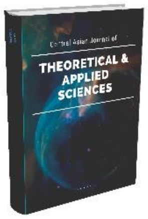

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Physical and Technological Aspects of the Sensor on the Field Transistor

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Abstract: *At present, the attention of researchers has turned to non-trivial modes of switching on field-effect and bipolar transistors. It turned out that in the case of creating a variant of a two-current transistor, its properties of sensitivity to deformations are enhanced.*

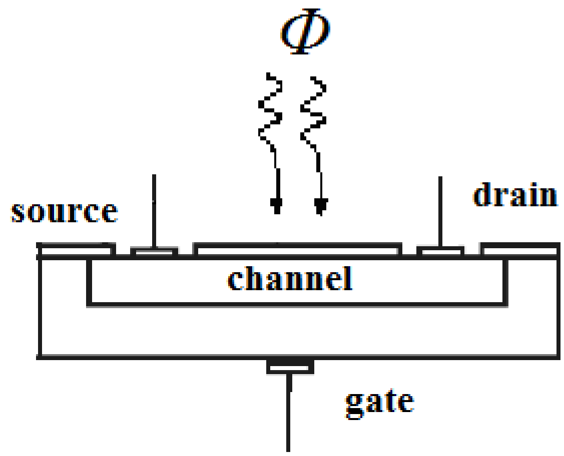
Key words: *field-effect and bipolar transistors, non-trivial modes, multifunctional sensor, drain-gate voltage, solar radiation.*

I. Introduction

Execution or inclusion of a field-effect transistor in the form of a two-transistor cell with channels connected in series provides amplification of constant and alternating signals with a high coefficient [2-4]. To make the field-effect transistor sensitive to external influences, it is proposed to turn it on in the channel blocking mode with the drain-gate voltage, and select the cutoff voltage as a measuring parameter [5]. This section describes the features of a field-effect transistor in the channel blocking mode with a drain-gate voltage as a multifunctional sensor, especially as a receiver of solar radiation.

The investigated field-effect transistor. The multifunctional sensor is made of silicon. For this, an epitaxial n-type layer with a carrier concentration of 2×10^{15} cm^3 with a thickness of 0.7 ÷ 1.5 μm was grown on a silicon substrate with a thickness of 200 μm of p-type conductivity with a carrier concentration of 1×10^{19} cm^3 (the optimal values of which are given in Table 2). Then, through the windows in the mask, contact regions were formed from the deposited indium and silver.

The distance between the drain and the source, that is, the channel length was equal to 150–200 μm. On the back side of the substrate, a continuous contact was formed by sputtering indium and silver. One of the design and technological features of the investigated field-effect transistor is the accessibility of the channel to external influences (Pic. 1).



Pic. 1. The investigated field-effect transistor

To ensure a fast response to changing temperatures, the thickness of the substrate should be chosen as thin as possible. That is, not 200 microns, which we have, but about 100 microns.

The main criteria for choosing the parameters of a field-effect transistor for multifunction sensor

As shown in Pic. 1 the investigated field-effect transistor with a control pn-junction contains a low-resistance substrate of the first type with a lower gate electrode, an epitaxial (diffusion) high-intelligence layer of the second type with ohmic contact regions of the drain and source formed on its surface, between which the channel (L length) is located, the thickness of the a channel is $\sqrt{2}$ times greater than the initial thickness of the p + -n junction depletion layer. This thickness provides a channel cutoff voltage value twice the diffusion potential $U_{omc} = 2U_D$.

The thickness of the p^+-n-junction depletion layer decreases with increasing temperature or exposure to light (Q, Φ). The substrate and high-resistance layer can be of both n- and p-type, or vice versa. The sensor can be made on the basis of germanium, silicon, gallium arsenide, or on the basis of any semiconductor in which it is possible to obtain a rectifying junction.

To obtain optimal modulation of the channel under external influence, the cut-off voltage is selected from the calculation of $U_{omc} = 2U_D$.

As shown in Table 1, at zero bias, we have a space charge thickness of 0.65 μm with a contact potential difference of 0.61 V. Then, for a cut-off voltage of 0.61 V x2 = 1.22 V or for a reverse voltage blocking channel $U_{обр}$ = 0.6 V, we have a thickness $W_{ooз}$ 0.90 μm ... That is, when the voltage is doubled, the space charge region increases $\sqrt{2}$ times, which corresponds to the optimal channel thickness.

Table 1: Space charge layer thickness data against reverse voltage

$U_{обр}$, V	0	0,1	0,2	0,4	0,6	0,8	1	1,3	1,6
$W_{ooз}$, μm	0,65	0,70	0,74	0,83	0,90	0,97	1,04	1,13	1,22

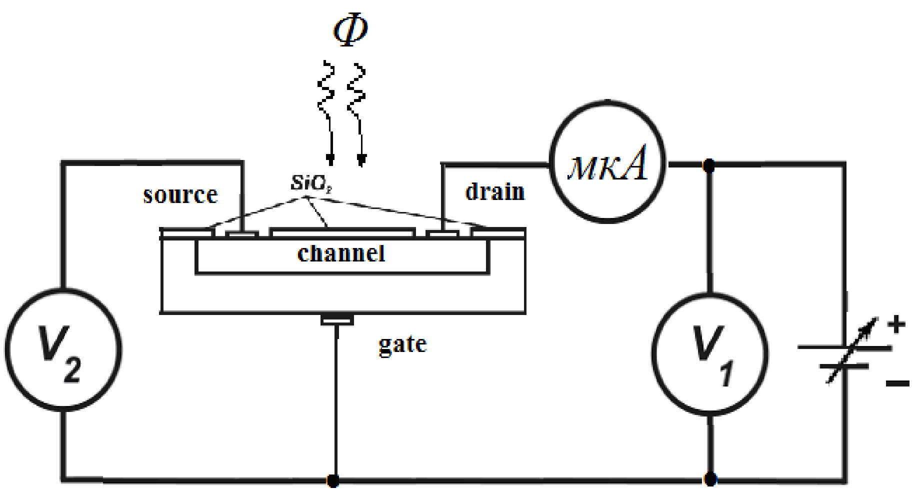
The choice of the channel thickness within $\sqrt{2}$ of the space charge layer thickness of the p-n-junction is due to the fact that at large thicknesses the sensitivity of the field-effect transistor to external influences will decrease, and at lower values, it becomes possible to form hysteresis during an increase and decrease in the cutoff voltage under external influences due to for the differences in the course of expansion and contraction of the space charge region caused by a sharper decrease in the carrier concentration at the boundary of the p-n-junction.

The physical feature of a multifunctional sensor is that if in a known temperature-sensitive field-effect transistor the negative temperature coefficient of the channel conductivity is suppressed by choosing the carrier concentration near the transition point of the temperature sensitivity of the mobility from high to low values [4-6], then in our case, along with temperature sensitivity, it is also necessary to provide photosensitivity, pressure sensitivity.

These properties can be provided by turning on the field-effect transistor in the channel blocking mode with the drain-gate voltage, when with an increase in the operating voltage before the channel cutoff, the voltage drop at the source-gate junction increases linearly, and then after cutoff acquires a potential equal to the channel cutoff voltage. At a given operating voltage, exposure of the channel to light or temperature (pressure) leads to a change in the potential at the source-gate junction, which, as suggested in [3-5], is identified as a measurement parameter.

Investigation of the dependence of the photocurrent on light radiation in the mode of short-circuits current and channel cutoff

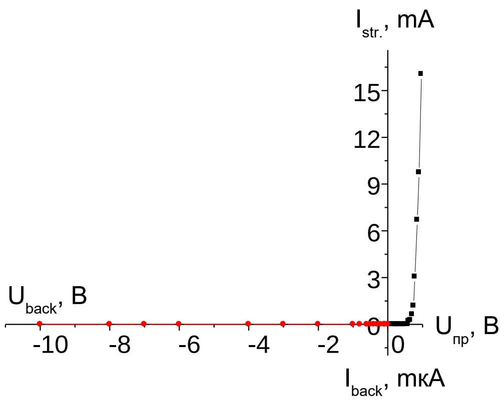
When the channel is illuminated in the space charge region of the gate - channel transition, electron-hole pairs are generated, which create a photocurrent at the source-gate transition, leading to a decrease in the resistance of this transition, which, in turn, leads to a decrease in the voltage drop and to a corresponding increase in the drain current - gate. The electronic circuit for measuring the dependence of the voltage drop at the source-gate junction from external influences is shown in Pic. 2.



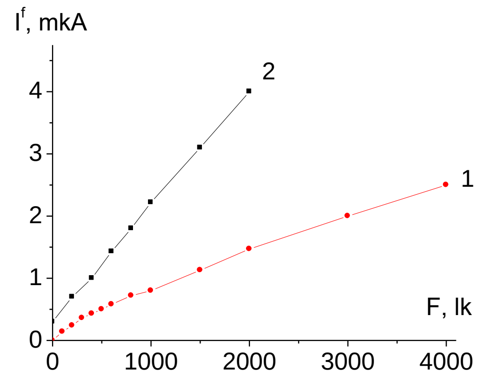
Pic. 2. Circuit for measuring the voltage drop at the source-gate junction in the channel blocking mode with the drain-gate voltage

As can be seen from the figure with respect to the operating voltage, the gate-channel junction can be said to be switched on in diode mode, or when illuminated it acts similarly to a photodiode. However, in principle, it differs significantly from a photodiode. So, in the proposed operating mode of channel blocking, the voltage at the drain-gate junction is two or more times higher than at the source-gate junction. In the case when the source terminal is closed with the drain (diode mode), it turns into a diode with a thin base.

As shown in Fig. 3, in the diode switching mode, the reverse current up to 10 V does not exceed 1 nA, and in the forward direction, starting from 0.7 V, a sharp increase in current is observed and at a voltage of 0.9 V, the forward current reaches 9.75 mA.



Pic. 3. Current-voltage characteristic of the p-n-junction of the gate

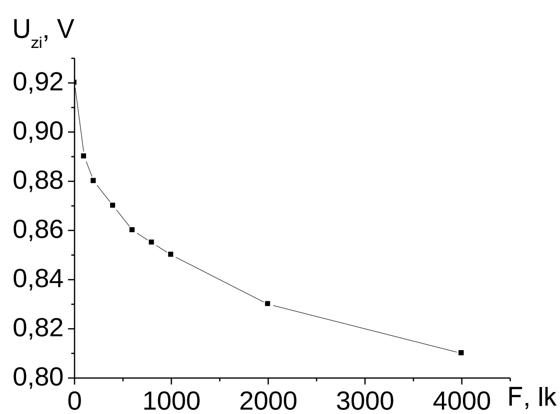


Pic. 4. Dependences of the photocurrent on the intensity of illumination in the mode short circuit and blocking the channel with drain-gate voltage

Accordingly, in the channel blocking mode, such an insignificant reverse current of the gate-source junction will practically have no effect on the photocurrent generated from the channel illumination.

As studies have shown, in the short-circuit mode, when the gate and source leads are short-circuited to the ammeter with an increase in the channel illumination intensity from the halogen lamp, the photocurrent increases close to linear, Pic. 4, curve 1. In this case, in the channel blocking mode with the drain-gate voltage, we have in two times higher photocurrent (curve 2).

As for the voltage drop, its value with an increase in the illumination intensity initially decreases significantly at low illumination intensities, and then, decreasing nonlinearly, the dependence weakens. In the first section, the sensitivity is 0.00025 V / lx, and in the 1000-2000 lx section, the photosensitivity is an order of magnitude lower and equal to 0.00002 V / lx.



Pic. 5. Dependences of the voltage drop at the gate-source junction on the illumination in the channel blocking mode with the drain-gate voltage

The sensitivity of the voltage drop at the source-gate junction to illumination is due to the following. Thus, illumination of an n-type channel by quanta with energies greater than the band gap leads to the generation of nonequilibrium electron – hole pairs, and an increase in the illumination intensity leads to a decrease in the contact potential difference of the p-n-junction

$$U_{\phi} = \frac{kT}{e} \ln \frac{n_n}{n + n_{\phi}}, \qquad (1)$$

Where n_{ϕ} is the concentration of holes generated by photons when the n-region is illuminated.

In turn, the photocurrent arising at the source-gate junction decreases its resistance, which leads to a decrease in the falling voltage as compared to the dark one.

Thus, a field-effect phototransistor in the channel cutoff mode can be used to measure the intensity of light radiation.

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