Nano-SQUIDs with controllable weak links created via current-induced atom migration

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As the most sensitive magnetic field sensor, the superconducting quantum interference device (SQUID) became an essential component in many applications due to its unmatched performance. Through recently achieved miniaturization, using state-of-the-art fabrication methods, this fascinating device extended its functionality and became an important tool in nanomaterial characterization.

During the past years we have developed an accessible and yet powerful technique of targeted atom displacement in order to modify the properties of superconducting weak links. Recently, we showed that the sequential repetition of such customized electro-annealing in a single niobium (Nb) nanoconstriction can broadly tune the superconducting critical temperature T_c and the normal-state resistance R_n in the targeted area [1]. Once a sizable R_n is reached, clear magneto-resistance oscillations are detected along with a Fraunhofer-like field dependence of the critical current, indicating the formation of a weak link but with further adjustable characteristics.

In a next step we used electromigration on an Aluminium DC nano-SQUID to modify the parallel weak links beyond the limits of conventional lithography [2]. The controllability of our protocol allows us to characterize in situ the full superconducting response after each electromigration step. From this in-depth analysis, we reveal an asymmetric evolution of the weak links at cryogenic temperatures. A comparison with time resolved scanning electron microscopy images of the atom migration process at room temperature confirms the peculiar asymmetric evolution of the parallel constrictions. Moreover, we observe that when electromigration has sufficiently reduced the junction's cross section, superconducting phase coherence is attained in the dissipative state, where magnetic flux readout from voltage becomes possible.

References

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