Converse Flexoelectric Effects in PFM

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There are a number of electromechanical phenomena that can give rise to mechanical oscillations of an AFM tip during *ac* electric excitation of a sample: from inverse piezoelectric effect in PFM to the movement of ionic charges in the so-called Electrochemical Strain Microscopy (ESM). In this presentation, I will focus on an additional contribution that has so far been overlooked: the converse flexoelectric effects [1] induced by the electric field gradient generated at the tip end of a conductive AFM cantilever. Due to the flexoelectric effect, the presence of strong local electric field gradients can induce a mechanical strain of the sample even in dielectric centrosymmetric materials. The upshot is that an effective piezoelectric-like response (a deformation induced in response to the tip voltage), with an effective piezoelectric coefficient, can be elicited even from materials that are not piezoelectric. This kind of response strongly depends on the tip geometry and size, and the contact area, as these parameters determine the electric field gradient, and can be detected as a piezoelectric-like signal in PFM experiments. I will show the experimental results of converse-flexoelectric strain induced measurements on different dielectric materials, and numerical simulations of the flexoelectrically-induced effective d_{33} coefficient as a function of tip showing good agreement with the measurements. Finally, I will also discuss about the implications of converse flexoelectricity in quantitative AFM based piezoresponse measurements and in general in PFM imaging.

[1] U. Bhaskar, N. Banerjee, A. Abdollahi, Z.Wang, D.G. Schlom, G. Rijnders, G. Catalan, *A flexoelectric microelectromechanical system on silicon*, Nature Nanotechnology, **11 (**2016) 263