Direct imaging of electrical fields using a scanning single electron transistor

Jorge P. Nacenta Mendivil[a*], Roman B. G. Kramer[a], et Laurent Lévy[a]

a. Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble, France

* jorge.nacenta@neel.crns.fr'

We have developed a scanning microscope which uses a single electron transistor (SET) as a local probe of surface charges and electric fields. It works at very low temperatures (50 mK) and high magnetic fields (18 T). The SET consists of a small metallic island connected to source and drain electrodes through two tunnel junctions. The current through the SET varies periodically with respect to the electrostatic potential of the island coming from the local electric field. In the low temperature regime (T<<5 K) small electric field variations lead to strong current changes which makes the device a highly sensitive charge detector. A side gate close to the island is used to tune the operating point of the transistor through conducting and blocked regions (Coulomb diamonds) as shown in figure 1(a). The SET is engineered close to a sharp corner of a silicon wafer in order to approach it to a few nanometer from the sample surface. When the SET scans above the surface, the island's electrical potential is governed by local electrical fields making it possible to map the sample's surface electrical properties.

Here we use the side gate in a feedback loop to keep the current constant during the scanning. Monitoring the side gate voltage enable us to map directly the local electric field. We demonstrate this new method on an interdigitated array of nanometer scale electrodes shown in figure 1(b). Figure 1(c) shows the electrical field of the electrodes measured in a distance of about 1 µm above the surface. Besides the precise mapping of electrical fields the SET can be used to measure the compressibility of electronic states making it a unique tool to investigate localized and delocalized states in quantum Hall systems e.g. in GaAs [1], graphene [2] and topological insulators.

-This project has been supported by the Nanoscience Foundation and LANEF, Grenoble.

[1] M. J. Yoo et al. Science **276** (1997) 579.

[2] B. E. Feldman, B. Krauss, J. H. Smet, A. Yacoby Science **337** (2012) 1196.

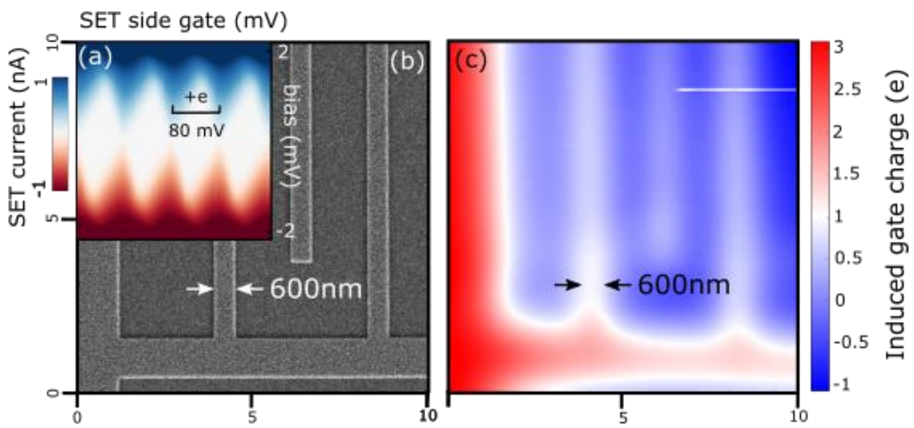

Figure 1 : (a) Coulomb diamonds of the SET measured at 50 mK (b) 10x10 µm SEM image of the interdigitated array of 600nm large Al electrodes on a Si-SiO2 substrate. (c) 10x10 µm SET image of the same region showing the electrostatic potential.