Quantum sensing of supercurrent and phase transition in superconducting device

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Abstract

Josephson junction is a building block useful in quantum sensing, quantum computing and fundamental research on strong correlation and superconductivity. [1-3] However, direct imaging of the supercurrent flow and superconducting phase remains elusive, leading to controversies in detailed analysis of findings such as local current distribution [2-3] and asymmetry [4,5]. Here, we present direct visualization of supercurrent flow in Josephson junction using scanning nitrogen-vacancy (NV) magnetometer. NV centre in diamond can detect nanoscale magnetic field as well as dynamics. We demonstrate the evolution of supercurrent with external bias and field and uncover the competing ground states that are electrically switchable within zero-resistance regime. We further reveal new mechanism of Josephson diode Effect [5] which arises from kinetic inductance of the superconductor by revealing the underlying symmetry breaking of the system. This newly explored mechanism allows universal construction of non-dissipative, non-reciprocal device. The nanoscale supercurrent flow is demonstrated as a powerful experimental observable for examining superconductivity and optimizing superconducting devices.

References

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Figures

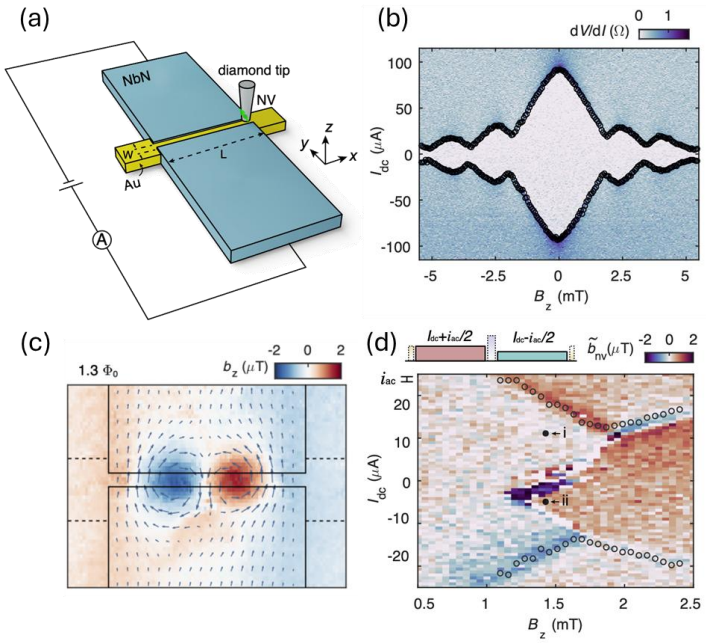

Figure 1 : Imaging of supercurrent flow in superconducting Josephson junction and phase transition within superconducting state (a) Schematics of sample and scanning tip geometry. (b) Superconducting "Fraunhofer" pattern from Josephson junction. (c) Image of supercurrent flow at the Josephson junction measured by scanning NV center magnetometry. (d) Superconducting phase transition visualized by sensing local supercurrent