NOISE PROPERTIES OF THE STRUCTURES CONTAINING A LAYER OF POROUS SILICON, IN AIR AND IN CONDITIONS OF GAS ADSORPTION

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1. Introduction

Noise properties of the structures containing a layer of porous silicon (PS), at adsorption of active gases were investigated by us for PS with porosity of 50% [1, 2]. The purpose of the present work was an experimental research of low-frequency noise in layers of PS with porosity of 73% in dry air, in a mix dry air + 0.4% CO and in a mix dry air + 2% CO, as well as the determination of the noise parameter α_H and parameter γ in the frequency dependence of the noise voltage spectral density $S_U\left(f\right)$ from experimental data.

2. Technical equipment of experiment and samples

Samples with the layer of porous silicon having the Au/PS/SCS/Al structure were investigated, where SCS is the single crystal silicon. PS layer was formed by electrochemical etching on a substrate from strongly alloyed p^+-type silicon with the orientation (100). On a rear part of the substrate for creation of ohmic contact is a layer of aluminum with thickness of 20-30 nanometers spray structure. The top contact from gold sprayed on the surface of PS had a diameter of 1.5 mm. Conclusions to the top contact glue with the help of current-carrying glue on the basis of silver “Conductive Epoxy”.

Measurements of noise characteristics were carried out by the direct filtration method at room temperature in the frequency range of 0.1 Hz − 500 Hz. Measuring installation for research of noise in the system semiconductor − gas [3] includes the input circuit containing low-noise power supply, a measuring gas cell from term glass, low-noise preamplifier having ultra low noise (3,8 nV/Hz$^{1/2}$) and high input resistance (2 GΩ), the spectrum analyzer, HANDYSCOPE 2 (TiePie Engineering). For the Windows software an output on computer was used.

3. Experimental results and discussion

From the resulted plot in Fig. 1, with introduction in air carbon oxide parameter γ in the frequency dependence of the spectral density voltage the noise grows: γ (air) = 0, 5; γ (air + 0.4 % CO) = 1, γ (air + 2 % CO) = 1, 3.

The parameter α_H was determined for the frequency 10 Hz from empirical Hooge’s formula

$$\alpha_H = S_U N f^{\gamma} / U^{\delta} . \tag{1}$$

Here S_U is the spectral density of the noise voltage, N is the number of free carriers in a sample, α_H is the dimensionless Hooge parameter, U is the applied voltage on the studied structure, γ is the frequency index which usually is approximately equal to unit, $\delta \approx 2$.

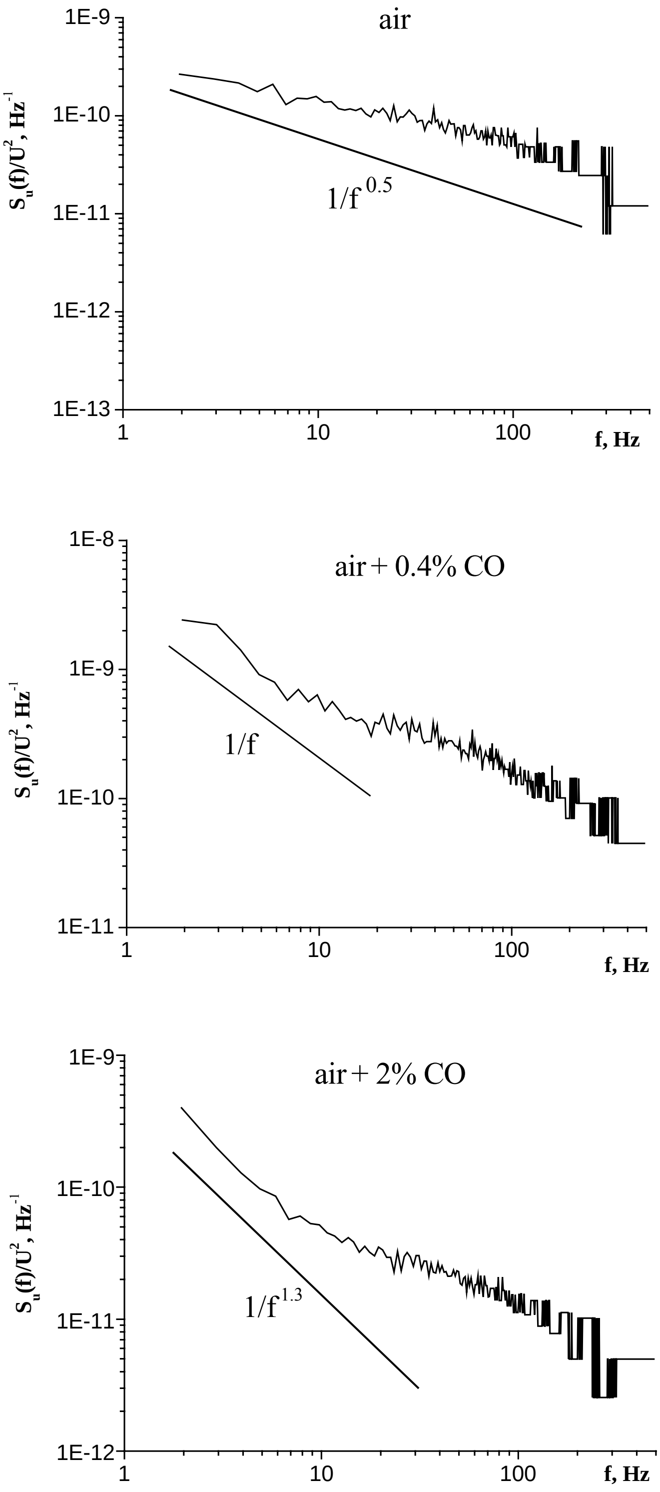

Fig. 1

The values of S_U, U^{δ} and γ were determined experimentally from the spectra measured in work (Fig. 1), the value of N was estimated from the formula $N = l^2 / Rq\mu$, where l is the thickness of PS layer, q is the elementary charge equal to $1.6 \cdot 10^{-19}$ C, R is the resistance of a sample, μ is the hole mobility equal to 7.4×10^{-3} cm ^{2}/V·s [4].

Comparison of the values of α_H show that for crystal materials α_H is several orders higher, than in crystal structures. But, as was noted in [5], in numerous researches it has been shown that in the disordered structures, including PS, α_H can take values from 1 up to 10^4. One of the reasons of this is a very low mobility of carriers in the disordered materials to which porous silicon concerns also. The non-uniform current density through a sample also can bring to great values of α_H [6]. Probably in our case this can be caused by the nano-crystallite structure of the PS layer. The non-uniform density of the current in a nano-crystallite arises for several reasons: a) coral-like systems of silicon variable cross-section strings, b) the presence of the depletion region around each pore, and c) inhomogeneity of free charge carriers' density and mobility.

It was obtained that the value of α_H varies at introduction of carbon oxide in air, and with increasing fraction of CO in air α_H increases. We explain this as follows. With the increase in the concentration of gas molecules the number of molecules adsorbed on a surface increases and then the density of traps located at the interface of PS/SCS increases. The hetero-barrier height at gas adsorption decreases with increasing adsorbate concentration. Therefore the effect of a potential barrier, in comparison with increasing concentration of surface traps, becomes less important.

With increase in porosity and in air of polar molecules CO carbon $S_U(f)$ grows. Accordingly varies and noise parameter α_H.

4. Conclusion

Numerical values of the noise parameter α_H which are in agreement with values of α_H obtained for disordered structures are appreciated. The dependence of the noise parameter α_H on chemistry of the environment gas in which there is a sample is found out. The possible reasons of great values of α_H for samples in air and its increase in conditions of gas adsorption are discussed. With introduction in air carbon oxide in the frequency band of 1 Hz - 10 Hz is found out growth of a frequency index γ in dependence $1/f^{\gamma}$.

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