Ultrathin niobium superconducting films: towards Josephson junction arrays

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In this talk I will review our recent experiments undertaken with the goal to clarify the nature of inhomogeneous superconducting (SC) state in ultrathin films of niobium (Nb). The studies of destruction of SC state by disorder in ultrathin films of both conventional and unconventional materials have been used for decades to probe the nature of SC state. Recent experiments suggest the SC state in ultrathin films is inhomogeneous, what may be responsible for so-called anomalous metallic state, in which the resistance in the thinnest films in $T = 0$ limit saturates at the level much smaller than expected for conventional metal [1]. Some experiments on artificial SC islands on metallic substrates [2] support the idea that the inhomogeneous SC state resembles Josephson junction array (JJA), in which SC islands couple across junctions via proximity effect.

We have studied current-voltage (I-V) characteristics of ultrathin Nb films, with thickness in the range 3.4 to 8.5 nm. In the thinnest films we observe features which are clearly identified as JJA behavior in a system of polycrystalline Nb islands immersed in the amorphous Nb background, with SC state arising from proximity effect which couples polycrystalline islands. In particular, we observe 2 different switching currents, and 2 different superconducting transition temperatures, higher temperature related to coherence inside islands, and lower related to global coherence. Minima in differential conductance appear to be caused by multiple Andreev reflection, while vortex creep analysis indicates quantum tunneling of vortices in the milikelvin region. These features confirm the idea that quantum tunneling of vortices is responsible for low-T transport in ultrathin Nb films.

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References

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