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Study of the Structure of the SnO_2 Thin Films Obtained by the RGTO Technique

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The results on the use of technology of rheotaxial growth and thermal oxidation to prepare sensory layers of stannic oxide (SnO_2) are presented in this study. Sensory properties of the SnO_2 layers greatly depend on a stage of tin layer rheotaxial growth. Observations of tin layer surface made after the process of rheotaxial growth and of the SnO_2 surface on the oxidation stage performed by means of a scanning electron microscope permitted drawing of many substantial conclusions regarding technology of production. The worked out technology made it possible to form sensor structures, which were next measured.

Ключові слова: водень, зарядність, бозон, ферміон, метал, масоперенесення.

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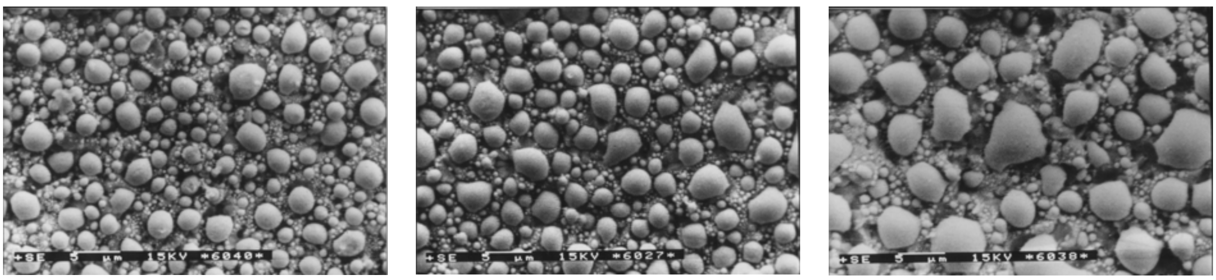
Introduction

Physical and chemical properties of the SnO_2 thin films have elicited great interest as they appeared to be suitable for use in the sensor systems.

The paper describes research work which was aimed to optimise technological processes for the preparation of the Sn thin films by the RGTO *(Rheotaxial growth and thermal oxidation)* technique and their oxidation into SnO_2 in order to increase sensitivity to gas (NO_2)). Particular attention was drawn to the possibility of precise predicting of a thickness of the Sn thin film obtained, as the processes of SnO_2 reactions with gases take place within a thin surface layer of this material. The ratio of the thickness of reacting layer to the overall layer thickness has an essential effect on the sensitivity coefficient of the material with the sensor structure.

I. Tin deposition

The RGTO technology employs characteristic property of tin – its relatively low melting temperature $T_t = 231.84^0C$ [1]. Tin is deposited in this technology onto a substrate heated to the temperature above T_t. The material deposited onto a hot substrate aggregates into small balls uniformly distributed on the surface of a substrate and this distribution persists after material cooling. Identification of numerous parameters of this process would enable obtaining technologically stable Sn thin film, whose quality has significant effect on the result of the oxidation process and, subsequently, parameters of the sensor [3,4].



a) b) c)

Fig. 1. SEM images of the Sn thin films on a ceramic substrate (×4200) for different sedimentation temperatures: a) 265°C; b) 275°C; c) 285°C

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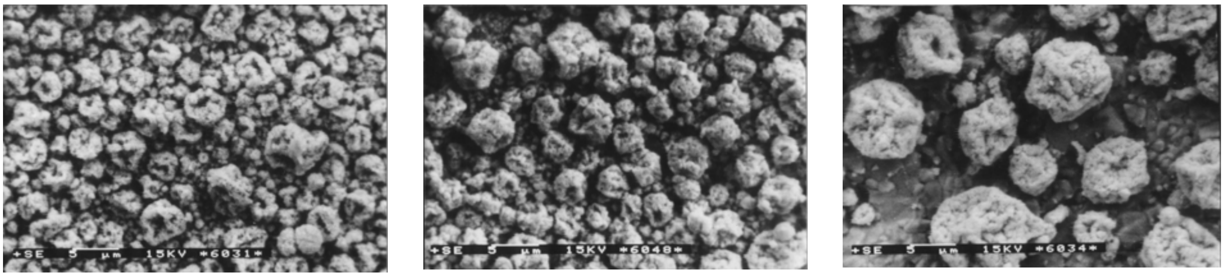

Fig. 2. SEM images of the SnO_2 thin films on a ceramic substrate (×4200)) for different heating basis temperatures: a) 265°C; b) 275°C; c) 285°C

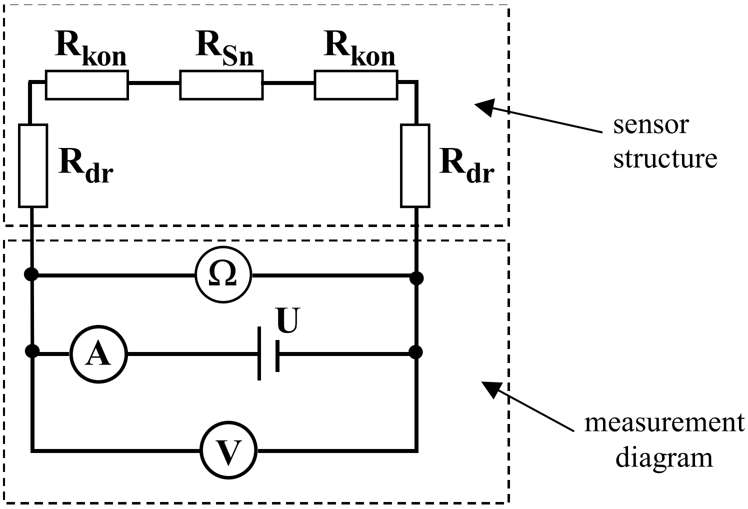

Fig. 3. Diagram for measuring the dependence of various sensor structures resistance.

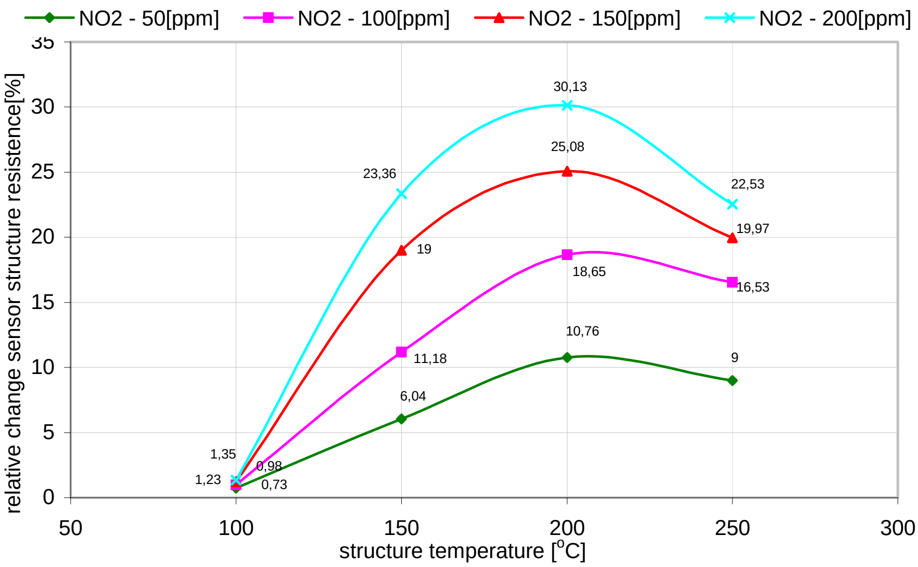

Fig. 4. Relative changes of sensor structure No I resistance, with the possibility to change gas NO_2 concentration and the operating temperatures.

II. Thermal oxidation of Sn into SnO_2

During this operation, the tin surface became covered with a spongy layer of tin dioxide, and the volume of spherical structures increased by about 30 %. This enabled formation of electric connections between these structures so that such layer could be used in the resistance type gas sensors [2].

III. Electric properties of the SnO_2 thin films

The SnO_2 thin films obtained during the experiments carried out were used to make test sensor structures. Next, they were subjected to further tests for detecting

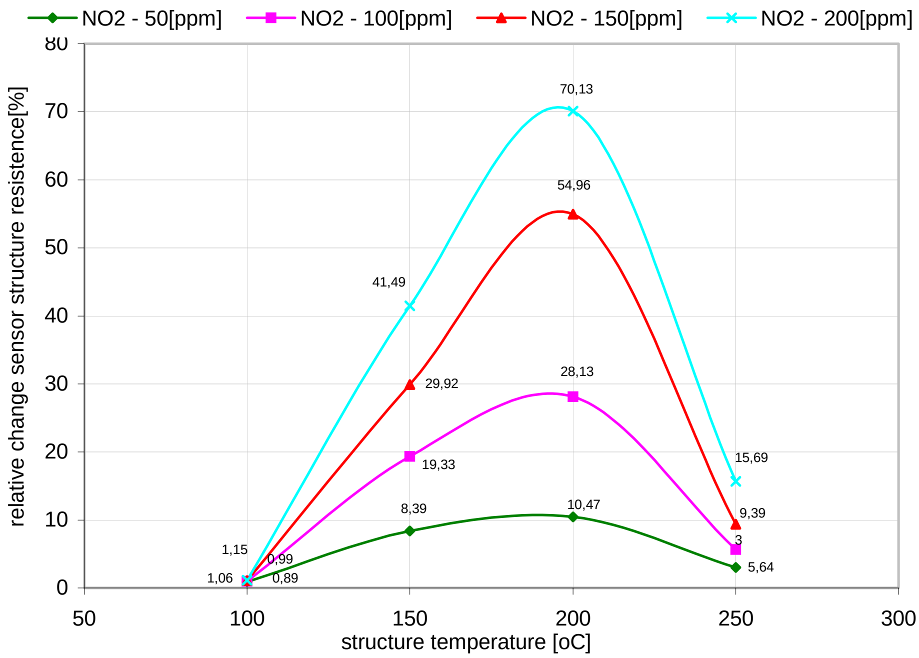

Fig. 5. Relative changes of sensor structure No II resistance, with the possibility to change gas NO_2 concentration and the operating temperatures

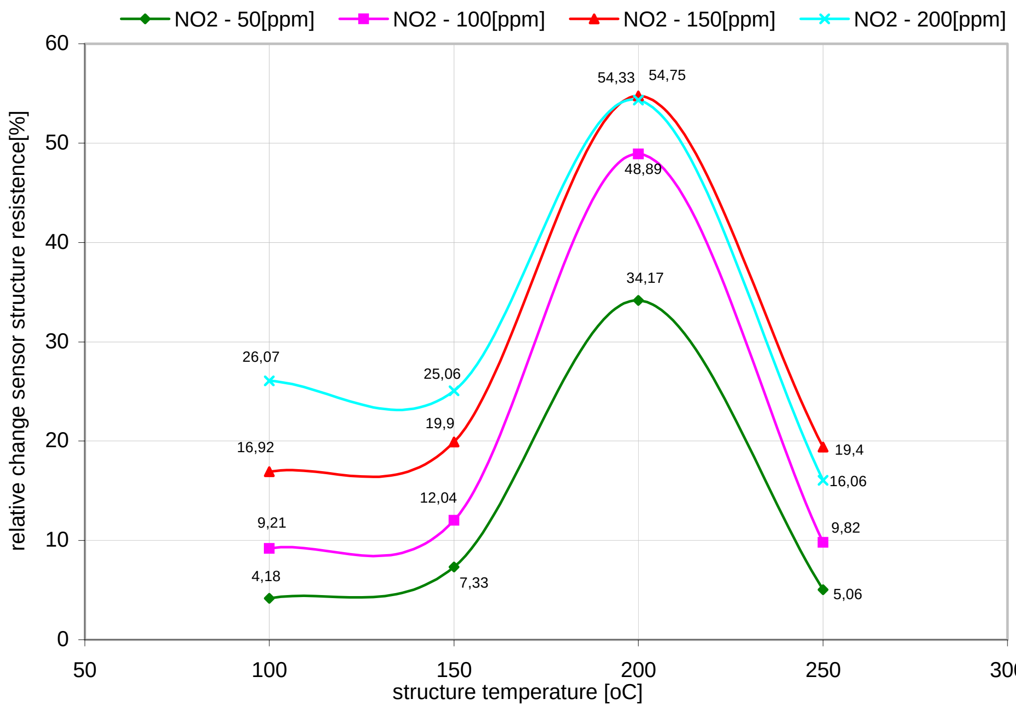

Fig. 6. Relative changes of sensor structure No III resistance, with the possibility to change gas NO_2 concentration and the operating temperatures

NO_2 concentration. Parameters of the structures were measured at the experimental stand and with the possibility to change gas concentration and control the temperature for particular structures [3].

Fig. 3. Diagram for measuring the dependence of various sensor structures resistance.

R_{Sn} – sensor structure resistance,

R_{kon} – contacts resistance,

R_{dr} – wires resistance,

U – solid power source,

it was found, that the contacts and wires resistance, obtained during further tests to detectc NO_2, are:

$$R_s=2R_{kon} + 2R_{dr} = const$$

Relative changes of SnO_2 sensor structures No I, II and III resistance, which were made in different heating temperatures T_{basis} = 265°C, 275°C, 285°C, with the possibility to change gas NO_2 concentration and the operating temperatures have been shown in Fig. 4, 5, 6.

Conclusions

This work enabled modification of the known process of rheotaxial tin deposition by application of some technological and design solutions. It was found that application of a simple procedure for estimating thin film thickness enabled reaching satisfactory results. Experimental sensor structures were made and subjected to tests with the use of specialized measuring instrumentation, showing that these structures were suitable for use in gas sensors.

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Йержі Ульянов, Кшиштоф Вачинські

Дослідження структури тонких плівок SnO_2, одержаних за RGTO- технологією

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В даному дослідженні представлено результати застосування технології епітаксійного росту і теплового окислення, для підготовки чутливих шарів олов'яного оксиду (SnO_2). Сенсорні властивості шарів SnO_2 дуже залежать від стадії епітаксійного росту олов'яного шару. Обстеження поверхні олов'яного шару, зробленої після епітаксійного росту і поверхні SnO_2 на стадії окислення, за допомогою скануючого електронного мікроскопа. Робота поза технологією дала можливість сформувати сенсорні структури, які були надалі виміряні.