Internship offered in M2

2018-2019

Responsible for internship

Name: Christophe BRUN, Tristan CREN,

Location:
4 place Jussieu, 75005 Paris

Group: Spectroscopy of novel quantum states

E-mail: christophe.brun@upmc.fr, tristan.cren@upmc.fr

Tel: +33 (0)1 44 27 46 76

Group website: http://www.insp.jussieu.fr/-Spectroscopie-des-nouveaux-etats-.html

Internship topic: Local Spectroscopy of two-dimensional Mott insulators

Today, surface systems prepared under ultrahigh vacuum became highly suitable materials to study two-dimensional physics in a very controlled manner. In particular, while the physics induced by electronic correlations in solids has been studied a lot in bulk materials, studies on purely two-dimensional materials remain rather few. This is particularly interesting because electron-electron repulsion is enhanced in 2D. In this internship we propose to investigate two-dimensional crystals consisting of tetravalent metal atoms (lead: Pb or tin: Sn) grown on silicon or germanium tetravalent (111) surfaces. A crystalline structure exists forming a single layer of metal atoms, with a coverage of 1/3 of a monolayer, where each metal atom sits above three underneath semiconducting atoms to which it is chemically bound. The remaining free electron of each metal atom can hop to the neighboring metal atoms through a strong hybridization with underneath semiconducting atoms. This results in a narrow half-filled band located inside the semiconducting bandgap. As in two dimensions electronic repulsion is enhanced, these systems were predicted to be potential Mott insulators. Experimental results at low temperature show that Sn/Si(111) and Sn/Ge(111) undergo a transition driven by the electronic correlations and become Mott insulators [1,2]. On the other hand, Pb/Si(111) was predicted to be less correlated [3] and we have found its groundstate to be a correlated metal at low temperature with a tremendous effect of spin-orbit coupling [4].
A fascinating aspect of these 1/3ML Mott insulators deals with their poorly known magnetic properties. They correspond to spin-1/2 Heisenberg systems on a triangular lattice. Geometric frustration is thus intrinsically present in these systems. Nevertheless it was argued theoretically and experimentally suggested that a surprising ordered magnetic phase is stabilized in Sn/Si(111). We propose to pursue these studies by investigating Sn/Si(111) with low-temperature (300mK) scanning tunneling spectroscopy in high magnetic field. The long-term goal of this project is to try to induce unconventional superconductivity on a triangular lattice, considering that it was shown to be possible on a square lattice for high-temperature cuprates superconductors.
We are searching for someone highly motivated to pursue this internship in a PhD work.

[1] R. Cortès et al., Phys. Rev. Lett., 96, 126103 (2006) [2] S. Modesti et al., Phys. Rev. Lett., 98, 126401 (2007) [3] P. Hansmann et al. Phys. Rev. Lett., 110, 166401 (2013) [4] C. Tresca, C. Brun et al. Phys. Rev. Lett. 120, 196402 (2018) [5] G. Li et al. Nat. Commun. 4, 1620 doi: 10.1038ncomms2617 (2013)

Techniques involved: Scanning tunneling microscopy/spectroscopy, very low-temperature, high magnetic field, ultrahigh-vacuum, surface physics characterization tools: LEED, Auger

Type of internship: experimental
Paid internship: Yes
Can this internship be continued for a PhD? Yes
If yes, type of PhD funding envisaged is: ANR