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Coherent quantum phenomena in ultimate 2D superconductors: A STM study

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In 1964 V. L. Ginzburg predicted that new superconducting phases could appear in ultrathin films deposited on insulating surfaces. In 2010 superconductivity below 2K was discovered in some crystalline atomic monolayers of Pb grown on atomically clean Si(111) [1,2]. Owing their peculiar electronic properties, these two-dimensional materials manifest a number of intriguing superconducting phenomena. In crystalline monolayers of Pb on Si(111) the superconducting condensate is an intrinsic Josephson network formed by superconducting terraces coupled by Josephson links at individual atomic steps [1]. The detailed atomic arrangement at each step decides the strength of the Josephson coupling. In a magnetic field, the superconducting vortex phase contains different kinds of vortices, ranging from Abrikosov (Pearl) to Josephson limits. By contrast, amorphous monolayers of Pb are non-superconducting correlated metals. Playing with geometry of in-situ grown samples enables realizing ultimately thin lateral SNS junctions, reveal and study Josephson proximity vortices inside their N-parts [2]. When individual magnetic impurities are added, the Cooper pairs are scattered in a peculiar manner, resulting in so-called Yu, Shiba and Rusinov (YSR) bound states. While in three-dimensional superconductors these states rapidly decay around impurities on atomic scale, superconductors with two-dimensional electronic structure such as 2H-NbSe2 or Pb-monolayers on Si(111) host YSR bound states with spatial extents orders of magnitude larger [3]. These long-range magnetic states could be used to produce new topological phases in hybrid systems such as arrays or clusters of magnetic atoms [4] and molecules coupled through the 2D-superconducting medium. In our lecture we describe a series of recent experiments which mapped superconductivity, vortices and YSR states in Pb/Si(111) and 2H-NbSe2 by scanning tunneling microscopy and spectroscopy at ultralow temperatures.

[1] Ch. Brun, et al. Nature Phys. 10, 444 (2014) [2] D. Roditchev, et al. Nature Phys. 11, 332 (2015) [3] G. Ménard, et al. Nature Phys. 11, 1013 (2015) [4] G. Ménard, et al. Nature Comm. 8, 2040 (2017)

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