Keynote

ELECTROSTATIC FORCE MICROSCOPY OF INGA AT CRYOGENIC TEMPERATURES

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Both nanoelectronic devices as well as 'classical' devices such as field effect transistors usually rely on precise control of the electrostatic potential. Clearly the effect of electrostatic potential fluctuation in both space and time becomes critical for their proper operation. Potential fluctuation can lead to decoherence in quantum devices such as quantum dot based transistors or variations of the operation point of scaled down transistors.

Electrostatic force microscopy has the sensitivity to detect charges smaller than that of a single electron, small potential differences can be detected with high spatial and temporal resolution. I will discuss these techniques and present our studies of single electron detection as well as the measurement of spatial and temporal electrostatic potential fluctuation in InAs/InP heterostructure samples characterized with a low-temperature atomic force microscope (AFM).

The InAs/InP samples investigated are epitaxially grown by chemical beam epitaxy and have a InGaAs quantum well below the surface which serves as a two-dimensional electron gas (2DEG). In this system, self-assembled quantum dots (QD) can also be grown due to lattice strain effects by choosing proper growth conditions. Using FM-AFM techniques we were able to observe single charging events due to Coulomb blockade effects of the QD at 4.5K (fig. 1). Using an amplitude-modulation (AM) imaging mode the surface topography was determined at 4.5 K to be atomically flat with mono-atomic steps (fig. 1). An active Q damping technique was applied to reduce the otherwise very high Q factor (several ten thousand) to an appropriate value (about 1000) for AM mode imaging. It turns out that in frequency modulation (FM) mode imaging it was impossible to get such images because the cantilever oscillation stops as the tip-sample distance gets smaller due to the sudden topographic change associated with QDs. At larger tip-sample distances, by operating the AFM in FM mode and employing Kelvin probe techniques we were ale to observe variation of the surface potential in the region with no QDs as high as 0.5 V. We observe fluctuations of this magnitude over distances of 50 nm (fig. 2). Finally, we will present preliminary results showing how we can change these fluctuations by locally shining light on the sample.

Work done in collaboration with R. Stomp, L. Cockins and Y. Miyahara (McGill University) and P. Poole, S. Studenikin andA. Sachrajda (NRC-IMS)

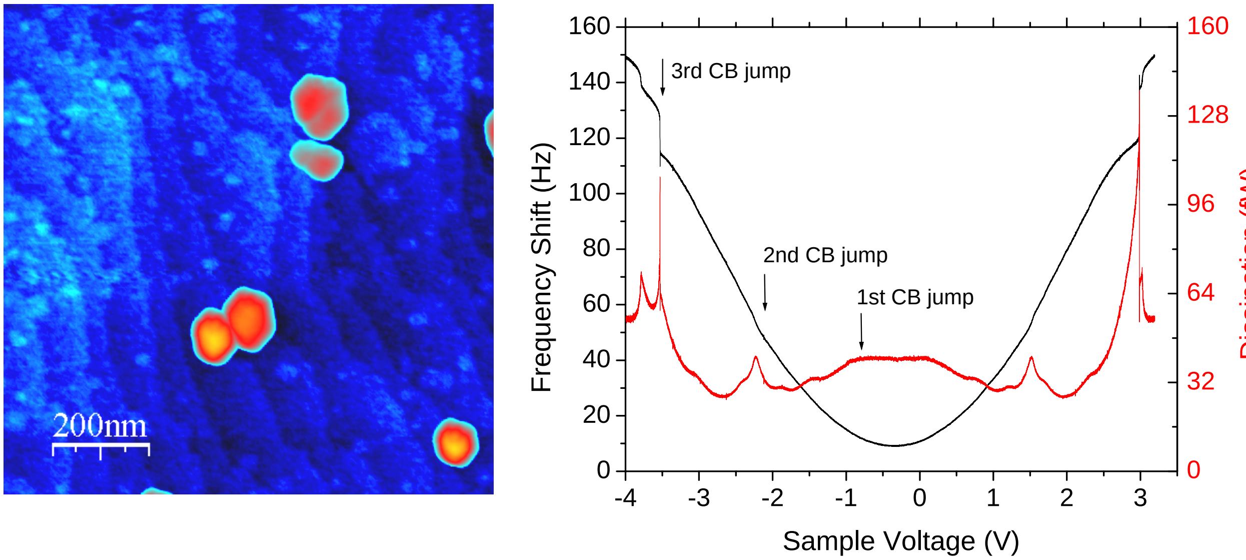

Fig. 1: AM-AFM of QD at 4.5K (left) and detection of Coulomb blockade events by electrostatic force microscopy (Stomp et al. Phys. Rev. Lett., **94**, 056802 (2005))

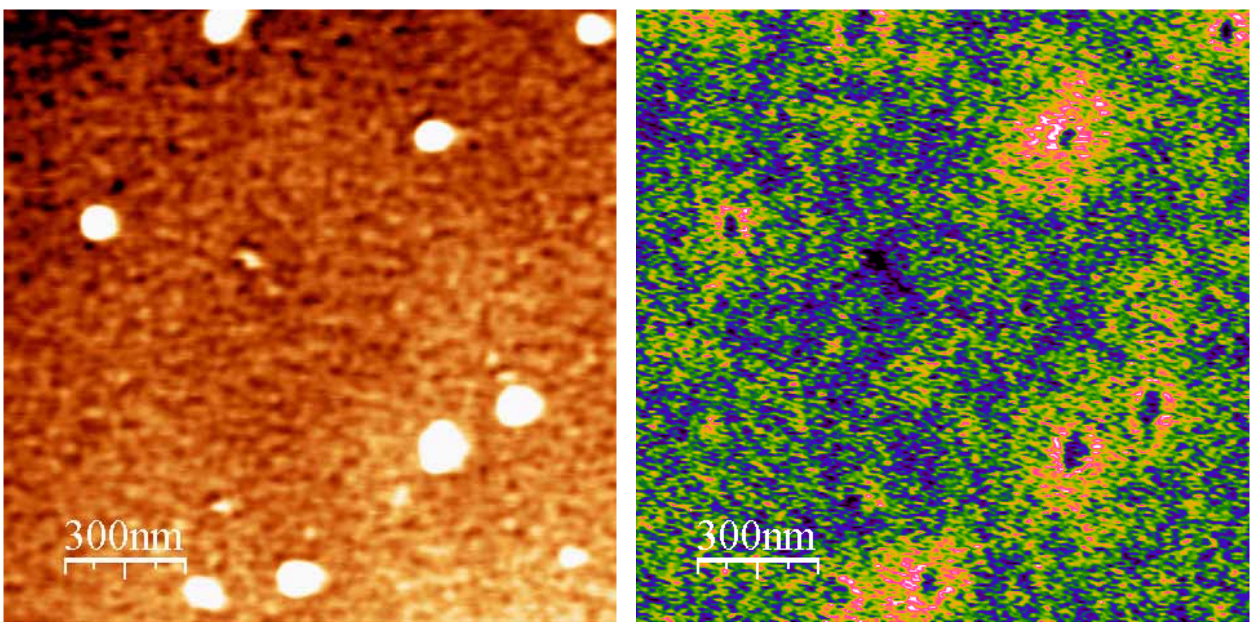

Fig. 2: Topography and contact potential difference measured simultaneously at 4.5 K on InAs/InP sample with QD (contact potential range 1V) (Cockins et al, unpublished)