Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

Laboratory name: **Institut des Nanociences de Paris**
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Web page: http://www.insp.jussieu.fr/-Spectroscopie-des-nouveaux-etats-.html
Internship location: Sorbonne Université, campus Pierre et Marie Curie, 75005 Paris
Thesis possibility after internship: YES
Funding: NO

Local Spectroscopy of two-dimensional Mott insulators

Today, surface systems prepared under ultrahigh vacuum have become highly suitable materials to study low-dimensional physics in a very controlled manner. The reason is that low-dimensional materials are usually fragile systems whose structural and electronic properties can be strongly modified as they react in ambient conditions. In this internship we propose to study a very simple 2D model system for correlated electron physics, prepared under ultrahigh vacuum. The idea behind this family of materials is that they consist of a single atomic plane of (Sn or Pb atoms) grown on Si(111) or Ge(111). They are characterized by a half-filled single electronic band located in the middle of the bulk band gap of the substrate. As the distance between Sn or Pb atoms is large, the on-site Coulomb repulsion between electrons is strong. If the Coulomb energy becomes large enough it triggers a transition from a metallic surface state to a Mott insulator state. This situation makes these systems very attractive because they can be used to study complicated phenomena appearing in other quasi-2D materials presenting Mott physics, like the iconic superconducting cuprates. However, since our materials present a much simpler chemical structure they will enable simplifying and having a better control over various theoretical models attempting to describe electronic properties of strongly correlated phases.

We have recently studied by very-low temperature scanning tunneling microscopy and spectroscopy (STM/STS) the Pb/Si(111) phase [1]. While it was theoretically predicted to be on the verge of transiting from a correlated metal to a Mott insulator [2], we have shown that its ground state is the one of a correlated metal with local charge ordering [1]. Our results have been confirmed by an independent study with a different interpretation of the charge ordering [3]. We here propose to investigate Sn/Si(111), probably the most interesting phase because early experimental results suggested it to be a canonical Mott insulator [4]. Many-body theoretical approaches [2] as well as state-of-the-art *ab initio* methods performed in our group partially support this interpretation. During the internship, we propose to perform a detailed study by STM/STS of the Mott state of this material: from advanced local spectroscopy techniques using quasi-particle interferences we aim at determining both the charge and spin ordering. The long-term goal of this project, is to induce unconventional superconductivity in these materials, as it was done on a square lattice for high-temperature cuprates superconductors.

The candidate should like experimental quantum/condensed matter physics. We are searching for someone highly motivated to pursue this internship in a PhD work.

References:

[1] C. Tresca, et al. PRL, 120, 196402 (2018)
[2] P. Hansmann et al. Phys. Rev. Lett., 110, 166401 (2013)
[3] F. Adler et al., Phys. Rev. Lett., 123, 086401 (2019)
[4] S. Modesti et al., Phys. Rev. Lett., 98, 126401 (2007)

Condensed Matter Physics: YES Macroscopic Physics and complexity: NO
Quantum Physics: YES Theoretical Physics: NO