TOPOLOGY- AND GEOMETRY-DRIVEN EFFECTS IN SUPERCONDUCTOR ROLLED-UP NANOARCHITECTURES

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Advances in the high-tech fabrication methods have provided novel curved micro- and nanoarchitectures of superconductors, e.g., nanostructured microtubes, helical microcoils and their arrays. Their highly controllable superconducting properties as well as possible applications have been attracting increasing interest [1]. Vortex dynamics in open superconductor microtubes thickness at nanoscsale in the presence of a transport current are determined by the interplay between the scalar potential and the inhomogeneous magnetic field component, which is normal to the surface. Rolling up superconductor Nb nanomembranes into open tubes and helical microcoils allows for a new, highly correlated vortex dynamics regime that shows a three-fold increase of a critical magnetic field for the beginning of vortex motion and a transition magnetic field between single- and many-vortex dynamic patterns. These results demonstrate pathways of tailoring nonequilibrium properties of vortices in curved superconductor nanoarchitectures leading to their application as tunable superconducting flux generators for fluxon-based information technologies. Using an inhomogeneous transport current enables an efficient control over the branching of vortex nucleation periods and allows for a significant reduction of the average number of vortices that occur in the microtube per nanosecond. The related energy dissipation reduction is of importance for extension of the spectrum of superconductor-based sensors to the low-frequency range.

The voltage generated by moving vortices as a function of magnetic field is revealed using FDTD-simulations for an open Nb microtube. The induced voltage as a function of the magnetic field provides information about the vortex pattern. In particular, an increase of the number of vortex chains in the tube results in a 6-fold decrease of a slope of the induced voltage as a linear function of the magnetic field [2]. A three-fold increase of the magnetoresistance in its peak value at 10 mT in an ultrathin Nb tube of radius 400 nm and length 5 μm is attributed to the occurrence of a phase slip area at such magnetic fields when the quasi-stationary pattern of vortices changes from single to double chains in each half-turn [3]. The effect is promising for application design of novel superconductor switching-based detectors. In superconductor helical microcoils, the distribution and number of vortices in a quasi-stationary pattern can be controlled by the helical radius, pitch distance and stripe width [4]. In the helical microcoils, quasi-degeneracy of vortex patterns, which emerges under the condition that the total number of vortices is incommensurable with the number of half-turns, opens up new possibilities for bifurcations and the related control of the vortex transport. In summary, rolled-up nanoarchitectures show fascinating potential in tailoring the electronic, optical and phonon properties because of topology and geometry-controlled effects.

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