DETECTION IN THE CONTACTS AT LOW TEMPERATURES: INFLUENCE OF THE FREE ELECTRONS CONCENTRATION ON THE DETECTING PARAMETERS

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The diode detectors (DD) play an important role in radio technique and electronics. The use of high frequencies (above 1 GHz) stimulated the careful study of diodes with Schottky barrier. These diodes use the quick-acting metal-semiconductor contacts.

The further improvement of their parameters was achieved due to fall of the working temperature (T). This direction was named cryoelectronics, it allows to raise the nonlinearity of the current-voltage dependences and current responsivity. The thermal noise power decreases too. For example there were elaborated DD based on the contacts Pb-pGaAs . At the signal frequency f = 9 GHz and T= 4.2 K these diodes had current responsivity (CR) 500 A/W and noise equivalent power (NEP) 5×10^{-15} W/$\sqrt{Hz}$. At the same frequency and T= 1 K there parameters were: CR ≈ 2500 A/W and NEP ≈ 4×10^{-16} W/$\sqrt{Hz}$. Also the deep cooling allows using the materials with little energy gap width but high mobility of electrons, such as solid solutions Bi-Sb.

After the discovery of the high temperature superconductors (HTSC) the possibilities to use HTSC in cryoelectronics were studied too. 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. The further studies allowed to create the structures with VR=5000 V/W and NEP = 2×10^{-12} W/$\sqrt{Hz}$ at the signal frequency f=31 GHz and temperature T = 77 K. According to our publication the diode detectors based on the contacts HTSC-InSb may have CR ≈ 40 A/W, VR ≈ 10^6 V/W and NEP ≈ 8×10^{-15} W/$\sqrt{Hz}$ at T = 77.4 K and f = 10 GHz . At the same temperature and f = 30 GHz these DD may have CR ≈ 15 A/W, VR ≈ 3.5×10^5 V/W and NEP ≈ 2×10^{-14} W/$\sqrt{Hz}$.

On the other hand often there is an oxidation of semiconductor in HTSC-semiconductor contacts, because oxygen is an integral part of HTSC. Also cooling to the liquid nitrogen temperature 77.4 K may be insufficient to obtain the good DD parameters. In this situation, taking into account the rapid development of cryogenics, the study of DD based on the contacts traditional superconductor – semiconductor seems to be actual problem. Usually these diode detectors work at liquid helium temperatures (T ≤ 4.2 K).

In this paper the numerical modeling of the electrical potential distribution and current passing in the contacts of different materials with semiconductor alloy bismuth-antimony was made. The contacts of semiconductor solid solution $Bi_{0.88}Sb_{0.12}$ with normal metal or superconductor were considered. The normal metal may be aluminum at T ≥ 1.2 K and silver or gold at lower temperatures. Niobium or niobium nitride (NbN) may be chosen as superconductors at liquid helium temperatures. The influence of the free electrons concentration on the detecting parameters was shown too.

The comparison with HTSC-semiconductor structures was realized. The main advantages of bismuth-antimony alloys were discussed.