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# The Study of the Various Factors Current-Voltage Characteristics of the Gas Sensor Sensing Element

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**Abstract:** ***The work deals with the influence of various factors (temperature, gas environment, doping the sensor) on the current-voltage characteristics (CVC) of thin-film structures based on gas-sensitive tin dioxide***

## 1. Introduction

Effect of sorption thermally resisting metal oxide thin films are widely used in gas sensors. Miniaturization gas sensors while maintaining the operating voltage causes an increase in the electric field in the gap between the contacts, which stimulates the migration ionosorbirovannyh gas particles on the surface of the active layer and affect the performance of gas-sensitive devices in general that can be used to detect the type of gas being analyzed [1, 2].

The aim is to investigate the influence of different factors (temperature, gas environment, doping the sensor) on the current-voltage characteristics (CVC) of thin-film structures based on gas-sensitive tin dioxide.

Research object a crystal of the gas sensor 1 × 1 $mm^2$, containing the following elements: a heater and contacts for sensitive layer in the form of interdigitated structures of platinum with a contact separation of 10 microns, and two gas-sensitive element (SE) based on tin dioxide, one of which is doped with silver, and the second sensor and by undoped used for comparative characteristics [3, 4]. For the study used the following equipment: two power supply DC Power Supply HY 3005, three multimeter MASTECHMY64, measuring cell. The current through the gas sensing element is controlled by the magnitude of the voltage drop across the reference load resistor in series with the SE. Voltage fed to CHE in the range from 0 to 30 in steps of 0.5 V For prolonged storage the oxygen sensor from the air molecules are adsorbed on the surface of the film of tin dioxide, and an electron from grabbing material become ions. Negatively charged ions are repelled from the surface of the conduction electrons, reducing their concentration and leaving uncompensated positively charged donor centers.

Oxygen ions adsorbed on the surface, increase the potential barrier and significantly increase the resistance of sensing element. To return the sensor to a working condition, it is necessary to carry out its high temperature annealing at stabilizing the crystal sensor 300 $^{o}$C for at least 2 hours, and during the operation 30 minutes for the sensors with sensing elements doped annealing is not necessary. The effect of temperature on the CVC SE based on tin dioxide (Fig. 1). It was found that with increasing temperature over the entire range voltage current through SE increases up to temperatures of 100 °C and then in the range of 100 - 350 $^{o}$C decreases (Fig 2.). Consequently, the resistance of the sensitive elements to a temperature of about 100 °C decreases and then increases. changes sensitive elements of resistance mechanism is not a semiconductor, and includes two components: up to temperatures of around 100 °C $SnO_2$ film behaves like a semiconductor, and at higher temperatures, an increase in resistance due to a change in the form of chemisorbed oxygen from $O_2$ to $O_2^-$.

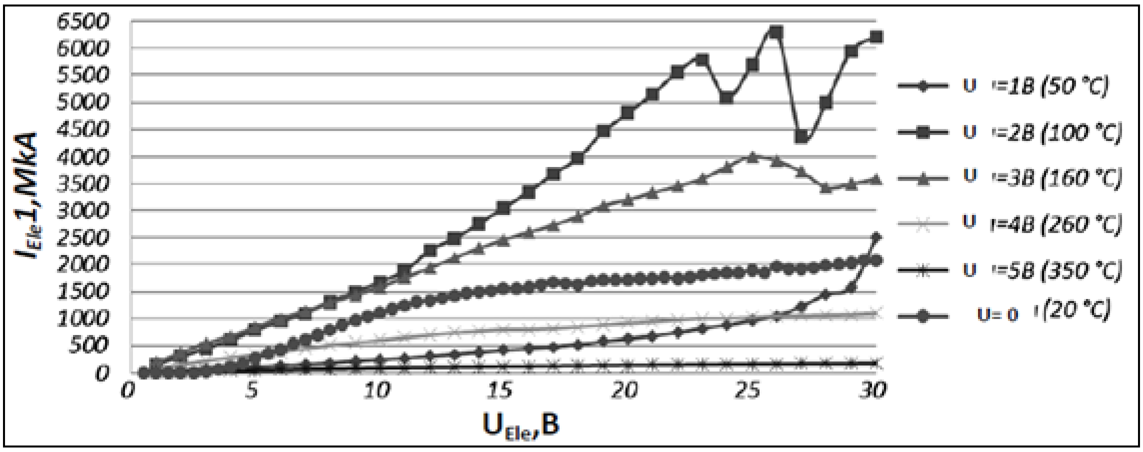



**Figure 1:** Effect of temperature on the current-voltage characteristics of the gas sensor CHE1

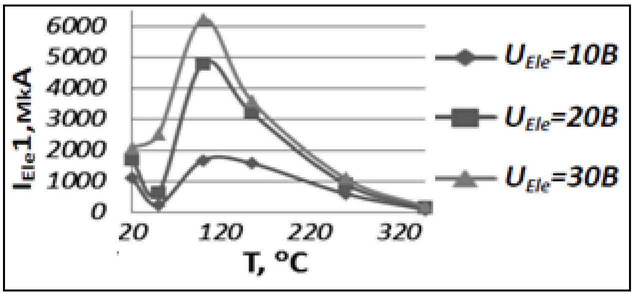



**Figure 2:** The dependence of the current through the temperature sensitive element

It was determined the maximum temperature of the gas sensitivity of SE based on tin dioxide to the pairs of ethyl alcohol $C_2H_5OH$ - 340 °C, to pairs of isopropyl alcohol $C_3H_8O$ - 280 $^{o}$C. The influence of vapors of different substances on the CVC SE. The most heavily CVC sensitive elements in pairs substances diverge at an appropriate temperature of maximal gas sensitivity (Fig .3). CVC Che in air and substances pairs have different inclination angle, which allows to determine the presence of gas in the air CVC, but the quantity of gas sensitivity current (2 to 3 rel. ele) is less than the amount of gas sensitivity on the resist (20 rel. Units).

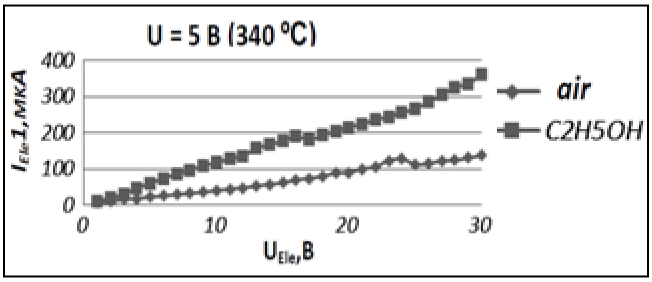



**Figure 3:** CVC undoped CHE air and vapor $C_2H_5OH$ 2000 ppm at atemperature of 340 $^{o}$C

The effect of doping on the silver CVC SE. It is established that at any temperature, the current through the doped Jae higher than undoped; angle SE CVC doped more than the undoped element indicating different mechanisms of current through the doped and undoped material (Fig. 4).

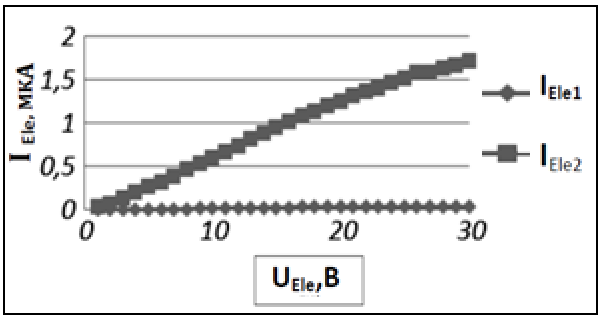
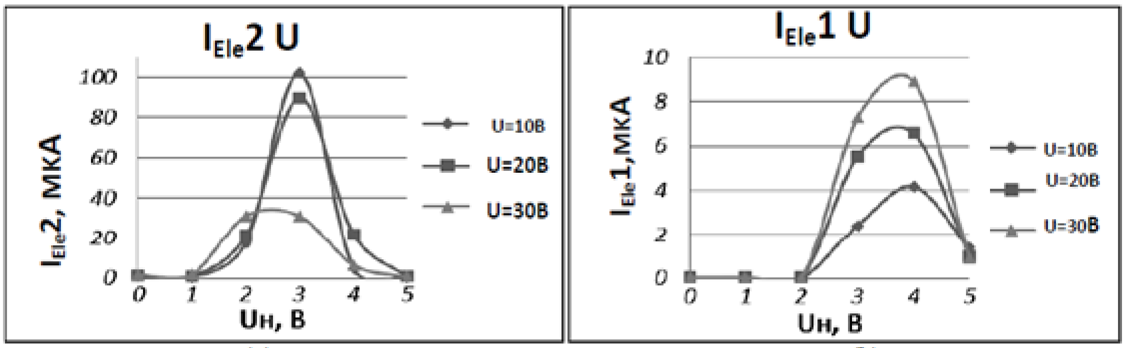



**Figure 4:** The current-voltage characteristics of undoped and doped CHE1 CHE2 at a temperature of 20 ºC

With increasing temperature over the entire range voltage current through SE increases up to about 250 °C temperature for undoped SE and 170 $^{o}$C for Jaedoped, and then in the range of 250 - 370 ºC and 170 - 370 ºC decreases (Fig 5).




(a) (b)

**Figure 5:** The dependence of the current through the SE of the voltage on the heater (temperature) for undoped (a) and doped (b) SE

Consequently, the resistance of the sensitive elements to temperatures of 250 °C and 170 °C decreases and then increases. changes sensitive elements of resistance mechanism is not a semiconductor, and includes two components: up to temperatures of 250 ºC and 170 ºC $SnO_2$ film behaves like a semiconductor, and at higher temperatures, an increase in resistance due to a change of the form of chemisorbed oxygen $O_2^-$ to O (150 - 260 $^{o}$C) or from O to $O_2$ (300 - 500 ºC). It can be assumed that the doping effect on the shape of chemisorbed oxygen.

The temperature dependence of gas sensitivity of doped and undoped SE in ammonia vapor and ethyl alcohol in the air. It was found that the temperature of maximal gas sensitivity to ammonia vapors undoped SE - 120 ºC (3 on the heater), doped with silver SE - 100 $^{o}$C (2.5 volts on the heater). At elevated temperatures, the value of the gas sensitivity in doped SE is much higher (60 rel. Units.) Than that of unalloyed SE (3.5 rel. Units.). Furthermore doped silver SE feels ammonia vapor at room temperature and the sensitivity value of 5 rel. u, which is higher than that of undoped SE at elevated temperatures (Fig. 6).

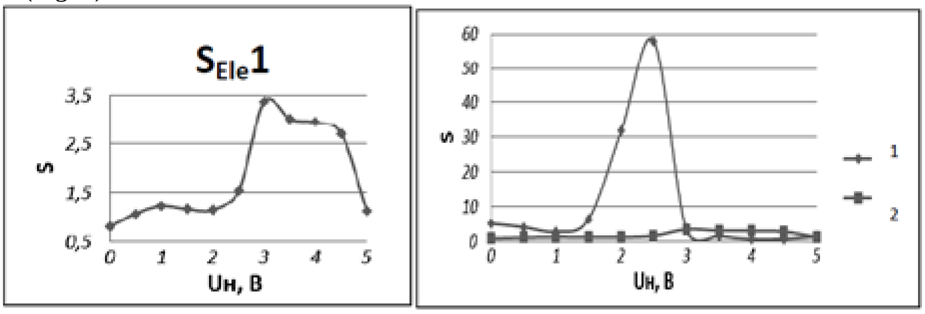



**Figure 6:** Temperature dependence of gas sensitivity of undoped and doped with silver CHE1 CHE2 to 3400 ppm of ammonia vapors in the air

Maximum sensitivity to gas C2H5OH couples on undoped sensing element is shown at 280 °C (4.5 on the heater), to the doped SE - at 80 °C (0.5 on the heater). The amount of gas for the sensitivity of doped and undoped SE 3 is almost the same - 3.5 rel.u, and the temperature at the sensor element doped 3.5-fold lower (Fig. 7).

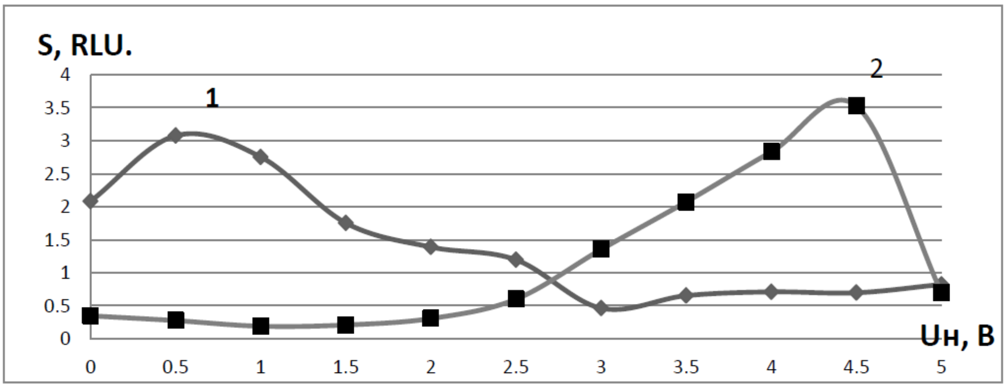



**Figure 7:** Temperature dependence of gas sensitivity of undoped and doped with silver CHE1 CHE2 to couples $C_2H_5OH$ 2000 ppm in air

CVC doped ChE in air and ammonia vapor at a temperature of 20 °C (Fig. 8) and in air and $C_2H_5OH$ vapor at a temperature of 80 °C have a different angle, which allows to determine the presence of gas in the air CVC, but the magnitude of the gas current sensitivity less than the amount of gas sensitivity on resistance. Results of the study can be used in gas sensorics sensors to determine operating temperature at which the possible recognition of the type of gas. It was found that the slope of the current-voltage characteristics with temperature changes, which indicates a change in the resistance Che and that the angle of inclination of the CVC in vapors of different substances from different VAC angle measured in air.

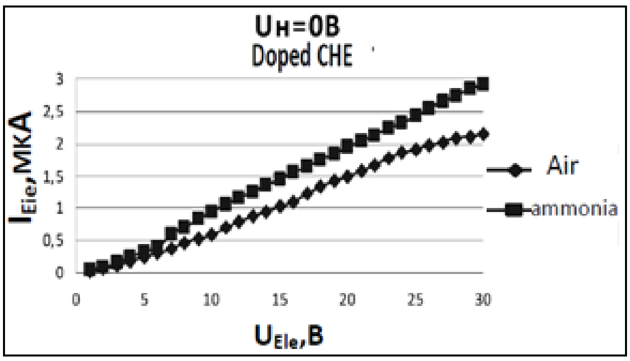



**Figure 8:** CVC doped CHE air and ammonia vapors of 3400 ppm in the air at a temperature of 20 °C

Consequently, according to the CVC SE can judge the value of the gas sensor sensitivity. Doping with silver tin dioxide lowers the temperature of maximal gas sensitivity and increase the amount of gas sensitivity. Additionally, alloying silver tin dioxide allows to produce sensors for determination of ammonia in air, operating at room temperature

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