METAL– SEMICONDUCTOR AND HTSC – SEMICONDUCTOR CONTACTS FOR DIODE DETECTORS

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The numerical modeling of the electrical potential distribution and current passing in the contacts of the high temperature superconductor with semiconductor InSb had been made. There were analyzed the possibilities to create the diode detectors (DD) based on these contacts and working at liquid nitrogen temperature 77.4 K.

The comparison with existent literature data shows the proposed DD can be 10÷100 times better. Therefore these DD are perspective for cryogenic electronics and there is an actual problem to elaborate them.

Key words: *high-T_c superconductivity, Schottky diodes.*

1. INTRODUCTION

At present the perspectives of the high temperature superconductor (HTSC) technical application are widely studied. The possibilities to create the diode detectors (DD) with Josephson HTSC junctions are also investigated. At the liquid nitrogen temperature T = 77 K and signal frequency f = 37.5 GHz the corresponding structures revealed the voltage responsivity VR=3000 V/W [1]. The further studies [2] allowed to create the structures with VR=5000 V/W and noise equivalent power NEP = 2×10-12 W/$\sqrt{Hz}$ at the signal frequency f=31 GHz and temperature T=77 K. We suppose that the elaboration of DD working at T=77.4 K which are based on the HTSC-semiconductor contacts may be done too. These structures are the Schottky super diodes. HTSC is used in exchange for metal. According to [3] this substitute may sufficiently increase the nonlinearity of the current-voltage dependences (CVD) due to peculiarities of the electronic density of states in superconductor. These DD may detect the radio frequencies signals and they may provide the very high parameters due to this big nonlinearity. The band diagram of this structure is similar to one in [3]. At present the contacts of HTSC with semiconducting SrTiO3 [4] and GaAs/AlAs superlattices [5] are already obtained. Taking into account the experimental problems the numerical analysis seems to be actual.

2. RESULTS AND DISCUSSION

In order to solve this problem the calculation method was elaborated and the numerical analysis of the contacts HTSC-semiconductor (InSb) was made. The potential distribution, current-voltage dependencies and DD parameters were calculated. The surface states at the boundary, the charges of electrons and holes in the narrow gap semiconductor, the superconductor tunneling peculiarities and other phenomena were taken into account. The calculations both for contacts with HTSC and normal metal allow distinguishing the high-T_c superconductivity factor separately. The flat contacts with a $100\mu^2$ area were considered and estimated current density was more than 400 times less the critical one [6]. Fig. 1 shows the calculated current responsivity (CR) dependence on the free electrons concentration (FEC) n in InSb (at f=30 GHz).

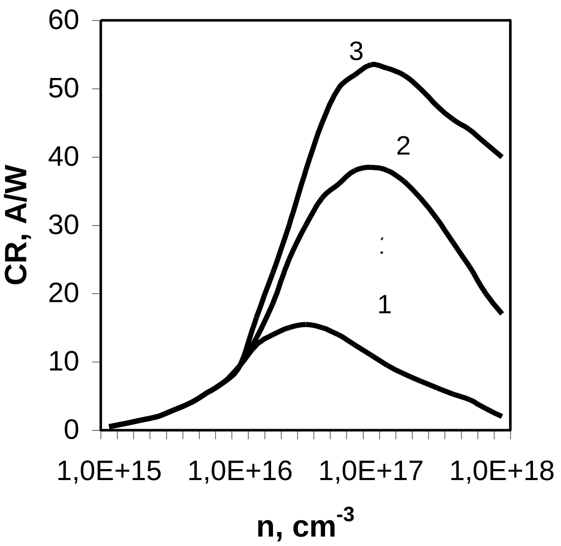

Fig. 1. The calculated current responsivity dependence on the free electrons concentrations in InSb. Curve 1 corresponds to the contacts with normal metal, curves 2 and 3 correspond to the contacts with HTSC having energy gap width Δ=15 meV and Δ=25 meV respectively.

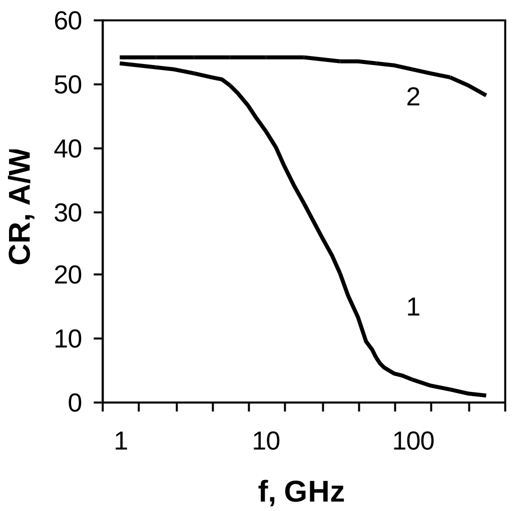

Fig. 2. The calculated current responsivity dependence on the signal frequency. Curves 1 and 2 correspond to situation $n=10^{16}$ cm^{-3} and $n = 10^{17} cm^{-3}$ respectively.

At the first the current responsivity increases with FEC rise because the ohmic volume resistance drops faster that the contact capacity resistance. But the further FEC rise leads to the barrier permeability increase. As a consequence the CVD nonlinearity and current responsivity reduce. The contacts metal-InSb with $n > 10^{18}$ cm^{-3} are practically ohmic. If metal is replaced by HTSC the CVD nonlinearity and DD parameters are improved essentially. This effect increases when energy gap width becomes more. This fact points out the necessity to select HTSC with maximum energy gap.

According to fig.1 the HTSC use is effective at n > 10^{16} cm^{-3}. If FEC is lower the potential barriers are wide. In this situation the tunneling of electrons near the Fermi level is not important. The main contribution in the current is due to electrons from higher energy levels, where the superconductor densities of states anomalies are negligible.

The calculated current responsivity, voltage responsivity and NEP dependences on the signal frequency are shown at fig. 2, 3, 4 respectively.

The HTSC-InSb contact with Δ = 25 meV was considered. In fig. 2 the logarithmic scale for X-axis is used. In figs. 3, 4 the double logarithmic scale is used.

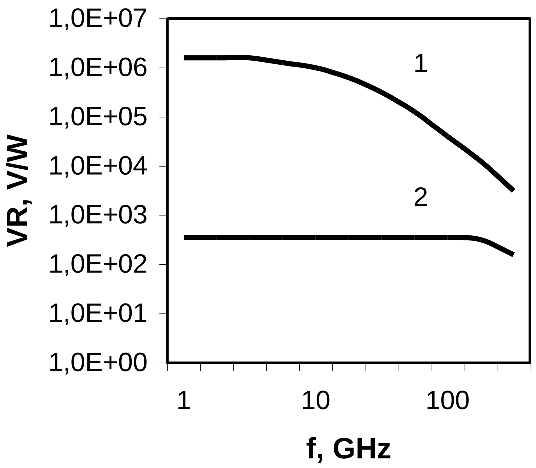

Fig. 3. The calculated voltage responsivity dependence on the signal frequency.

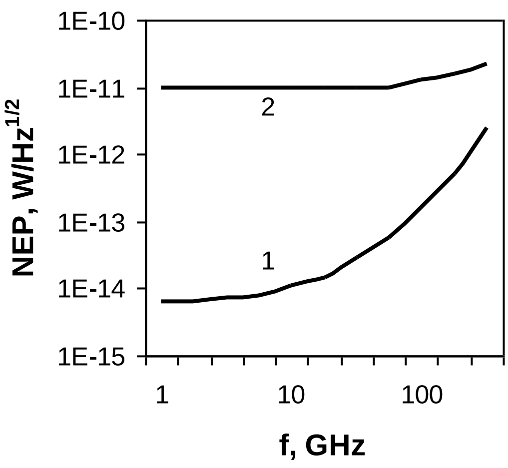

Fig. 4. The calculated noise equivalent power dependence on the signal frequency.

In both figures curves 1 and 2 correspond to situation n = 10^{16} cm^{-3} and n = 10^{17} cm^{-3}respectively.

Fig. 2, 3, 4 show the current and voltage responsivities decrease and NEP increases at the frequencies more 10 GHz. At these frequencies the negative role of the barrier capacity is revealed and it begins to shunt the nonlinear contact resistance. The current redistribution occurs, it leads to reduction of the rectified current and DD parameters become worse. In order to diminish this effect the grater FEC may be used, but in this case the contact resistance decreases and the noise currents increase; these effects lead to voltage responsivity reduction and NEP increase (see curves 1 and 2 at fig. 3, 4).

According to our results InSb with n ≈ 10^{17} cm^{-3} is the best material to increase voltage responsivity and to reduce NEP.

3. CONCLUSION

The comparison with [1, 2] data shows the proposed DD can be 10÷100 times better than existing DD. The contact area reduction allows improving DD characteristics. This fact draws the conclusion the HTSC-semiconductor contacts are perspective to elaborate them.

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