Electronic-phase engineering in a one-atomic-layer metal film on a semiconductor

Supervisors	Stéphane Pons, Sergio Vlaic, and Dimitri Roditchev stephane.pons@espci.fr, Sergio.vlaic@espci.fr, dimitri.roditchev@espci.fr
Research laboratory	Physics and Materials Study Laboratory (LPEM), ESPCI ParisTech 10, rue Vauquelin 75005 Paris
Website	https://qs.spip.espci.fr/
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Possibility for a thesis	Yes

Rich physics arises at the interface with semiconductors driven by electron and spin-orbit correlations, peculiar interfacial phonon dispersion and low dimensionality. The ground state of a single atomic layer deposited on a semiconducting substrate may range from a superconductor to a wide band insulator. It is related to phenomena of various nature such as Mott transition [1], Charge and Spin Density Waves (CDW/SDW) [2], ordered magnetic phases [3], 1D-physics [4], superconductivity [5], and structural fluctuations. The relevant energies such as Coulomb potential, exchange energy, Rashba spin-orbit coupling, electron-phonon and electron-magnon interactions, depend strongly on the chemical nature of the deposited atomic layer and substrate, on the crystallographic structure of the overlayer and on the doping level of the semiconductor. For all these systems, the characteristic energies are often competing and they make the prediction of the phase diagram very challenging, even for advanced theory calculations. As a consequence, there are many discrepancies between experiments and theory. For instance, the remarkable phenomenon of superconductivity, evidenced in 2010 in single layers of Pb/Si(111) [5], was completely unexpected from the theoretical and experimental points of view [6]. Our recent experiments on Pb/Si(111) show that the superconductivity develops at the very interface of Pb and Si and is not directly related to the superconducting nature of Pb bulk material [6]. We also have discovered a new mechanism inducing superconducting fluctuations at shorter scale than the coherence length of the Cooper pairs (e.g. Fig 1). For lower coverage, the Pb/Si(111) systems show various structural and electronic orders compatible with different scenarios related to a charge (or spin) charge density wave, Mottness and/or magnetic order. The physical origin of many structural and electronic transitions occurring at low temperature in Pb/Si(111) (as it is in Sn/Si(111) or Sn/Ge(111)) are the object of long lying controversy. In particular, there is an uncertainty on the relative importance of electron-electron correlations versus electron-phonon interactions in these systems.

The main purpose of this research program is to provide a systematic combined experimental analysis of a single atomic metal layer on semiconductors. Precisely, the goal is to understand how to control the parameters driving the emergence of new ordered phases and thus paving the way towards an efficient method for electronic-phase engineering and disentangle the effects of superconductivity, electron-electron correlations and spin-orbit interactions.

With us, the student will daily handle state-of-the-art high resolution and low temperature apparatuses for atomic scale, local (scanning tunneling and atomic force microscopy at 1K under ultra-high vacuum) or k-resolved spectroscopy (angle resolved photoemission spectroscopy at low temperature and very high resolution). He will benefit of a careful and responsive supervision of the members of the research group who are used to communicate their scientific and technical knowledge. He will also be formed to the application of toy models for data analysis and benefit of our long standing collaborations with renowned theorists.

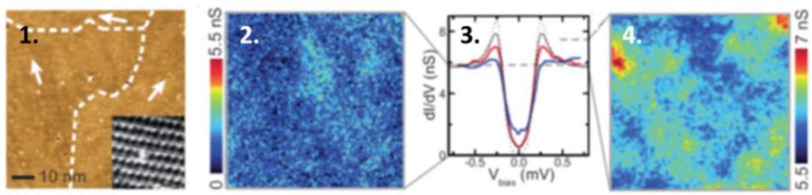

Figure 1: Superconductivity in $\sqrt{7} \times \sqrt{3}$ Pb/Si(111). T=300mK. **1.** Topography image; **2.** Map of the local fluctuations of the gap filling; **3.** Typical recorded superconducting spectra showing electronic gaps (0.25 meV) centered at the Fermi level, surrounded by quasiparticle peaks; **4.** Map of the local fluctuation of the coherence peak amplitude.

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