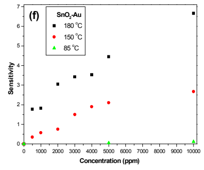


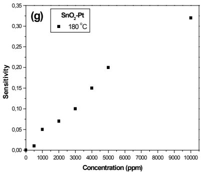






- Hydrogen sensing tests were performed in an aluminum vacuum test chamber. The hydrogen concentration was calculated on the basis on the partial pressures of the sensing gas and dry air inside the chamber. A bias of 1 V was applied, and the current through the film was recorded. Current modifications helped to monitor the hydrogen sensing in real time.
- The sensitivity was defined as: S = (Ro-Rg)/Rg where Ro is the resistance of the film in dry air and Rg is the resistance of the film in the gas/air mixture
- It is clear that the sensitivity of all SnO2 sensors towards hydrogen showed a strong dependence on both the operating temperature and gas concentration. For the same operating temperature, the response of the sensors towards hydrogen sharply increased with the increase of gas concentration.
- Modifying SnO_2 with Au nanoparticles decreased the sensor working temperature with respect to the unmodified one from 180 down to 85°C, while the response increased almost by 50 times at the temperature of 180 °C. Hydrogen detection as low as 500 ppm was then possible.
- At 180 °C the SnO_2 films have shown a response of about an order of magnitude while this was enhanced distinctly by the presence of Pt in the SnO_2-Pt modified films.

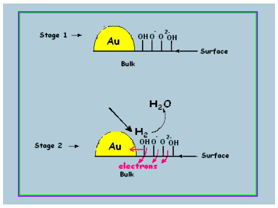




Sensing mechanism

- The atmospheric oxygen adsorption may remove electrons from the conduction band, resulting in the formation of localized either O^- or O_2^- depending on the temperature. In the presence of metal (Pt or Au) catalysts on the sensor surface, the hydrogen gas splits up into hydrogen atoms, which form protons by donating the electrons to the conduction band of nanocrystalline doped SnO_2 film.
- The electron gain increases the film conductivity, which is reflected in the drop in the initial sensor resistance. The generated protons get associated with the surface adsorbed oxygen-ions (O^- or O_2^- ions) and hop from one oxygen-ion to another. During this process, the two adjacent OH-groups may condense to form H_2O that evaporates. The overall reaction can be summarized as:

$$H_2 + O^- \rightarrow H_2O + e^-$$



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