HIGH-VELOCITY VORTEX DYNAMICS IN SUPERCONDUCTORS

O.V. Dobrovolskiy[1,2], M. Huth[1], V. A. Shklovskij[2], R. V. Vovk[2]

[1] *Physikalisches Institut, Goethe University, Max-von-Laue-Str. 1, 60438 Frankfurt/M, Germany*
[2] *Physics Department, V. N. Karazin National University, Svobody Sq. 4, 61077 Kharkiv, Ukraine*
e-mail: *Dobrovolskiy@Physik.uni-frankfurt.de*

The Ginzburg-Landau depairing current density j_{GL} is usually considered as the maximum current density that can be carried by a superconductor without (or with very low) dissipation. In experiments, however, at high vortex velocities achieved at large dc current densities and/or high ac frequencies, samples abruptly transit into the normal state at current densities $j^* \ll j_{\mathrm{GL}}$ because of the *flux-flow instability* (FFI). To describe the FFI near the superconducting transition ($T \approx T_c$), the Larkin-Ovchinnikov (LO) theory [1] and its Bezuglyj-Shklovkij [2] generalization can be applied. The LO FFI is due to a shrinking of core of the moving vortex and the respective drastic drop in the viscosity of the superconducting medium due to the diffusion of quasiparticles from the vortex core to the superconducting surrounding. On the contrary, in the low-temperature limit ($T \ll T_c$) of Kunchur [3] there are three effects: raising of the electronic temperature, creation of additional quasiparticles, and diminishing of the superconducting gap which leads to an expansion of the vortex. This expansion has the effect of reducing the viscous drag due to the softening of gradients of the vortex profile.

Therefore, finding strategies for expanding the low-dissipative current-carrying capability of superconductors at high current densities and microwave frequencies is an important topical problem in Abrikosov fluxonics. In my talk I will outline several successful strategies developed in our lab [5]. Namely, in the dc-driven regime I will address the effects of pinning [6,7], geometrical matching [8] and vortex guiding on j^* and the instability critical velocity v^* in Nb films with washboard pinning nanostructures. For the fabrication of artificial pinning sites we employ mask-less nanofabrication technologies of focused ion beam milling and focused electron-beam induced deposition [9]. Further, I will emphasize that the largest v^* values can be achieved in the temperature range $0.7T_{\mathrm{c}} < T < 0.9T_{\mathrm{c}}$, where the LO vortex core shrinkage is compensated by the Kunchur vortex core expansion. In the ac-driven regime [10], I will mostly dwell on the upper frequency limit for the rectifying effect [11] and will comment on the phenomena of microwave-stimulated superconductivity [12] and thermomagnetic instabilities (avalanches) [13].

This work was funded through the DFG project DO1511/3-1 and supported by the COST Action CA16218 (NANOCOHYBRI) of the European Cooperation in Science and Technology. Further, funding from the European Commission in the framework of the program Marie Sklodowska-Curie Actions – Research and Innovation Staff Exchange (MSCA-RISE) under Grant Agreement No. 644348 (MagIC) is acknowledged.

[1] A. I. Larkin and Yu. N. Ovchinnikov, Zh. Eksp. Teor. Fiz. **68**, 1915 (1975).
[2] A. I. Bezuglyj and V. A. Shklovskij, Physica C **202**, 234 (1992).
[3] M. N. Kunchur, Phys. Rev. Lett. **89**, 137005 (2002).
[4] O. V. Dobrovolskiy Physica C **533**, 80 (2017).
[5] Webpage of the Nano-Fluxonics lab at http://user.uni-frankfurt.de/~odobrovo/
[6] V. A. Shklovskij Physica C **538**, 20 (2017).
[7] V. A. Shklovskij, A. P. Nazipova, and O. V. Dobrovolskiy, Phys. Rev. B **95**, 184517 (2017).
[8] O. V. Dobrovolskiy *et al*, Supercond. Sci. Technol. **30**, 085002 (2017).
[9] M. Huth, F. Porrati, O. V. Dobrovolskiy, Microelectron. Engineering **185-186**, 9 (2018).
[10] E. Silva, N. Pompeo, and O. V. Dobrovolskiy, Phys. Sci. Rev. **10**, 20178004 (2017).
[11] O. V. Dobrovolskiy, M. Huth, V. A. Shklovskij, R. V. Vovk, Sci. Rep. 7, 13740 (2017).
[12] A. Lara, F. G. Aliev, A. V. Silhanek, and V. V. Moshchalkov, Sci. Rep. **5**, 9187 (2015).
[13] A. Lara, F. G. Aliev, V.V. Moshchalkov, Yu. M. Galperin, Phys. Rev. Appl. **8**, 034027 (2017).