Gate-Controlled Near-Surface Josephson junctions

Louise Olausson[1,2], Patrik Olausson[1,2], Erik Lind[1,2]
[1] Department of Electrical and Information Technology, Lund University, [2] NanoLund, Lund University

Introduction

Gate-controlled superconductor-semiconductor Josephson junctions are an interesting platform for emerging quantum technologies. The potential application of gate-tunable Josephson junctions spans from gatemon qubits for superconducting quantum computation to quantum-limited electrically tuned parametric amplifiers.

Method

We have investigated the superconducting properties of a near-surface Al–InGaAs–Al Josephson field-effect transistor (JoFET), where the channel is located directly at the surface and separated to a top gate by only 10 nm Al_2O_3/HfO_2, allowing for fabrication of devices with short gate lengths and high gate control. Such geometry is needed for very short gate length scaling, which together with RF-compatible T-gates, can be utilized for implementing quantum-limited amplifiers. We also developed a compact model of our JoFET using Verilog-A, which considers the gate tunability of the semiconductor, the carrier density-dependent mobility and transmission coefficients, semiconductor band tails, non-ideal interfaces, and nonlinear excess resistances.

Results

Circuit simulations in Advanced Design System using our compact model showed excellent agreement with the measured current-driven data at cryogenic temperatures. From the circuit simulations, an effective gate-dependent transmission coefficient, with a peak value of ~3.5%, was extracted, mainly limited by contact transparency.

Conclusion

We have combined processing, measurements, and modeling of gate-controlled near-surface Josephson junctions to facilitate circuit simulations of actual non-ideal JoFETs, which is essential for system-level integration. By combining advanced semiconductor technology with superconducting electrodes, we explore the possibilities to build quantum-limited cryogenic amplifiers.