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Exploring the limits to vortex pinning in superconductors[1]

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Vortices in type II superconductors sit on a potential energy landscape created by material inhomogeneities. In the presence of an electrical current these inhomogeneities produce a restoring force that precludes vortex motion, thus allowing dissipation-free transport, as long as the current density does not exceed the critical current density J_c. Based on present theoretical understanding, by introducing the appropriate type of pinning centers it should be possible to attain J_c values (for low vortex densities) as large as the physical limit determined by the depairing current density J_0. However, after decades of large efforts and resources dedicated to pinning enhancement (which has obvious technological relevance) we are far below that limit. Presently, the largest J_c/J_0 ratios have been obtained for very thin epitaxial $YBa_2Cu_3O_7$ films and are $\sim$0.3, slightly higher than in the conventional superconductor Nb-Ti (J_c/J_0 $\sim$0.25). I will analyze the possible reasons for this limitation and discuss possible ways to circumvent it. I will particularly focus on the influence of thermal fluctuations, which promote some level of vortex motion even below J_c, resulting in a temporal decay of the supercurrents and consequently lower J_c values as determined by standard experimental techniques. Based on general principles, I will discuss what pinning performance we may expect in yet-to-be-discovered superconductors with high T_c.

[1]Work performed in collaboration with B. Maiorov, S. A. Baily, H. Zhou, S.R. Foltyn, T.G. Holesinger, O. Ugurlu, M. Feldmann, Q.X. Jia, I.O. Usov, and P. Dowden.