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TEMPERATURE DEPENDENCES OF CURRENT-VOLTAGE CHARACTERISTICS IN STRUCTURES WITH POROUS SILICON LAYER UNDER INFLUENCE OF HYDROGEN ADSORPTION

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1. Introduction

Porous silicon (PS) is a promising nanomaterial combining the available technology and a diversity of physical properties. The constant decrease in dimensions in semiconductor electronics significantly changes the parameters and sometimes principles of semiconductor devices, imposing a need for new approaches and new materials. Therefore the study of properties of PS may become a basis for new generation electronic devices. An important property of PS is the highly developed inner surface, accessible to ambient molecules. This stipulates a high adsorptive activity of PS and influences its electrophysical properties. The main advantage of PS over other existing sensors is its ability to sense gases at room temperature. It appeared interesting to investigate the changes of PS sensing characteristics in the temperature range from 20°C to 90°C (due to fragility of the inner pore network higher temperatures are not possible).

2. Sample manufacturing technology and experiment setup

The researched samples had a sandwich structure metal/PS/monocrystalline Si/Al (Me/PS/SCS/Al). We investigated both samples with Au contacts (samples 1) and with palladium ones (samples 2). A view of samples is shown in Fig.1. The porosity of the PS films was 57% (samples 1 and 2); PS thickness was equal to $3\,\mu\mathrm{m}$.

The PS layer had been formed by electrochemical etching on a heavily doped ($\rho = 0.01\Omega\cdot\mathrm{cm}$) p^+ type silicon substrate. Detailed information on the sample manufacturing technology was reported in [1]. In order to prepare the samples for measurements, contacts were sprayed to the PS surface. The metallization of the surface was carried out by vacuum spraying of gold or palladium.

The bonds were made with the help of a special silver-based adhesive "Conductive Epoxy", immediately after spraying the contacts. They were placed upon the already sprayed metal layer and covered by the adhesive. Care is needed when performing the operation of bonding, as the samples may be easily damaged mechanically or even break if excessive pressure was applied.

The current-voltage characteristics (CVC) were viewed with the help of a characteristic tracer TR–4805. The data was digitalized and processed with the use of "Graph2Digit" and "Origin 7" tools.

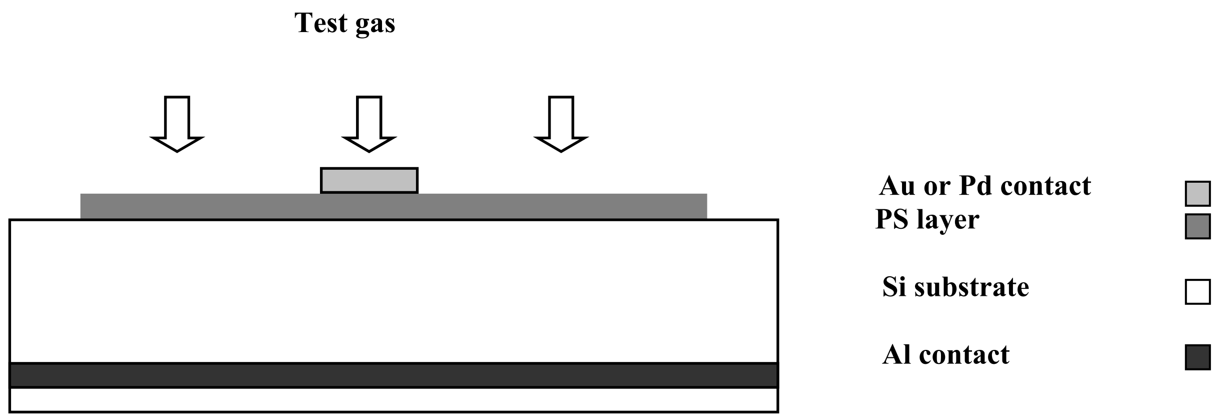

Fig.1. Schematic picture of the sample.

3. Experiment and discussion

CVC for a sample 2 are presented in Figs.2a and 2b for “air” and "air+0.1% hydrogen” media, correspondingly. The behavior of curves for the sample 1 does not differ qualitatively. The temperature dependences of the CVC’s forward region are presented. During the first heating an abnormal behavior of the CVC is observed, the curves shift down with the increase in temperature. Though when the heating is stopped and the sample returned to the initial temperature (20^0C), the hysteresis was observed: CVC lied much lower the initial position. However, if the oscilloscope scan voltage amplitude is increased and then decreased, the CVC return to the initial position and when the sample heated again the anomaly is not observed.

The sample conductivity grows with temperature. The low voltage region for all CVC exhibits a hysteresis (not shown in the figures) the surface of which decreases with increase in the sample temperature. We explain this phenomenon by the presence of water in pores of PS, which may evaporate when the temperature increases. In Fig. 3 CVCs with anomalous behavior are presented. As can be clearly seen, at initial heating a sample unusual behavior CVC is observed, and at rise in temperature direct branches of CVC is shift to lower values. After the heating and return of initial temperature (20°C) CVC of the sample shifts down much below the initial characteristic. But increasing of amplitude of an applied voltage leads to shifting of CVC to initial values, so there is a switching of CVC to original form. At repeated heating of a sample the anomaly on CVC disappears.

Figure 4 depicts the dependence of sensitivity of samples (G_R) measured at the ohm region of the CVC, i.e. by the traditional method [2].

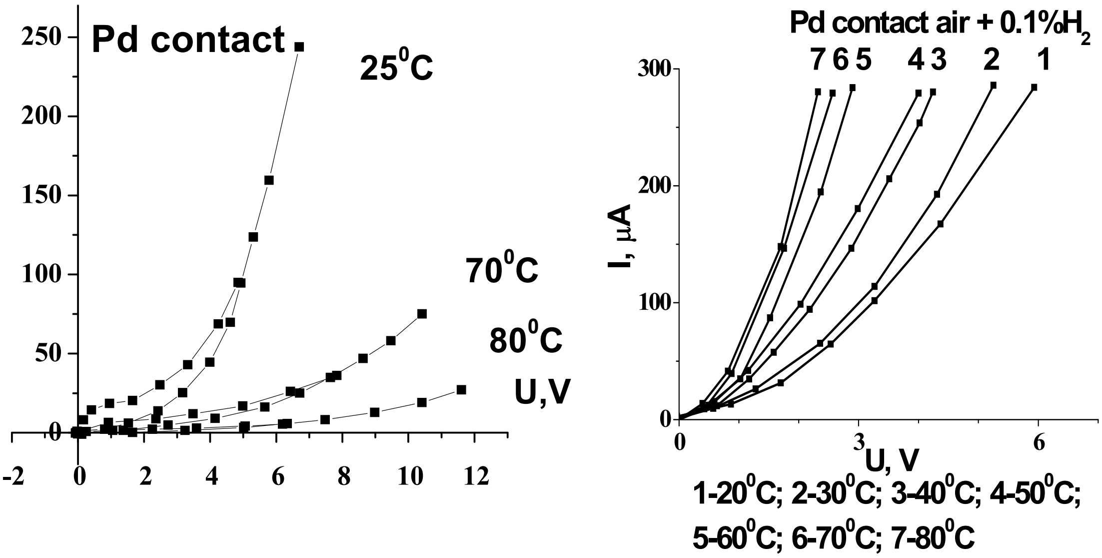

Fig.2. Dependences of CVC on temperature in air (a) and hydrogen (b).

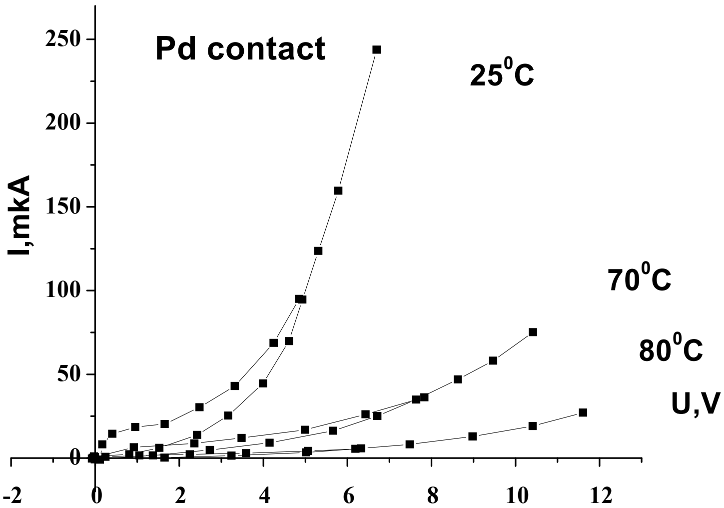

Fig.3. Anomalous CVC. On initial parts hysteresis is specified.

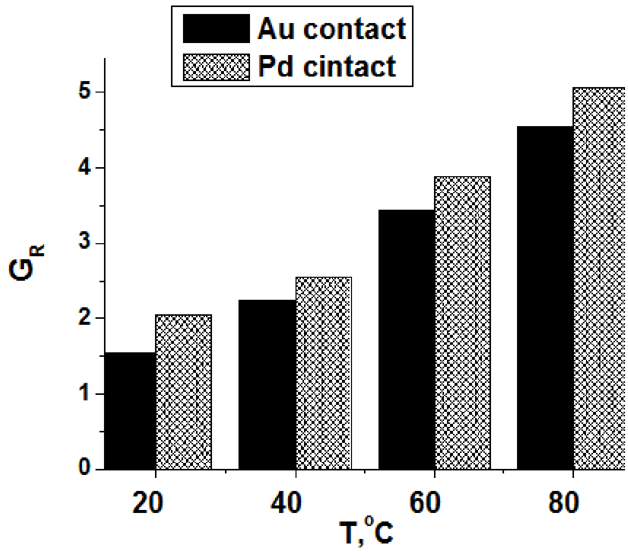

Fig.4. Dependence of the sensitivity G_R on temperature

As the dependence indicates, the sensitivity of the samples grows with the growth of temperature. Moreover, the PS surface covered with Pd is more sensitive to molecules of H_2, than the one covered with Au. The dependence of sensitivity G_R on temperature is shown in Fig.3.

4. Conclusions

1. The temperature dependences of the PS CVC for Au and Pd contacts have been measured.
2. The sensitivity of the investigated samples for the PS surfaces, covered by gold and palladium films, has been measured at different temperatures.
3. It is shown that the sensitivity to hydrogen for the samples with a PS layer grows with temperature.
4. The PS structures with Pd contact show higher sensitivity to hydrogen than ones with Au contact.

References

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2. J. Edert, J.M. Smulko, L.B. Kish, P. Heszler, and C.G. Granqvist. Sensors and Actuators B, 113, 310 (2006).