ELECTROSTATIC PROPERTIES OF DOPED SILICON NANOCRYSTALS PROBED BY KELVIN FORCE MICROSCOPY

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We present ultra-high vacuum (UHV) atomic force experiments performed on doped silicon nanocrystals fabricated by plasma enhanced chemical vapour deposition [1]. The aim of this work is to study the doping properties and charge transfers from doped nanocrystals using amplitude modulation Kelvin force microscopy (AM-KFM).

Intrinsinc, p- and n-type doped silicon nanocrystals have been deposited on silicon surfaces (p or n-type), passivated using diluted hydrofluoric acid, and then measured in UHV conditions using a home-made AM-KFM, in which the surface potential is measured using an electrostatic excitation of the cantilever at its second resonance (f_1, here ~450kHz), while the topography is acquired in non-contact mode using a mechanical excitation of the cantilever at its first resonance (f_0, here ~70kHz) [2].

The doping properties of nanocrystals are studied by monitoring the nanocrystal surface potential V_S as a function of the nanocrystal and substrate doping, and also as a function of the nanocrystal size. The case of intrinsic nanocrystals is illustrated in Figure 2 (left), in which the surface potential V_S of the nanocrystals is plotted as a function of their height, showing - in average - positive or negative charge transfer from the p-doped and n-doped substrate, together with strong potential fluctuations attributed to the variation of the nanocrystal surface states. This situation is then compared to the case of n-doped nanocrystals Figure 2 (right), for which much lower potential fluctuations can be observed, and for which the nanocrystal surface potential V_S is found almost independent of the doping level.

These two effects are understood as stemming from the doping of the nanocrystal, which provides the necessary charge to compensate for the nanocrystal surface states, and induce a charge transfer to the substrate. The interpretation of the charge transfer equilibrium will be detailed quantitatively [3], using numerical simulations of the KFM signals taking into account capacitance averaging effects known to occur in AM-KFM [4]. It will be shown that the charge transfer is enhanced due to the quantum confinement in nanocrystals with size <10nm in quantitive agreement with Ref [5].

References:

[1] N. Chaabane et al, Applied Physics Letters, **88** (2006)
[2] H. Diesinger et al, Ultramicroscopy, **108** (2008)
[3] L. Borowik et al, submitted (2009)
[4] F. Krok et al, Phys. Rev. B, **77** (2008)
[5] Y. M. Niquet et al, Phys. Rev., B, **62** (2000)

Figures:

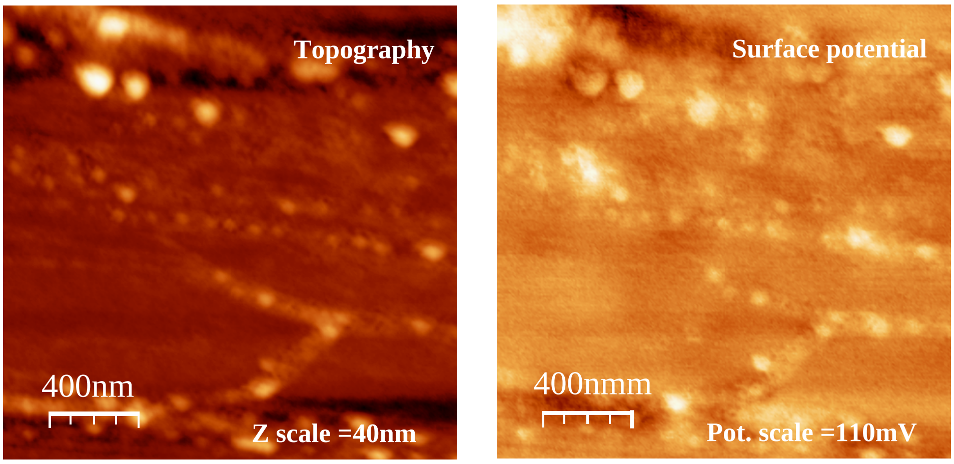

Figure 1: Images of n-doped silicon nanoparticles (topography and surface potential).

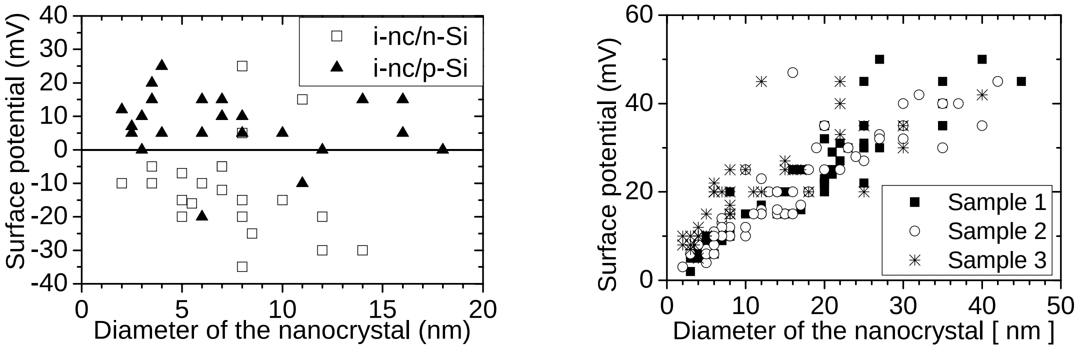

Figure 2: Left: surface potential of the intrinsic Si nanocrystals deposited on p- or n- doped substrates. Right: surface potential of the n-doped Si nanocrystals deposited on a n-doped Si substrate. The three samples correspond to SiH4:PH3 flux ratios of 5:1, 5:5 and 5:10 respectively.