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The causes of thickness dependence of CdSe and CdS gas-sensor sensitivity to oxygen

V.A. Smyntyna[a], V. Gerasutenko[a], S. Kashulis[b], G. Mattogno[b] and S. Reghini[b]
[a]*Odessa I.I. Mechnikov State University, Odessa (Ukraine)*
[b]*Istituto di Chimica dei Materiali, Area di Ricerca di Roma, Monterotondo Scalo (RM) (Italy)*

Abstract

The sensitivity of semiconductor sensors based on thin films depends on their thickness, in almost all cases. This phenomenon is of practical usage but its mechanism is not revealed completely. CdSe and CdS films were used as sensors for the detection of oxygen. CdSe films were made by thermal evaporation in vacuum, and CdS films by electrohydrodynamic spray of the liquid on to the heated substrate. Changes in composition and in adsorption sensitivity of the sensors were studied by X-ray photoelectron spectroscopy (XPS) and secondary ion mass spectroscopy (SIMS) methods. The irregular distribution of components along the thickness and the peculiarities in their ratio near the substrate have been observed. The model of CdSe and CdS sensor adsorption sensitivity dependence on thickness is developed, based on the obtained data.

Experimental

The surface of CdSe films with thickness of 2400 Å, 3600 Å, 4800 Å and after its etching for the thickness 90 Å have been investigated by the Auger spectroscopy method. The films were produced by evaporation on glass ceramic substrates under the open vacuum and substrate temperature equal to 300 K. The oxygen chemisorption was carried out at room temperature, then the film was held in vacuum at 10^{-7} Pa during 20 h.

The peaks of Cd, Se, O, S, C were observed at the Auger electron spectrum of CdSe as-prepared films (Fig. 1). After etching of the films by Ar^+ ions the peaks of O and S disappeared and the intensity of carbon peak considerably decreased. The evaluation of surface composition was carried out taking into account the factor of elemental sensitivity, *s* [1] and it was calculated according to the usual procedure [2].

Results

The ratio of Cd to Se concentrations (C_{Cd}/C_{Se}) at the film surface increases with the film thickness in the range of 2400 Å$<d<$4800 Å (Fig. 2, curve A). The difference between the values of C_{Cd}/C_{Se} characterizing the surfaces of the initial film (Fig. 2, curve A) and the one produced after etching (Fig. 2, curve

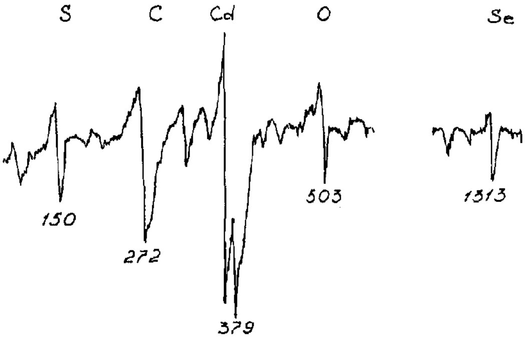

Fig. 1. The observed spectrum of Auger electrons, measured at cadmium selenide film surface with the following transitions: S, LMM; C, KLL; Cd, MNN; O, KLL; Se, LMM.

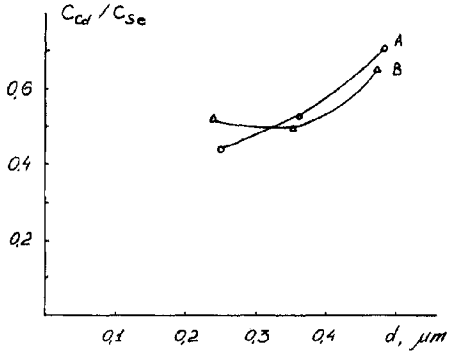

Fig. 2. C_{Cd}/C_{Se} concentration ratio vs. cadmium selenide film thickness: (A) surfaces of initial films; (B) surfaces created by initial film etching for the depth 90 Å by Ar^+ ions.

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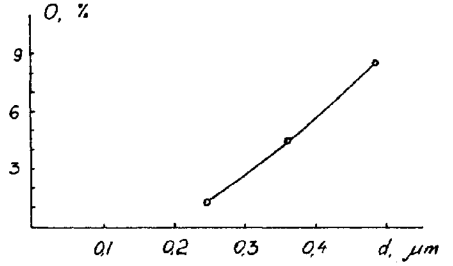

Fig. 3. Oxygen concentration at the surface of cadmium selenide films vs. their thickness.

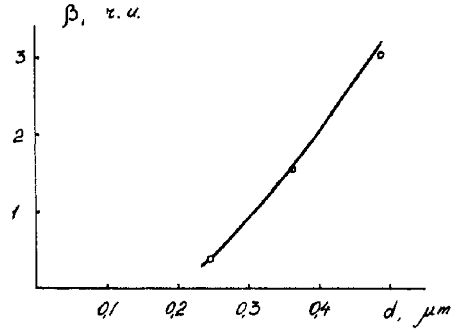

Fig. 4. Cadmium selenide film adsorption sensitivity vs. their thickness.

B) shows the various characters of the Cd and Se distribution profiles in the near-surface region.

Figure 3 shows the dependence of the concentration of chemisorbed oxygen on the surface of cadmium selenide films on their thickness. The data for Figs. 2 and 3 show that the cadmium surface concentration increase causes the chemisorbed oxygen concentration raising which results in an increase of electrons captured at the surface centres of the oxygen chemisorption.

The thermal treatment of such films containing the chemisorbed oxygen on their surface shall lead to an increase in the film electrical conductivity in vacuum, resulting in desorption of oxygen and electron ejection into the conduction band. Adsorption sensitivity of the films was determined according to the formula:

$$\beta = \frac{\sigma_t - \sigma_0}{\sigma_0} \quad (1)$$

where σ_t is the electrical conductivity after desorption, σ_0 the initial electrical conductivity of the films containing the chemisorbed oxygen on their surface. Figure 4 shows the increase in the sensitivity of the CdSe film adsorption versus film thickness.

Discussion

The results presented show that during the growth of CdSe films self-doping by Cd atoms takes place. The increase of the Cd relative content on the surface accompanies the increase in oxygen species chemisorbed on the film surface. Simultaneously, their adsorption sensitivity defined by the electrical conductivity changes also increases. Therefore, the Cd enrichment on the surface promotes the adsorption sensitivity increase for the sensors based on CdSe films.

References

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