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Quasiparticle Self-recombination in Superconducting Tunnel Junction X-ray Detectors

Main author:

ANDRIANOV Victor

Co-authors:

Andrianov Victor, Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics

Gorkov Valery, Lomonosov Moscow State University, Faculty of Computational Mathematics and Cybernetics

Cryogenic detectors based on superconducting tunnel junctions (STJ detectors) have high energy resolution and low energy threshold and can be used in the precision X-ray, ultraviolet and optical spectroscopy [1]. Unfortunately, in soft X-ray range the energy resolution is noticeably worse than the theoretical predictions. One possible mechanism of the energy resolution degradation is self-recombination of the excess quasiparticles, generated in superconducting absorber after X-ray quantum absorption.

In this work the amplitude and the temporal shape of the signals were calculated on the basis of 2D-diffusional model of quasiparticle motion in both electrodes of STJ-detector.

The model takes into account the quasiparticle tunneling by electron and hole channels, quasiparticle losses in the volume of the electrode and at the electrode boundaries, self-recombination terms and 2Δ-phonon exchange between electrodes. Detector signals were numerical calculated for different sets of the parameters describing the both electrodes of STJ-detector. It was shown that the self-recombination cause 1) a nonlinear dependence of the detector response on the photon energy; 2) broadening of the spectral line; and 3) changing in the temporal shape of the detector signals.

The calculations were compared with experimental data obtained for the so-called detectors with killed electrode. One set of parameters described the experimental data, including the different curvature of the dependences of the signal amplitude on the absorbed X-ray energy and temporal shape of the signals for top and bottom electrodes.

The conditions of the compensation of recombination losses were considered. Full compensation of recombination is possible only in the case of a symmetric detector having the same sets of parameters for both electrodes. Unfortunately, these detectors cannot be implemented practically. Noticeable weakening of recombination effects is

expected in cases when the compensation condition was satisfied for the electrode where the photon has been absorbed. For these detectors dependence of the signal amplitude on the photon energy is almost linear, and recombination broadening of the detector line is significantly weakened.

1. P.Lerch, A.Zender. Quantum Giaever Detectors in Cryogenic Particle Detectors. Topics in applied physics. Christian Enss, (Editor) Springer. 2005. V.99. P.217.
2. V.A.Andrianov, V.P.Gorkov et al. // Semiconductors. 2007. V.41. P.215.