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Research Article

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Investigation temperature sensitivity of the field-effect transistor in channel depletion mode

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Abstract It is experimentally shown that the temperature coefficient of sensitivity of field-effect transistor in channel depletion mode is independent from the process parameters of the transistor structure. In this case temperature coefficient of sensitivity and the magnitude of base thickness growth by temperature for all field-effect transistors have the same value.

Keywords field-effect transistor, temperature coefficient of sensitivity, pinch-off voltage, wide temperature range

Introduction

Recently sensors of temperature began intensively to enter into various spheres of ability to live of the man and technological processes. They become the integral part of various devices of the control and management thermo in dependent parameters of an environment and objects. As sensors of temperature use various semi-conductor structures such as thermo resistors, bipolar transistors and diodes structures [1]. Thus use receptions ensuring proportional dependence working (direct or opposite) of a current from temperature of object. For this purpose it is necessary to solve some problems connected to nonlinearity of temperature dependence of a return current p-n-transition and the large working currents in a mode of direct displacement. Except for that their temperature range is limited to allowable temperature punching. These problems are solved by application of the integrated circuits, and also amplifier of voltage with large factor of amplification [2].

Here it is necessary to note, that as against bipolar transistors the field transistors differ by a wide set of modes of inclusion ensuring positive or negative marks of temperature factor of a current of a drain [3], and use of known parameter (cutoff voltage) on new purpose can essentially improve functional parameters of the sensors on its basis [4].

The present paper is devoted to research thermo electrical properties of the silicon field-effect transistor with p-n-transition in a mode of lock-out of the channel by voltage a drain -gate at use as measuring parameter of cutoff voltage.

Experimental Samples

The investigated silicon field transistor with p-n-transition, shown on a fig. 1, is placed in the tiny metal case. Is executed on a substrate from monocrystal silicon p-such as with put on its surface epitaxial of a layer of a n-type with ohmic by contact areas of a drain and source between which the channel is located. The concentration of carriers in a substrate makes $1.0{\cdot}10^{19}$ sm^3, and in the channel $2{\cdot}10^{15}$ sm^3. The thickness of the channel is equal ~1 microns, and length 25 microns.

They have typical of the field transistor drain voltage-current of the characteristic with the maximal current of a drain 0.4÷8 mA and with cutoff voltage of the channel 0.5-2.4 V.

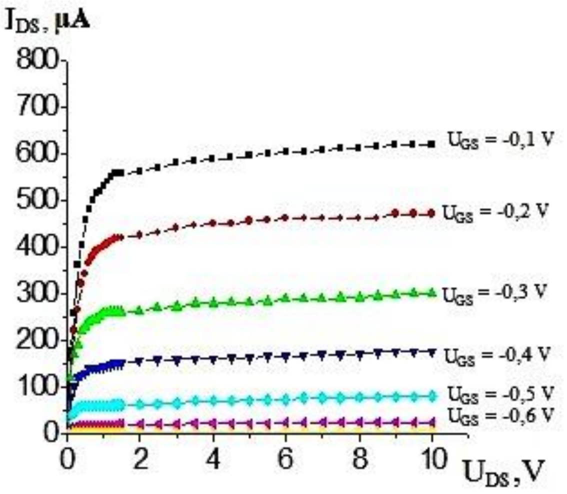

Figure 1: The drain voltage-current characteristic of one of investigated field-effect transistors

Technique of experiment

Sensitivity of transistor structure to temperature defined in the chamber with adjustable temperature with accuracy of 0.1 °C. Measurements of a current and the voltage spent with the help of the digital voltmeter with minimal measurement by meaning of a current 0.1 nA. Researches spent in a mode of lock-out of the channel by a voltage a drain - gate (fig. 2), and as measuring parameter used the cutoff voltage of the channel.

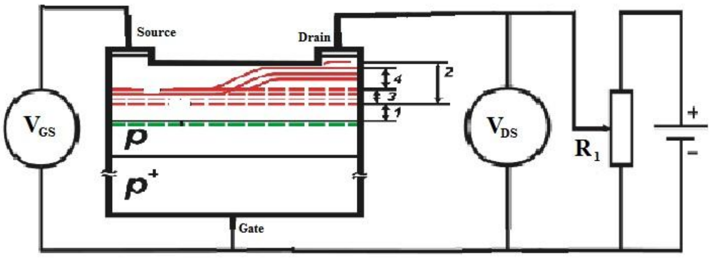

Figure 2: The circuit of measurement of a power failure on transition a source - gate in a mode of lock-out of the channel by voltage a drain -gate

As have shown researches in the given mode of inclusion increase of temperature in a wide interval from a minus 150 up to plus of 150 degrees, as shown in a fig. 3, results in linear increase of the cutoff voltage.

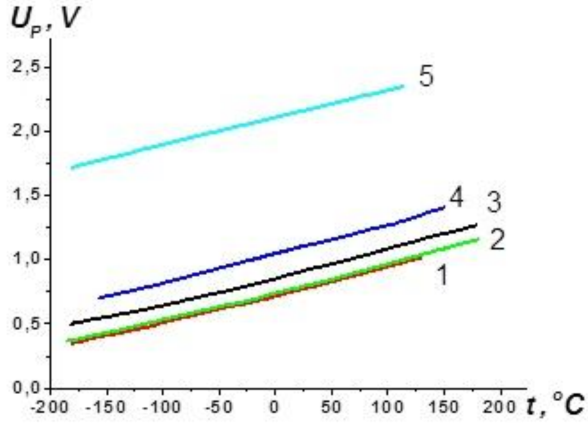

Figure 3: Dependences of voltage cutoff of the channel of field-effect transistors with various technological parameters

The observable increase of the cutoff voltage of the channel with temperature can be connected with reduction of a contact difference of potentials p-n- transition (1), own concentration, caused by increase, of carriers at increase of temperature

$$U_D = -\frac{kT}{q}\ln\frac{N_{кан}N_{зам}}{n_i^2}, \quad (1)$$

where N $_{chan}$ - concentration of charge carriers in channel, N $_{gate}$ - concentration of charge carriers in gate region, n $_i$ - concentration of charge carriers in intrinsic material.

In result initial thickness of area of a volumetric charge for $U_{GS} = 0$ will decrease

$$W_{avch} = \sqrt{\frac{2\varepsilon\varepsilon_0 U_d (N_{chan} + N_{gate})}{q \cdot N_{chan} \cdot N_{gate}}}, \quad (2)$$

but capacity p-n- transition will increase

$$C_{p-n} = \frac{\varepsilon\varepsilon_0 A}{W_{avch}}, \quad (3)$$

that will result in increase of thickness of a spending part of the channel

$$\Delta d = a - W_{avch}. \quad (4)$$

Where W_{avch} - initial thickness of the space charge region, A and C_{p-n} - area and capacitance of p-n-junction, ε_0 and ε - dielectric permittivity of vacuum and semiconductor, a - total thickness of channel, Δd - channel thickness increment.

Therefore for cutoff of the channel the even greater locking voltage U_{cutoff} is required

$$U_{cutoff} = \frac{N_{chan} q a^2}{2\varepsilon\varepsilon_0}\left(1 + \frac{N_{chan}}{N_{gate}}\right) = U_{cutoff} + U_D. \quad (5)$$

In the given mode the researched field transistor has temperature sensitivity not making a concession sensitivity diodes structures, but with that advantage, that practically does not consume energy. Thus temperature factor of the cutoff voltage

$$\alpha_{cutoff} = (U_{cutoff}^2 - U_{cutoff}^1)/(T_2 - T_1), \quad (6)$$

makes 2.2 mV/^{o}C, that is at a level of meanings having a place in diodes structures in a mode of restriction of a direct current ~ 10 mA [5].

Conclusion

The comparisons of dependence of the cutoff voltage from temperature for field-effect transistors with a various cutoff voltage in a wide range of temperatures (- 150 up to + 150 ^{o}C) have shown, that their temperature factor of sensitivity does not depend on technological parameters of transistor structure (fig. 3). That is the mechanism of temperature sensitivity submits to the same law, the size of a gain of thickness of base from temperature for all field-effect transistors has identical meanings. Thus in a wide interval of temperatures the dependence of the cutoff voltage from temperature is strictly linear. As the sensor of temperature the field-effect transistor surpasses of analogues on a basis diodes and transistor structures, in which limiting temperature makes 125 ^{o}C.

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