Hybrid Superconducting Electronics: From Materials to Applications

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Hybrid superconducting electronics, which combine superconductors and semiconductors, are emerging as a promising platform for scalable quantum and cryogenic technologies. InAs-based Josephson devices combine electrostatic tunability, high interface transparency, and planar fabrication compatibility.

The central focus of this talk is the InAs-on-insulator (InAsOI) platform, where an epitaxial InAs layer is integrated on an electrically insulating InAlAs buffer [1]. This architecture electrically isolates adjacent devices while preserving high critical current densities and excellent superconducting transport. Hybrid Josephson junctions fabricated on InAsOI exhibit switching current densities up to 7.3 $\mu A\ \mu m^{-1}$ and robust Fraunhofer-like magnetic interference patterns.

Gate-tunable Josephson field-effect transistors (JoFETs) employing HfO_2 and $Al2O_3$ gate insulators achieve on-demand complete suppression of the switching current and strong modulation of the normal-state resistance [2]. These devices enable novel cryogenic functionalities. JoFETs are integrated in realizing non-dissipative superconducting demultiplexers operating up to several GHz, providing a route toward scalable cryogenic signal routing [3]. Programmable JoFETs exploiting the HfO_2-based ferroelectricity further demonstrate non-volatile superconducting memory operation at mK temperatures [4].

Finally, superconducting diode architectures based on a biharmonic AC excitation [5] or a back-action rectifying effect [6] enable the control of diode polarity and nearly ideal rectification efficiencies without requiring exotic materials or static magnetic fields. Together, these results show how advances in hybrid materials and device engineering are driving superconducting electronics toward useful and scalable cryogenic technological applications.

References

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