METHOD TO DETERMINE THE INVERTED LAYER

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The thermoelectromotive force (thermal emf) for p-InSb surface layer of MOS (metal- oxide – semiconductor) structure is calculated depending on the voltage applied to gate. We propose a method for the experimental detection of a gate voltage value, at which the inverse layer appears by a change in a sign of the thermal emf of the semiconductor surface layer.

Keywords: thermoelectromotive force, inverse layer, structure, barrier, gate voltage, length of Debye
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RESULTS AND DISCUSSION

In light of increasing investigations on electric and thermal properties of semiconductor structures in the recent years, the experimental determination of a field, at which the inverse layer arises from the field effect, remains to be an actual question.

It is known that the inverse layer occurs at the semiconductor surface in the MOS structures when the gate voltage increases [1] in case of:

$$|E_c| \geq \frac{\sqrt{\varepsilon_g \mathrm{KT}}}{e\ell_d}, \qquad (1)$$

where ε_g is the forbidden band width; k is the Boltzmann constant; T is the absolute temperature; e is the electron charge; ℓ_d is the Debye length.

In this study, we propose a method providing the detection of the value of a field applied to gate, which excites the occurrence of the inverse layer, by changing the thermal emf sign from "+" to "-" for MOS structure prepared on with *p*-semiconductor.

Since we experimentally did not measure thermal emf in the dependence on the gate voltage, the value of electrons and holes concentrations and corresponding voltage value are taken from work [2].

Authors [2] measured electrical properties of *p*-InSb MOS structure with $p = 10^{13}$ cm^{-3} in the dependence on a gate voltage from 0 to 200 V at 4.2K and reported that the hole concentration decreased in the surface layer from $2 \cdot 10^{13}$ cm^{-3} to $3 \cdot 10^{11}$ cm^{-3} while the electron concentration increased in the inverse layer from $3 \cdot 10^{11}$ cm^{-2} to $7 \cdot 10^{12}$ cm^{-2}.

We first calculate thermal emf at 4.2K for a volume material *p*- InSb with $p=10^{13}$ cm^{-3} in the dependence on the gate voltage from 0 to 50 V using Pisarenko formula:

$$\alpha(0) = -\frac{k}{e}\left[r + 2 - \ln\frac{4\pi^{3/2}\hbar^3 p}{(m_p kT)^{3/2}}\right], \qquad (2)$$

for three concentrations of holes:
$\rho_1 = 2 \cdot 10^{13}$ cm^{-3}; $\rho_2 = 4 \cdot 10^{12}$ cm^{-3}; $\rho_3 = 3 \cdot 10^{11}$ cm^{-3} (r is scattering mechanism-dependant coefficient, p is the hole concentration, m_ρ is the effective hole mass, T is the absolute temperature).

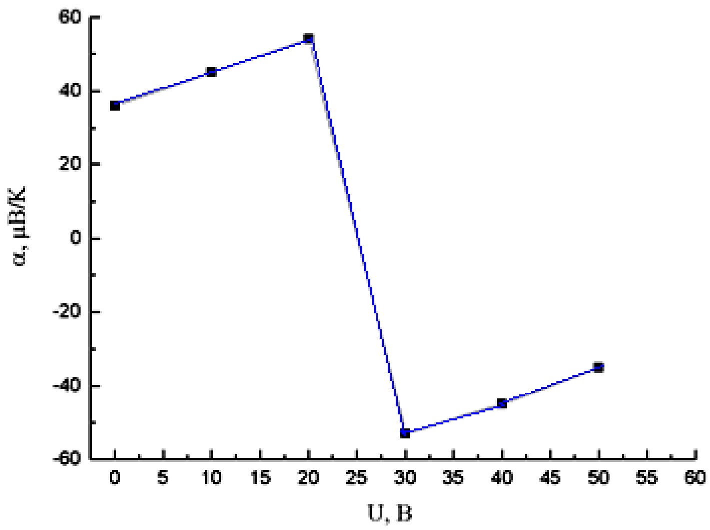

Fig. 1. Dependence of thermal emf of the *p*-InSb surface layer on the gate voltage of MOS structure estimated at 4.2 K.

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Then, thermal emf for three concentrations of electrons was calculated for electrons of degenerate statistics in the inverse layer using formula:

$$\alpha(0) = -\frac{\pi^2}{3}(r+1)\frac{k}{e}\frac{2m_n kT}{(3\pi^2 n)^{2/3}h^2}, \qquad (3)$$

$n_1 = 3 \cdot 10^{11}$ cm^{-2}; $n_2 = 4 \cdot 10^{12}$ cm^{-2}, $n_3 = 7 \cdot 10^{12}$ cm^{-2} (n is the electron concentration, m_n is the effective electron mass). The impurity ion scattering is accepted when calculating thermal emf by Formulae (1) and (2).

Figure 1 depicts estimated values of thermal emf at increasing the voltage up to 50 V.

As the figure demonstartes, hole thermal emf first increases with the decrease of the hole concentration in the surface layer and then that changes the sign at appearance of the inverse layer. Further increasing in the electron concentration results in decreasing in thermal emf due to rise in the electron concentration.

The figure depicts that at a certain gate voltage (in our case ~26 V) a field value, at which the inverse layer occurs, can be detected by measuring thermal emf of the surface layer.

CONCLUSION

For comparison, a field value, at which the inverse layer appears, is determined from Formula (1). According to Formula (1) the transverse field of beginning the inverse layer generation is of 912 V/cm at semiconductor thickness of 0.04 cm and at gate voltage of 36 V. The difference of a field value, at which the inverse layer appears, obtained at experimental measurement of thermal emf using both methods will disappear with increasing in experimental points. The goal of the study is to show that the occurrence moment of the inverse layer in MOS structure can be accurately determined by this method.

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