Gate-controlled metallic superconductors and superconducting diodes

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The constant demand for faster and more efficient electronics encourages the development of solutions beyond Moore-era of CMOS technologies on which power consumption and thermal management has become a reason of major concern. To address the problem of the increasing power demand of modern computers, hybrid architectures combining CMOS devices with low-energy dissipation devices made of superconductor materials have been proposed. However, several issues need to be addressed for a realistic implementation. In this talk I will discuss the current progress of two emerging fields in superconducting electronics: gate controlled supercurrent (GCS) in metallic superconductors [1] and the superconduct-ting diode effect (SDE) [2]. The suppression of superconducting correlations due to a gate voltage in metallic platforms offer a promising alternative to Josephson junctions-based technologies with superior performance in terms of (i) scalability, (ii) interfacing with CMOS circuits, and (iii) stability against magnetic performance [3].
On the other side, SDE refers to the asymmetric switching of the critical current required to turn a superconductor into the normal state depending on the current bias polarity. Breaking both inversion and time-reversal is the foundational aspect to enable the diode effect. In our latest works, we demonstrate the potential of conventional Niobium-based nanobridges as tunable superconducting diodes.
in a regime without magnetic screening [4]. Despite the intense efforts in designing highly efficient supercurrent diodes, most of the proposals relies on magnetic fields, magnetic materials, or vortices as time-reversal symmetry breakers [5]. We propose a new paradigm for nonreciprocal superconducting transport in a completely magnetic field-free fashion that does not rely on time-reversal symmetry breakers [6]. We demonstrate nearly ideal rectification of the supercurrent in a gate-controlled reciprocal weak link by employing a back-action supercurrent mechanism. The proof-of-principle not only provides new functionalities to GCS devices, but it also represent a general pathway to design supercurrent diodes independently of the specific mechanism that yields the supercurrent suppression.

[1] de Simoni, G. *et al*. Nat. Nanotechnol. 13,802 (2018)
[2] Ando, F. *et al*. Nature 584,373 (2020)
[3] Lupo, FV. *et al*. IEEE Trans. Appl. Supercond. 34, 3 (2024)
[4] Margineda, D. *et al*. Comms. Phys. 6,343(2023)
[5] Nadeem, M. et al. Nat. Rev. Phys. 5, 558 (2023)
[6] Margineda, D. et al. arXiv:2311.14503 (2024)

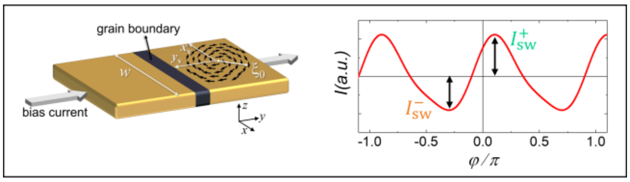

Figure 1: Model of sign-tunable diode effect in superconducting nanobridge. [4]

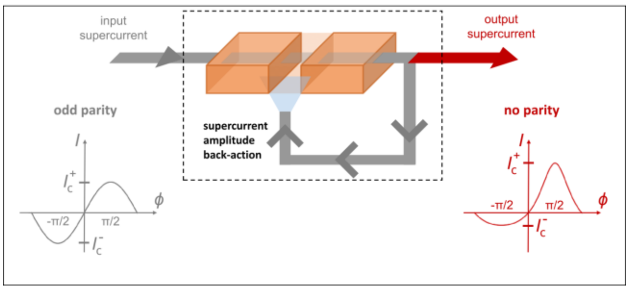

Figure 2: Principle of supercurrent diode effect by supercurrent amplitude back-action. [6]