GAS SENSING CHARACTERIZATION OF TELLURIUM THIN FILMS BY KELVIN PROBE TECHNIQUE

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Kelvin probe (KP) consist of a vibration capacitor inducing an a.c. between the sample and a vibrating reference electrode, as a consequence of the contact potential difference (CPD) resulting from the different work function of them. KP is a high precision method for the measurement of work function variation of the sample induced by adsorption of gasses, i.e. it is very useful for the characterization of materials for sensor application [1].

In this paper, the change of work function ($\Delta\phi$) of the tellurium thin films was studied in response to different concentrations of nitrogen dioxide, carbon oxide, ozone and water vapor using a KP with a gold grid reference electrode. In all experiments, the relative change of work function was determined at room temperature.

Tellurium sensitive layers were prepared by thermal vacuum deposition onto glass substrates under working pressure of 10^{-5} Torr. The structure and surface morphology of the films were studied by XRD analyses and SEM. Ambient air was used as carrier and reference gas. It was shown that pollutant vapors leads to increase of the change of work function defined as:

$$\Delta\phi = \phi_{vapour} - \phi_{air},$$

Where ϕ_{air} and ϕ_{vapour} are the work function of tellurium film measured in pure air and in the presence of vapour of interest respectively. The introduction of 1,9 ppm of NO_2 increases the work function by around 75 mV. The impact of humidity on the work function change of Te thin films is also quite noticeable. Relative humidity of 30% induces the work function change by approximately 100mV.The variation of work function by introduction of other gases, such as CO or ozone appears to be smaller by two orders of magnitude.

The work function of a semiconductor (e.g. Te) consists of several terms: $\phi = \mu + \phi_0 + \Delta\varphi$, where μ is a bulk chemical potential, ϕ_0 is the surface dipole potential and $\Delta\varphi$ is the eventual band bending. Consequently the work function variation, induced by either pollutants or water vapour adsorption, can be caused by any change in the last two terms contributing to ϕ, i.e. ϕ_0 and $\Delta\varphi$.

Adsorption of NO_2, carbon oxide or ozone results in increasing of both work function difference ($\Delta\phi > 0$) and electrical conductivity ($\Delta\sigma > 0$) [2]. As elemental tellurium exhibits p- type conductivity, such a behavior means the increasing of band bending due to acceptor character of NO_2 (or other mentioned gases) molecules.

Adsorption of water vapour leads also to increasing of work function change ($\Delta\phi > 0$) but diminishes the electrical conductivity of the film ($\Delta\sigma < 0$) [3]. Such a behavior cannot be caused by band bending variation and probably arises from variation of surface dipole potential, i.e. ϕ_0.

The water molecule exhibits a high ($15 \cdot 10^{-30}\, C \cdot m$) dipole moment. As it approaches the surface of positive charged Te film it rotates and orientates its dipole moment perpendicular to this surface with a negative pole inward. At the same time, the free lattice hole becomes localized at the surface, which diminishes the electrical conductivity of the film. Formation of a double electrical layer on the surface of Te film in a humid environment (water vapour adsorption), which influences the work function change is confirmed also by negative values of CPD measured vs. a vibration gold grid reference electrode.

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