Direct Evidence of Proximity Induced Abrikosov Vortex Core in a Nonsuperconducting Metal

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Abstract:
We report on the experimental observation and theoretical study of proximity induced Abrikosov vortices on the surface of a 50nm-thick layer of Cu in the hybrid structure Cu/Nb with ultra-low temperature Scanning Tunneling Spectroscopy (STS) [1]. It was shown that in the studied samples the non-superconducting Cu-layer acquires superconducting correlations due to the proximity effect with 100nm-thick superconducting Nb. The presence of the proximity effect at the surface of Cu is evidenced by observation of a proximity gap in the tunneling conductance spectra dI(V)/dV in clear relation to the value of the superconducting gap of bulk Nb. The evolution of the proximity spectra with temperature was also studied in the range (0.3-4.2) K. Upon application of an external magnetic field, spatial variations of the tunneling conductance spectra were observed in the detailed STS maps as round nm-size spots, in the centers of which the proximity gap vanishes. The density of spots rises continuously with magnetic field; it corresponds perfectly to the expected density of Abrikosov vortices in Nb. We identify the observed spots as proximity induced vortices in Cu. Using the quasiclassical Usadel formalism, theoretical approach was developed to calculate selfconsistently the quasiparticle spectra in the vortex core in three dimensions in a superconductor-normal metal bilayer. The results of numerical calculations are in excellent agreement with experimental data and make it possible to determine the size and the shape of the proximity vortex cores, and to evaluate the coherence length in Cu.

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