Tuning vortex fluctuations and superconducting transitions in thin film bilayers

Alex GUREVICH [1]

[1] *Old Dominion University, Department of Physics, Norfolk, VA 23529, USA*

The ways by which the temperature of the resistive transition T_r of a superconducting film can be increased by a thin superconducting or normal overlayer are discussed. For instance, deposition of a metallic thin overlayer onto a dirty superconducting film can give rise to an "anti-proximity effect" which manifests itself in an initial increase of $T_r(d)$ with the overlayer thickness d followed by a decrease of $T_r(d)$ at larger d. Such a nonmonotonic thickness dependence of $T_r(d)$ results from the interplay of the increase of a net superfluid density and the suppression of the critical temperature T_c due to the conventional proximity effect. This behavior of $T_r(d)$ is obtained by solving the Usadel equations to calculate the temperatures of the BKT transition and the resistive transition due to thermally-activated hopping of vortices in dirty bilayers [1]. The theory incorporates relevant materials parameters such as thicknesses and conductivities of the layers, interface contact resistance between them and the subgap quasiparticle states which affect both the phase fluctuations and the proximity effect suppression of T_c. The transition temperature T_r can be optimized by tuning the overlayer parameters, which can significantly weaken vortex fluctuations and nearly restore the mean-field critical temperature. The calculated $T_r(d)$ may account for the nonmonotonic dependence of $T_r(d)$ observed on (Ag, Au, Mg, Zn)-coated Bi films, Ag-coated Ga and Pb films or NbN and NbTiN films on AlN buffer layers [2-5]. Bilayers can be used as model systems for systematic investigations of optimization of phase fluctuations in superconductors.

References

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E-mail: gurevich@odu.edu