

**About the properties of the heterostructure based on the nano scale layers
(In₂O₃ + 5%Sn) - p – Si at the change of the gas environment**

V.V. Il'chenko¹, A.V.Yushchenko¹, R.V. Gul¹, L.G. Il'chenko²

¹64, Volodymyrska st.,Radiophysical Dept., 01033 Kiev University, Kiev, UKRAINE ,

² 17, General Naumov, Institute of Surface Chemistry NAS of Ukraine, 03164 Kiev, UKRAINE.

^{1,2}e-mail: vai@rpd.univ.kiev.ua, yav@univ.kiev.ua, grv@univ.kiev.ua

Abstract: In this work the properties of the heterostructure (In₂O₃+5%Sn) -p-Si with the mass thickness of the nano scale layer about 18 nm at the change of the gas environment from the laboratory atmosphere to the saturated vapor of the etyl alcohol were studied.

It is shown that the current - voltage characteristics in the gas environment change the parameters at the replace the gas of laboratory environment to the saturated vapor of the etyl alcohol. The change of the current -voltage characteristics parameters at the change of the gas environment depend from the change of the potential barrier height of the heterojunction and from the change of voltage drop on the adsorptive-active nano scale In₂O₃+5%Sn. The change of the potential barrier height of the heterostructure and redistribution of the voltage drop between the adsorptive-active nano scaled layer and the space charge region of the silicon substrate is determined by the change of the charges volume which are in the layer were established.

Key words: heterostructure, current - voltage characteristics, adsorptive-active nano scaled layer.

INTRODUCTION

Nonlinear current- and capacity-voltage characteristics of the heterostructure depend from the parameters of the intermediate layer between the metal contact and the semiconductor. If as the intermediate layer we use adsorption active nano scaled layer, the physical parameters of the heterostructures will change at the change of gas environment [1]. Non-linearity of response of the current -voltage characteristics and capacitance-voltage characteristics of the heterostructures allows to distinguish the change of type of the absorbed molecules on the adsorption active nano film and at the change of gas environment to estimate the change of interface charge (concentrations of the adsorbed molecules) on it.

EXPERIMENTAL

Heterostructure (In₂O₃+5%Sn)-p-Si was studied with adsorption active nano scaled layer In₂O₃+5%Sn with the mass thickness about 18 nm. We used the system of the magnetron sputtering based on the DVRD-74 equipment. The magnetron sputtering in oxygen-argon plasma from the metals target (95% In and 5% Sn) was used. The silicon wafer (100)- 1 Om·cm with thickness 300µm is used as a substrate . The speed of the magnetron sputtering were about 1 nm/s with the temperature of the substrate about 373 K. Samples with different weight thickness nano scaled layer were made in one working cycle. The investigation of the element composition of the surface of the film was produced by Auger-spectroscopy method. For level-by-level removal of the surface atoms of the film the Ar ion gun was used. The sputtering of the aluminium metal contact was made by the thermal evaporation of aluminium through the mask with the diameter of the contact window equal 1mm. On the back side of the silicon substrate the aluminium ohmic contact were made by the same method.

RESULTS AND DISCUSSION

Results of the research of the nano scaled layer composition by the Auger-spectroscopy method showed, that in the case nano scaled layer with weight thickness 18 nm their structure is non-uniform on the depth (fig. 1). Change of the environment, in which there are structures Al - (In₂O₃ + 5%Sn) -p-Si-Al from laboratory environment to the environment the ethyl vapor change the current –voltage characteristics (fig. 2). The relative response of current -voltage characteristics of heterostructures is considered at the replacement of laboratory environment to the environment of the ethyl vapor are: $\gamma=(I_v-I_g)/I_v$, where I_v , I_g are currents respectively in the laboratory and gas environment at equal voltage applied to heterojunction. On a fig. 3 is shown relative change of value of current through heterojunction depending from the applied voltage to the heterostructure. It is shown that the response of current -voltage characteristics can be expressed through the changes of potential barrier height of the heterojunction and change of voltage drop of the voltage on the adsorptive-active nano scaled layer: $\gamma=1-\exp[e(\Delta\phi_b+\Delta V_1)/kT]$, where $\Delta\phi_b$ is the change of potential barrier height at the change of gas environment; ΔV_1 is the change of voltage drop on the nanofilm at the change of gas environment. $\Delta\phi_b$ obtained by the method of current –voltage characteristics are equal $\approx 0,1\text{eV}$. Decrease of the potential barrier height of the heterojunction, caused by adsorption of molecules of the ethyl vapor introduce the additional positive charge to the adsorptive-active nanofilm In₂O₃+5%Sn . The value of change of the charge we defined through the change of the maximal electric field in the space charge region of the semiconductor. $\Delta E_{\max} = -(2\Delta\phi_b p_2 / \epsilon_0 \epsilon_2)^{1/2} \approx 5,5 \cdot 10^3 \text{ V/cm}$. Then $\Delta\sigma = \epsilon_0 \epsilon_2 \Delta E_{\max} \approx +5,8 \cdot 10^{-5} \text{ Кл/М}^2$, were $p_2 = 10^{16} \text{ cm}^{-3}$ is the

concentration of the hole in the silicon substrate at room temperature; $\epsilon_2=12$ is relative permittivity of the silicon substrate. Change of the voltage drop on the adsorptive-active nano scaled layer obtained from the current –voltage characteristics. The voltage drop on the adsorptive nano scaled layer consists of the voltage drop directly on the adsorptive-active nano scaled layer without taking into account the interfacial states and voltage drop on the interfacial states. In a fig. 4 the dependence of change of the voltage drop at the adsorptive-active layer at the change of gas environment is shown. At direct voltage the increase of a general voltage on the heterojunction results in reduction of the voltage change at the adsorptive-active nanofilm.

CONCLUSIONS

Current –voltage characteristics of heterostructures Al- (In₂O₃+5%Sn) - p - Si -Al with the mass thickness adsorptive nano scaled layer In₂O₃+5%Sn about 18 nm differ in the laboratory atmosphere and in the vapor ethyl and can be used for the creation of gas sensors. Changes of the parameters of the current -voltage characteristics at the replacement gas environment is determined by the change of potential barrier height and change of voltage drop on the adsorptive active nano scaled layer. Offered analysis of the potential barrier height and voltage drop on the adsorptive active nano scaled layer allows to define the sign of the adsorbed charge and its value at the change of gas environment. The future trends of the usage of such heterostructures as element of gas sensors allows to use the well developed of modern silicic microelectronic technology and advantages related to it.

REFERENCES

1. Strikha V.I.; 1982, Contact phenomena in the semiconductors; Higher School; Kiev; pp.321:
2. Il'chenko V.V., Kravchenko A.I., Telega V.M., Chahun V.P., Gaskov A.M., Grinchenko V.T.; 2003; Frequency dependence of the second derivative of the current-voltage characteristic of the heterostructure SnO₂-Si at the gas adsorption Book of abstracts Second IEEE International Conference Sensors. Toronto, Canada, p. 567-568,

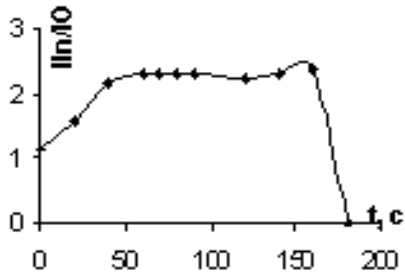


Fig. 1: Relative modifications of intensities of Auger-lines of indium and oxygen during an etching for mass thickness of films $\text{In}_2\text{O}_3 + \square\square\square 5\% \text{Sn}$ 18nm.

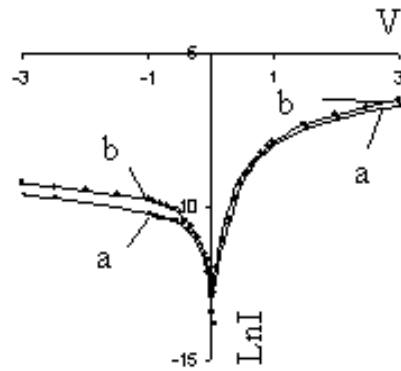


Fig. 2: The current -voltage characteristic of the heterostructure: a) in the laboratory atmosphere b) in the vapor of the etyl .

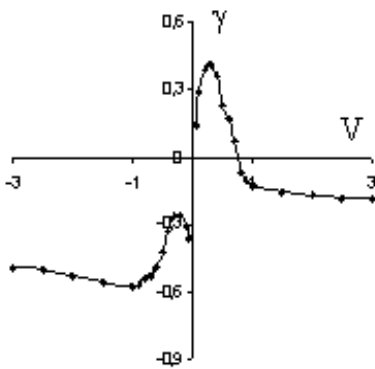


Fig. 3: The response of the current -voltage characteristics at the changes of the gas environment from laboratory atmosphere to the vapor of the etyl.

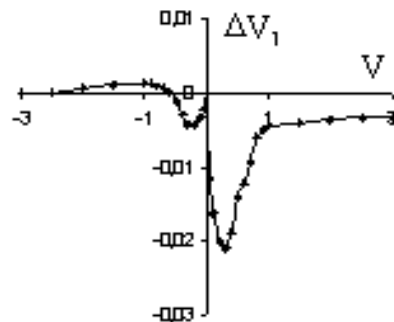


Fig. 4: Change of a voltage on nano scaled layer at the changes of the gas environment from laboratory atmosphere to the vapor of the etyl.