Coulomb blockade in 2DEG potential fluctuations revealed by SGM

H. Sellier [1], **P. Liu** [1], **B. Hackens** [2], **F. Martins** [2],
X. Wallart [3], **L. Desplanque** [3], **V. Bayot** [1,2], **and S. Huant** [1]

[1] *Institut Néel, CNRS & Université Joseph Fourier, BP 166, F-38042 Grenoble*
[2] *IMCN/NAPS, UCLouvain, 2 chemin du cyclotron, B-1348 Louvain-la-Neuve*
[3] *IEMN, UMR CNRS 8520, UST Lille, BP 60069, F-59652 Villeneuve d'Ascq*

Semiconductor heterostructures with remote doping create two-dimensional electron gases (2DEGs) with ballistic transport over several microns at low temperatures thanks to the absence of impurity in the conduction channel. The random distribution of ionized dopants in the barrier, a few tens of nanometers from the 2DEG, is however a source of long-range potential fluctuations. This disorder potential controls the transition to the insulating state at low electron density by breaking the 2DEG into several electron puddles. This behavior has been extensively studied by global transport experiments using planar gates that control electron density over the entire sample. Local microscopic investigation of the disorder potential is a much more difficult task because the 2DEG is buried deep below the surface. Scanning capacitance microscopy [1] has been employed to study large un-patterned 2DEGs and scanning gate microscopy (SGM) [2] has been developed for nanoscale devices.

Here, we present new results on SGM experiments that reveal detailed features of the disorder potential in a low density InGaAs/InAlAs 2DEG etched into 200 nm wide wires. SGM images at 4.2 K reveal the presence of discrete spots where the conductance is strongly affected by the negative potential perturbation induced by the tip of the microscope. These very sensitive spots correspond to the hills of the electrostatic potential that become barriers for transport. In addition, we found that the conductance of these spots does not decrease continuously when the tip bias is getting more negative, but shows periodic oscillations which are typical of Coulomb blockade. These single electron charging effects can be explained by the presence of localized states with low capacitance when the potential landscape presents two barriers in series. Similar Coulomb blockade oscillations have been observed by SGM in epitaxial nanowires [3] and graphene [4], but surprisingly have not been reported for 2DEGs where only charge traps in the barriers have been observed [5].

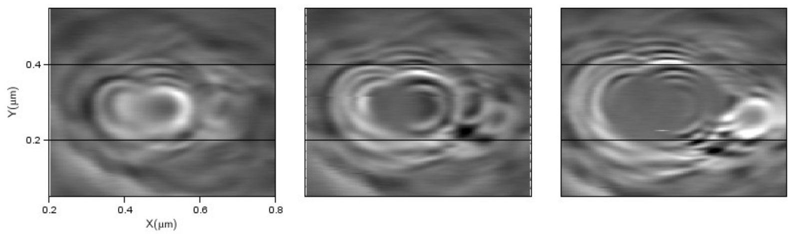

Figure : SGM images recorded above a 200 nm wide horizontal wire (between the two lines) for tip voltages equal to -2.2, -2.5, -2.8 V (from left to right). Several sets of concentric circles appear in the transconductance signal dI/dV_{tip} due to Coulomb blockade in the 2DEG potential fluctuations.

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