Condensed Matter Seminar

Confinement in Superconductors: A Scanning Tunneling Spectroscopy Study

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Tuesday, December 17 ◆ 3:00 P.M. ◆ Room 202 NSH

The most famous macroscopic quantum phenomenon–superconductivity–is characterized by a nanometer-length scale, called coherence length ξ, at which the superconducting condensate evolves in space. The confinement of a superconducting material to scales comparable to ξ should substantially modify the superconducting properties. We addressed the problem of confinement in superconductivity by choosing a quasi-ideal model system–Pb atoms deposited in-situ on atomically clean surface of Si(111) semiconductor. Depending on growth conditions, we are able to produce superconducting Pb-nano-crystals of various sizes and shapes, but also to reach the ultimate thickness limit when only one atomic layer of Pb exists at Si-surface. We studied the superconductivity in these artificial materials by Scanning Tunneling Spectroscopy in UHV at low temperatures down to 0.3K, and under magnetic fields up to 8T.

We will first discuss the simplest case of a vortex lattice weakly confined in relatively large superconducting samples $D \approx 10\xi$. We will show how the increasing confinement influences the vortex lattice, leading to novel ultra-dense configurations, impossible in bulk superconductors. At even higher confinement, $D \approx 3\text{-}4\xi$, the Giant Vortices–quantum tornados characterized by a multiple phase accumulation $L \times 2\pi$, $L = 2; 3; 4$ - are experimentally revealed, and their unusual cores probed [1].

In the second part of the lecture we will discuss the electron confinement effects, i.e. the cases when the carriers are spatially confined to k_F^{-1}. We will present how the superconductivity evolves with the reduction of Pb-film thickness down to a single atomic layer limit. In the latter case, the electronic properties become extremely sensitive to the precise structure of the Pb/Si interface, and may result in an insulating, metallic or superconducting behaviour [2]. In superconducting samples, such tiny and usually ‘inoffensive’ defects as single atomic surface steps or stacking faults disrupt the superconducting order. The samples become a nanometer-scale network of atomic superconducting terraces weakly connected by native Josephson links at steps and stacking faults [3].

[1] Cren, T., Serrier-Garcia L., D., Debontridder et al., Phys. Rev. Lett. 107, 097202 (2011).

[2] Serrier-Garcia L., Brun, C., Cuevas, J., Cren, T., et al., Phys. Rev. Lett. 110, 157003 (2013).

[3] Cerchez, V., Brun, Cren, T., et al., (2013) to be published.

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