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The Microelectronic Transducers of Pressure with the Frequency Output

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Introduction

The microelectronic transducers of mechanical quantities define precision and reliability of monitoring systems of processes, environmental propertys, safety of operation of nuclear, thermal, chemical installations, aircrafts, sea objects, etc. In this connection to the microelectronic transducers which measure manifold mechanical quantities, in particular pressure, the strong requirements are showed. They should be economic, unjammable, provide high fast operation, sensitivity and a measurement accuracy, to have small gabarits and a weight, to be compatible with the modern PCs and will allow coding and an information communication on major distances.

One of perspective scientific directional, allowing to solve a complex of the tasks in view suggested in the given operation, use of dependence of jet properties and a negative resistance of semiconductor devices of effect of pressure and making on this basis of a new class of the microelectronic transducers is. In devices of such type there is a transformation of pressure to the frequency signal that allows to establish transducers on integrated technology and enables to boost fast operation, precision and sensitivity, to improve reliability, noise performance in terms of error probability and long-term parameter stability. Besides integrating single-crystal the transducer of pressure with the plan of an information handling enables makings "intellectual" devices. Use as information parameter of frequency allows to avoid application of intensifying devices and analog-to-digital converters at an information handling that reduces the cost price of monitoring systems and guidances [1 - 4]. In the given operation surveyed theoretical and experimental researches of effect of pressure on parameters of the bipolar transistor and its use as tensiosensitive a device of the microelectronic transducer of pressure in the frequency signal.

Theoretical and experimental researches

In the capacity of the basic electrophysical factors which cause change of parameters and characteristics of bipolar transistor structures, as well as other semiconductor devices under activity of pressure, biases of energy levels of the semiconductor, i.e. change of breadth of a forbidden region, change of effective masses and carrier mobility act. It is considered, that in impurity semiconductors change of a lifetime of carriers of current under activity of pressure missing [5, 6]. In the capacity of tensiosensitive a device of the transducer the bipolar transistor acts. Therefore it is definable deformation приросты electrical parameters of bipolar structure.

Deformation accession parameters $G_i = f(E_g, n_n, n_p, p_n, n_i, \mu_n, \rho)$ a equivalent circuit bipolar to the transistor, figured on Fig. 1, are defined on the basis of blanket expression

$$\Delta G_i(P) = \frac{\partial G_i}{\partial E_g}\Delta E_g(P) + \frac{\partial G_i}{\partial n_n}\Delta n_n(P) + \frac{\partial G_i}{\partial n_p}\Delta n_p(P) + \frac{\partial G_i}{\partial p_n}\times$$
$$\times\Delta p_n(P) + \frac{\partial G_i}{\partial n_i}\Delta n_i(P) + \frac{\partial G_i}{\partial \mu_n}\Delta \mu_n(P) + \frac{\partial G_i}{\partial \rho}\Delta \rho(P). \qquad (1)$$

In the capacity of parameters G_i the following parameters and devices of a equivalent circuit act in expression (1): R_e - resistance of the emitter; R_b - resistance of base field; R_c - resistance of a collecting channel; C_{be} - an emitter-junction capacitance which will consist from diffuse C_{ed} and charging C_{eq} capacities; C_{bc} - a collector capacitance which will consist of diffuse capacity C_{cd} and charging capacity between interior basis and collecting channel C_{bcq} and capacities between an exterior deduction of basis and collecting channel C_{Bc}; a_N and a_I - according to direct and inverse amplification constants of a current in the plan common-base; diodes with performances I_{be} and

I_{bc} which simulate forward bias emitter and reverse bias collector the junctions connected towards each other; V_{ce} - a voltage applied between the interior emitter and a collector; V_a - voltage Early [7-14]. Expression (1) allows to spot a deformation change of parameter of equivalent circuit G_i by definition of the total of the partial derivatives given to parameter from physical properties of a semiconductor material which, in turn depend on pressure. For bipolar n-p-n the transistor analogously to expression (1) are defined deformation changes its parameters which are caused relevant deformation charge concentrations of natural charge carriers $\Delta p_p(P)$ and mobilities of holes $\Delta\mu_p(P)$.

On the Fig.2 – Fig.4 are presented dependencies of the parameters of the equivalent circuit of the bipolar tensiotransistor (Fig. 1).

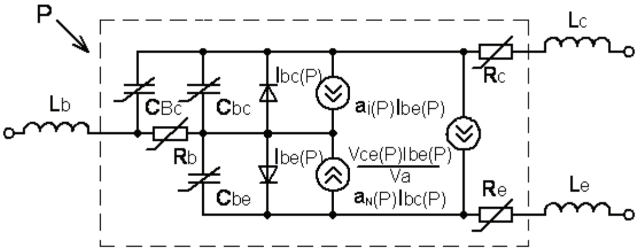

Fig. 1. A equivalent circuit bipolar p-n-p tensiotransistor

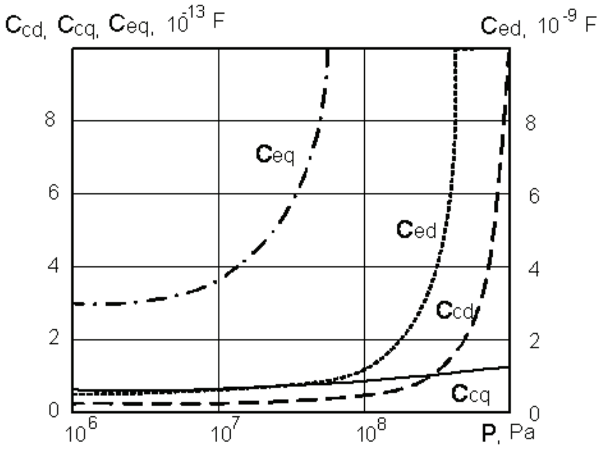

Fig. 2. Electrical parameters (capacities p-n junctions) the bipolar transistor under activity of pressure

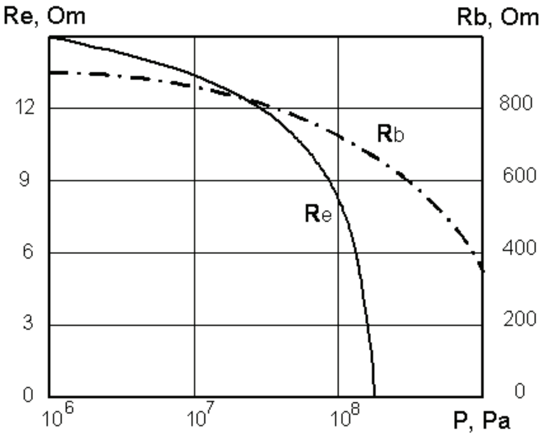

Fig. 3. Electrical parameters of active regions of work of the bipolar transistor under activity of pressure (resistance of areas basis and the emitter)

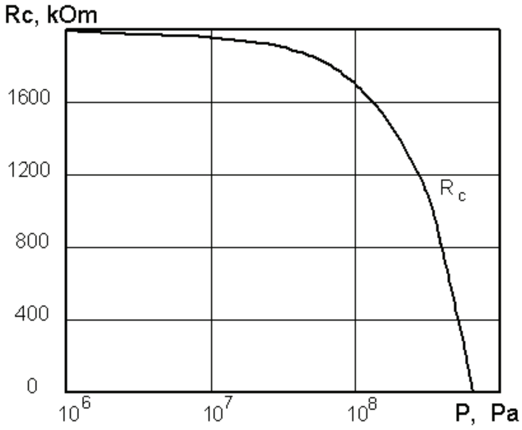

Fig. 4. Theoretical dependence of resistance of a collector the bipolar transistor from pressure

Thus, having spotted deformations changes elements of an equivalent circuit tensiosensitive the bipolar transistor, we shall transfer to the description of work of the transducer of pressure and its characteristics. The circuit of the frequency transducer of pressure presented on Fig. 5. The transistor structure of the frequency transducer of pressure contains bipolar and MOSFET - transistors, and the emitter bipolar to the transistor is connected to sink MOSFET - transistor. Tensiosensitive a element is the bipolar transistor.

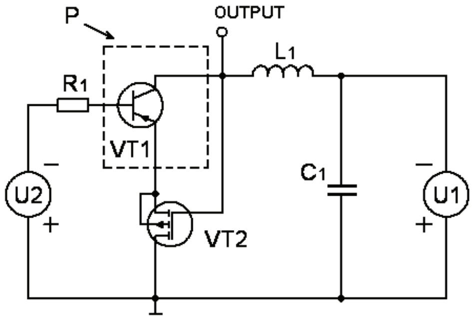

Fig. 5. A circuitry of the transducer of pressure on the basis of transistor structure

The generator of electrical oscillations is created on the basis of transistors structure with a negative resistance. Presence of a differential negative resistance speaks necessity to cancel to them of an energy loss in an oscillation circuit created reactive component impedance on electrodes a collector - sink and an exterior inductive resistance. One of basic characteristics of the transducer is dependence of its function of transformation. Function of transformation is featured by the equation

$$F = \frac{1}{2\pi\left|R_g^{-}(P)\right|C_{ekv}(P)}\left[\frac{R_g^2(P)C_{ekv}(P)}{L}-1\right]^{1/2}, \quad (2)$$

where $R_g^{(-)}(P)$ - a dynamic negative resistance of an oscillation circuit, $C_{ekv}(P)$ - the equivalent capacity of a oscillation circuit of the transducer, L - a tuned-circuit inductance. Sensitivity of the transducer is defined on the basis of expression (2) behind the formula

$$S_F^P = \frac{\dfrac{R_g(P)C_{ekv}(P)\dfrac{dR_g(P)}{dP}}{L} + \dfrac{R_g^2(P)\dfrac{dC_{ekv}(P)}{dP}}{L}}{4\pi R_g(P)C_{ekv}(P)\sqrt{\dfrac{R_g^2(P)C_{ekv}(P)}{L}-1}} - \frac{\sqrt{\dfrac{R_g^2(P)C_{ekv}(P)}{L}-1}\,\dfrac{dR_g(P)}{dP}}{2\pi R_g^2(P)C_{ekv}(P)} - \frac{\sqrt{\dfrac{R_g^2(P)C_{ekv}(P)}{L}-1}\,\dfrac{dC_{ekv}(P)}{dP}}{2\pi R_g(P)C_{ekv}^2(P)}. \quad (3)$$

For definition of numerical value of formulas (2) and (3) it is necessary to know theoretical and experimental dependences of the active and reactive component a computing impedance on an output of the transducer which pay off on the basis of a nonlinear equivalent circuit of the transducer of pressure. On Fig.6 theoretical and experimental dependences of the active component the complete output resistance from pressure presented. Apparently from the diagram, voltage excursion of a power supply U_1 essentially influences quantity of the active component and its linearity.

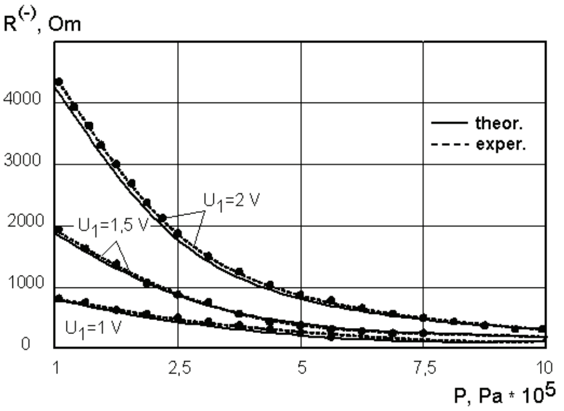

Fig. 6. Theoretical and experimental dependences of the active component impedance of the transducer from pressure

On Fig. 7 theoretical and experimental dependences reactive component the complete output resistance of the transducer from pressure presented.

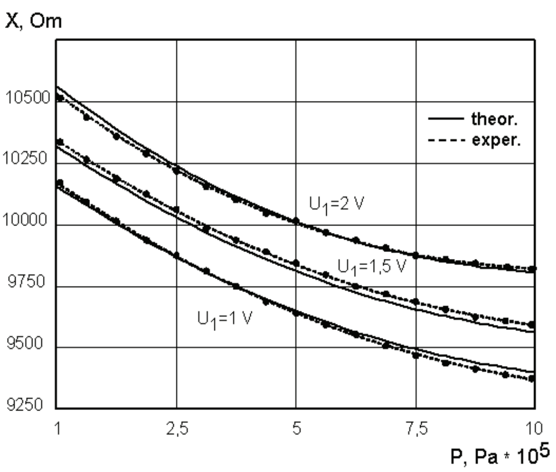

Fig. 7. Theoretical and experimental dependences reactive component impedance of the transducer from pressure

Apparently from the diagram at a supply voltage $U_1 = 1$ V this dependence is almost the linear, that is an optimum behaviour of feed, thus sensitivity of the transducer is the best. The diagram of function of transformation presented on Fig. 8, and the diagram of sensitivity on Fig. 9. Apparently from this diagram, sensitivity of the transducer changes from 4,25 kHz / Pa·10^5 up to 2,0 kHz / Pa·10^5 over the range from 0 up to 12·10^5 Pa.

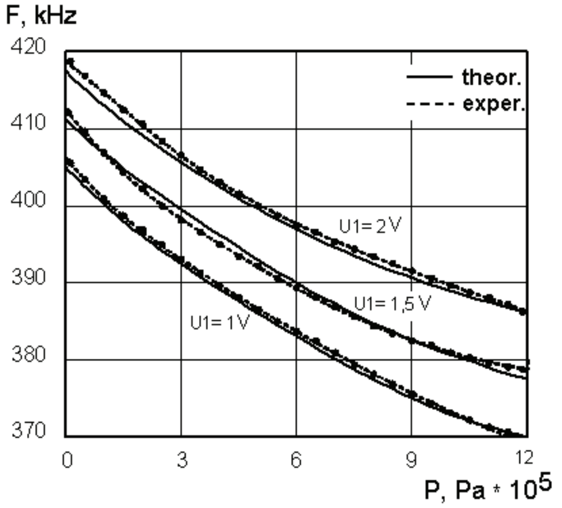

Fig. 8. Theoretical and experimental dependences frequency generation of the transducer from pressure

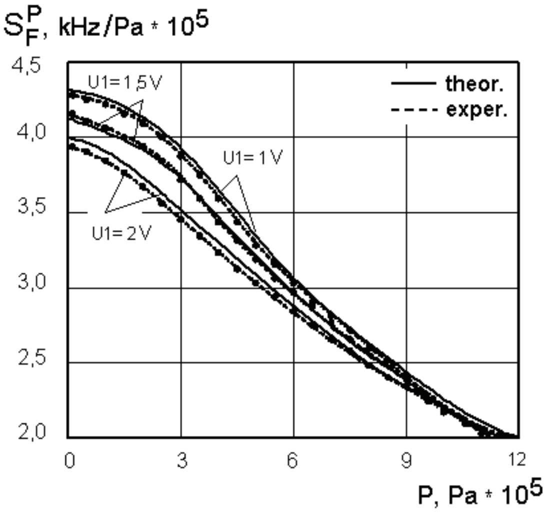

Fig. 9. Dependences of sensitivity of the frequency transducer of pressure

Conclusions

On the basis of deformation effects in semiconductors analytical dependences of elements of nonlinear equivalent circuits bipolar tensiotransistors from activity of pressure are received. The integrated circuit of the transducer of pressure with the frequency output is offered on the basis of bipolar and field transistors in which tensiosensitive as a element acts bipolar tensiotransistor on a membrane. Sensitivity of the transducer of pressure makes 2,0-4,25 kHz / Pa·10^5 over the range pressures from 0 up to 12·10^5 Pa.

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In the given article the possibility of making the microelectronic transducer of pressure with a frequency output signal is shown on the basis of the autogenerating arrangement which will consist of bipolar transistor and MOSFET transistor. The change of pressure of bipolar transistor is proportionally the frequency generation. Analytical dependencies of function transformation and sensitivity are received. The deformation changes of the parameters tensiosensitivity bipolar transistor are designed. Sensitivity of the arrangement 2,0-4,25 kHz / Pa$\cdot 10^5$. Ill. 9, bibl. 14 (in English; abstracts in English and Lithuanian).

V. S. Osadchuk, A. V. Osadchuk. Mikroelektroninis slėgio keitiklis su dažniniu išėjimo signalu // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 5(121). – P. 105–108.

Parodyta, kad mikroelektroninio slėgio keitiklį su dažniniu išėjimo signalu galima pagaminti autogeneratoriaus sudaryto iš MOSFET ir dvikrūvio tranzistoriaus, pagrindu. Dvikrūvį tranzistorių veikiančio slėgio pokytis proporcingas generavimo dažniui. Gautos analitinės keitimo funkcijos ir jautrumo lygtys. Nustatytos tenzojautraus dvikrūvio tranzistoriaus parametrų priklausomybės. Il. 9, bibl. 14 (anglų kalba; santraukos anglų ir lietuvių k.).