Electrical characterization of semiconductor nanostructures using ultra high vacuum AFM techniques

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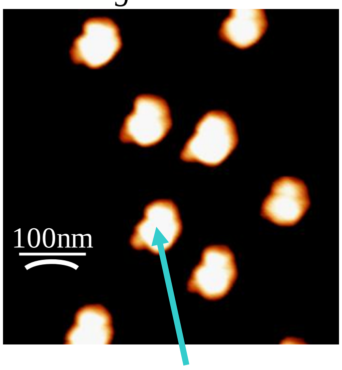
Charge storage in semiconductor nanocrystals has received considerable interest as a means of non-volatile, high-density storage (nanocrystal memories) as well as fundamental studies of tunneling, coulomb blockade phenomena, and modeling of tip-surface forces encountered in electrostatic force microscopy (EFM). As such, it is important to understand the charging and retention behavior of nanocrystals along with local probe techniques used to quantitatively image charge and monitor leakage in nanostructures.

For this practical work, charge injection and storage characteristics of Si/Ge nanocrystals (5-60 nm diameter) and thin oxide layers will be studied using a newly developed EFM technique under ultra high vacuum conditions [1]. We will begin by highlighting the differences between AFM experiments conducted in air and vacuum from the perspective of cantilever resonance, force sensitivity, and non-contact measurement modes. Capacitive forces and their influence on measurements of stored charge in nanostructures will be addressed through experimental determination of the tip-surface capacitance behaviour. Non-linear effects in tip resonance will be discussed and measured to demonstrate the importance of understanding the tip oscillation characteristics with respect to lift height. Next, Si and Ge nanocrystal samples will be charged using the AFM tip in contact mode, followed by measurement of the deposited charge using "amplitude-mode" EFM spectroscopy and imaging.

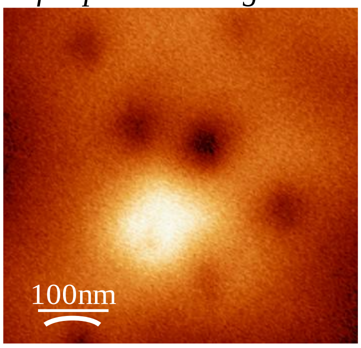
Background knowledge or prior experience with AFM measurements is helpful but not necessary to follow this practical work.

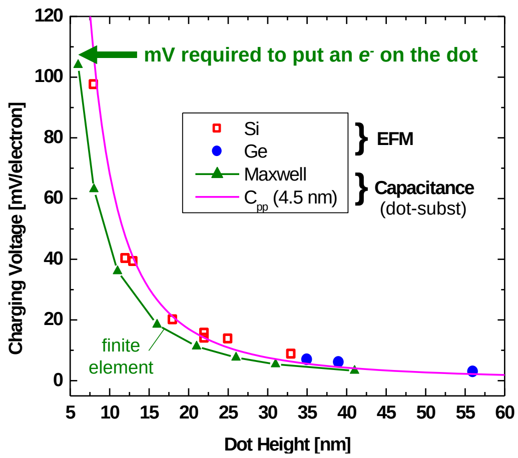
Topography image of 40 nm high Ge dots



Hole injection with V_{tip} = -2V

Non-contact EFM image of deposited charge





Dot charging behavior measured with EFM vs. theoretical predictions.

[1] M. Gordon and T. Baron, **Phys. Rev. B 72**, 165420 (2005) and references therein.