RESEARCHES OF TWO AND THREE-OUTPUT STRUCTURES WITH EFFECT OF RESONANT TUNNELING.

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ABSTRACT

The present paper is devoted to the development of production process of transistor structures with effect of resonant tunneling (RTT), researching static and dynamic characteristics and working frequency band of the samples and definition of possible areas of their application

INTRODUCTION.

The apparent extension of functionality’s of two-barrier quantum structures (DBQS) is connected to effect of resonant tunneling with organization of control of a potential in a quantum hole with the help of one more electrode transforming structure in transistor. This idea, however, is connected with the technological difficulties, and the overcoming of some of them, probably, will require an exit from frameworks of the epiplanar technology.

Main of these difficulties arise at attempts to realize high-frequency capabilities of structures with nanometer by the sizes of active areas. They are caused by that circumstance, that the reduction of vertical dimensions by depletion carriers of active areas (in particular, barriers) with the purpose of usage of quantum effects, inevitably results in increase of interelectrode capacities (for example, doped quantum hole), and also results in increase of resistance along these areas.

As the actual frequency capabilities of control of potentials in a quantum hole will be determined largely by time of charging of interelectrode capacities, it is necessary to aim at minimally possible lateral dimensions.

Further, the small distances between areas with different potentials acutely put a problem on reliable isolation of these areas from each other, and if there is such isolation - about preservation her at any operations and processes spent at manufacturing of the device, first of all at creation of contacts to these areas.

If to keep in the party of difficulty with obtaining of minimum lateral dimensions, which just and can require transition to the technology “ of nuclear assembly ”, the remaining requirements to resonance - tunneling structures quite mastering within the framework of the modern epiplanar technology.

In a number of activities [1-14] the designs of unipolar transistors on hot electrons were offered [1-6], of bipolar transistors [7,8] of field-effect transistors with a Schottky barrier (planar [10]) and with vertical transport [11-17]) c built-in DBQS - resonance - tunneling transistors (RTT). In these activities is shown, that usage of effect of resonant tunneling of electrons introduces new units to the characteristics of transistors, considerably expanding their functionality’s. Changing the sign of a potential difference a source - drain (the emitter - base) and value of voltage on the base, is possible over a wide range to vary the form a current-voltage characteristic, value of negative differential conductivity, working intervals of currents and voltage and other parameters of the transistor. As if to response of such devices, it limits not by a lag effect of resonant tunneling of electrons in DBQS, and time of their flyover through other sites of semiconducting structure (in particular, through a layer n-GaAs) and duration of a recharge undergate and other spurious capacities.

The application of diode and transistor structures with resonant tunneling in devices of microelectronics is business rather perspective owing to high response, low level of noise, singularity of a voltage-current characteristic, which can have, basically, however large quantity of peaks. Now foreign sources inform manufacturing experimental is model of functional devices (multilevel logic, different generators and logical devices), permitting to receive new element base of devices with unique functional properties.

MANUFACTURING AND RESEARCHES OF THE RTT.

The main purpose of the present activity was the manufacturing of structure, the position of which operating point can be changed with the help of the "gate".We selected a design RTT with vertical structure similar offered in [13]. From our point of view, this design combines a relative simplicity of manufacturing with a capability in a sufficient measure to realize the main advantages of resonance – tunneling structures.

RTT was realized by us on the basis of heterostructure AlGaAs/GaAs c by two-barrier quantum structure. In a Fig. 1 the scheme of a design of the device is adduced. The electrodes of the device had the minimum sizes about 40 microns. The general size of a chip 500*500 microns.

The typical voltage-current characteristics RTT, made on designed in the given activity of the technology are shown in a Fig. 2a (return actuation) and Fig. 2b (direct actuation). In the Table 1 the experimental values of fundamental parameters of a voltage-current characteristic RTT are adduced at return actuation.

Thus, changing the sign of a potential difference the source - drain and value of voltage on the gate, is possible over a wide range is to varied the form of a current-voltage characteristic (value Ip and Iv, Up and Uv, dI/dU) determining parameters of the transistor.

Till the static current-voltage characteristic is possible to evaluate a limiting frequency of generation (obtained devices [18]. We have

$$\omega = (h / \varepsilon\varepsilon 0S) * (G/Rs)^{1/2} \qquad (1)$$

Where **εε0=1,4** pF/cm for GaAs, **S** the area of structure, **h-**width of layers RTT between contacts, **Rs** - resistance of losses, **G** - steepness of a diode characteristic RTT in area ANC (Uç=0).

As a result of substitution in (1) numerical values of parameters (h=0,5*10E-4 sm, S=40*40 mcm*mcm, G=3,0-6,0*10Å-2 S, Rs=100 Ohm), we receive **ω= 50 - 60 GHz**.

For functional check RTT in frequency band up to **21 GHz** the transistor was included as a quadripole with negative resistance on an input (entrance) of a spectrum analyser HP8559A. Feature of the given analyzer is the infiltration (seepage) on his signal input of an internal local oscillator with a scan frequence 1-21 GHz.

In our experiment the signal amplitude, reflected from an insert with a chip with operation voltages outside of area with negative differential conductivity (fig. 3a) and inside of area with negative differential conductivity (fig. 3b) was measured. As it is visible from a fig. 3b, the signal not only was mirrored, but also has amplified. On a screen of a spectrum analyser the rise of a line of a noise track uniformly in all band was watched, without what or falls, on 20 dB, that displays a feasibility of researched chips RTT in frequency band down to 21 GHz.

CONCLUSION

1. The design and technology is developed and samples two-output (RTT) and three-output devices (RTT) are made.
2. Are researched static and dynamic characteristics of devices and their amplifying abilities in frequency band up to 21 GHz are shown.
3. Is apparent, that the further optimization of a design RTT both reduction(decreasing) of spurious resistance and capacities of structure will allow to expand range of their useful application to 100 GHz and above. Already now it is possible to speak about perspectivity of usage ÐÒÒ for fast-response logical units, generators, mixers, switches, amplifiers in the field of UHF and EHF of ranges with a capability of control of operational modes. However, not it now is, on our sight determining in these researches. At the given stage of development of this direction up to the end the base for optimum application of devices with resonance - tunneling effects is not determined. Apparently, that the application of element base of a new type require efforts of the developers of instrumentation adequate to efforts of the technologists - creators of this element base.

Fig. 1 A design of the resonance - tunneling transistor.(n+ GaAs -150 nm 3*10E18; n+-n- GaAs - 50 nm 3*10E18 – 1*10E16; i GaAs - 20 nm; AlAs - 2 nm; GaAs - 6 nm; AlAs - 2 nm; GaAs - 14 nm; n-GaAs - 170 nm 1*E16; n+ GaAs - 500 nm 3*E1018)

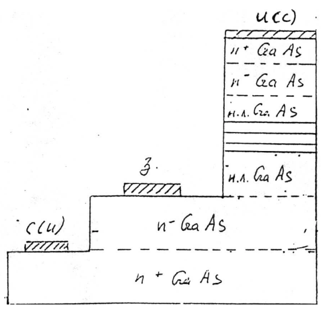
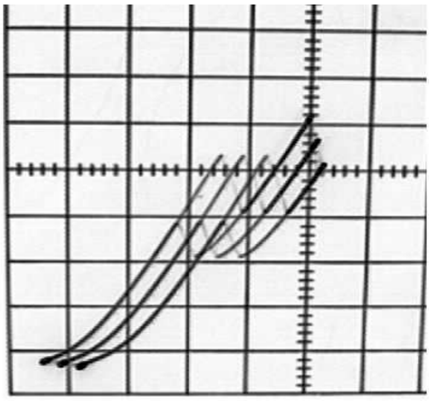


Fig. 2a A Volt-Ampere characteristic of the resonance - tunneling transistor at return actuation of voltage on a gate (1 - Ug=0 B, 2 - Ug =-0,5 B, 3 - Ug =-1,0 B).



The Table 1.   Static parameners of RTT

N of the sample	Ug=0 B Ip (mA)	Up (V)	Ip/Iv	Ug=-0,5 B Ip (mA)	Up (V)	Ip/Iv	Ug=-1,0 B Ip (mA)	Up (V)	Ip/Iv
1	10	0.5	2.5	10	0.58	2.5	10	0.66	2.5
2	10	0.58	2.5	10	0.66	2.5	10	0.74	2.5
3	9.6	0.56	2.3	9.6	0.64	2.3	9.6	0.72	2.3
4	8.8	0.5	2.2	8.8	0.58	2.2	8.8	0.66	2.2
5	9.8	0.58	2.04	9.8	0.66	2.04	9.8	0.74	2.04
6	9.6	0.56	2.4	9.6	0.64	2.4	9.6	0.72	2.4
7	10	0.56	2.5	10	0.64	2.5	10	0.72	2.5
8	10	0.58	2.5	10	0.66	2.5	10	0.74	2.5
9	10	0.56	2.5	10	0.64	2.5	10	0.72	2.5
10	10	0.56	2.5	10	0.64	2.5	10	0.72	2.5

Fig. 2b A volt-ampere characteristic of the resonance - tunneling transistor at direct actuation of voltage on a gate (1 - Ug=0 B, 2 - Ug =-0,5 B, 3 - Ug =-1,0 B, 4 - Ug =-1,5 B)

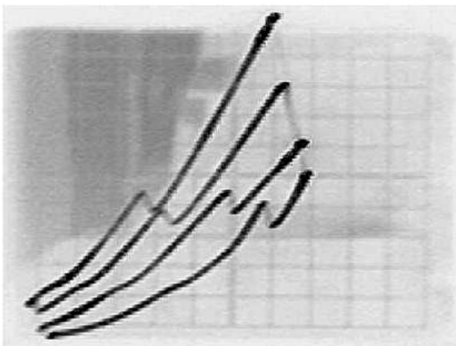


Fig. 3a A power level of UHF of a signal mirrored by the resonance - tunneling transistor with an operating point outside of the field of negative differential conductivity.

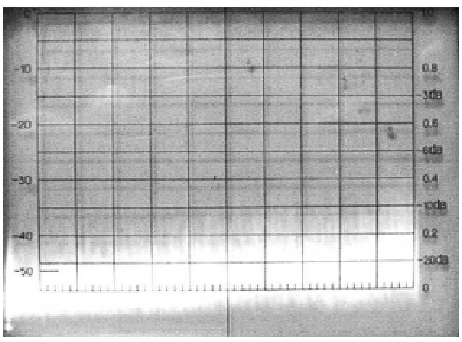
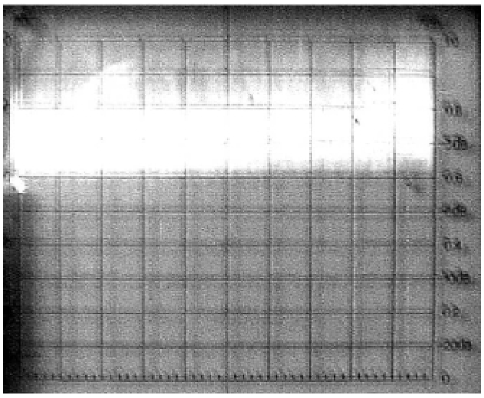


Fig. 3b A power level of UHF of a signal mirrored resonance - tunneling transistor with an operating point in the field of negative differential conductivity.



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