Advances in bimodal AFM imaging of molecules in liquid

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Improving spatial resolution, data acquisition times and material properties imaging are some long established goals in atomic force microscopy (AFM). Currently, the most promising approaches to reach those goals involve the excitation and detection of several frequencies of the tip's oscillation. Usually those frequencies are associated with either the higher harmonics of the oscillation or the eigenmodes of the cantilever. **Bimodal AFM** is an emerging **multifrequency** technique that is characterized by a high signal-to-noise ratio and the versatility to measure simultaneously different forces. The method is also compatible with molecular resolution imaging under the application of **sub-50 pN** peak forces.

Here we will show recent advances in the development of **bimodal force microscopy** for **molecular resolution** imaging **biomolecules in liquid** as well as the three dimensional mapping **of water layers** adsorbed on **proteins**. I will also show some bimodal AFM applications to map simultaneously different interactions such as **mechanical**, **electrical** or **magnetic** interactions. In the presentation I will also discuss the theoretical framework of bimodal AFM operation.

[1] D. Martinez-Martin, E.T. Herruzo, C. Dietz, J. Gomez-Herrero, and R. Garcia, Noninvasive protein structural flexibility mapping by bimodal dynamic force microscopy, *Phys. Rev. Lett.* **106**, 198101 (2011).
[2] C. Dietz, E.T. Herruzo, J.R. Lozano, and R. Garcia, Nanomechanical coupling enables detection and imaging of 5 nm superparamagnetic particles in liquid, *Nanotechnology* **22**, 125708 (2011).
[3] R. Garcia, Images from below the surface, *Nature Nanotechnol.* **5**, 101 (2010)
[4] J.R. Lozano and R. Garcia, Theory of multifrequency atomic force microscopy, *Phys. Rev. Lett.* **100**, 076102 (2008)

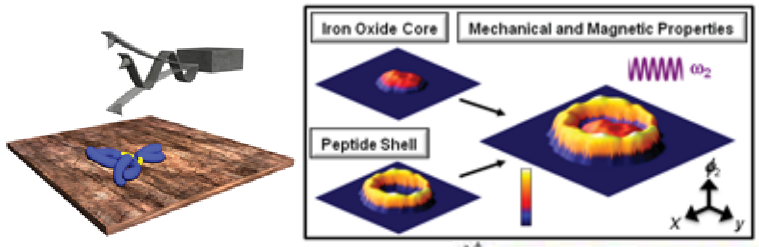

Figure 1. Scheme of bimodal AFM operation (left panel). Imaging the magnetic core of ferritn with sub-5 nm spatial resolution in liquid.

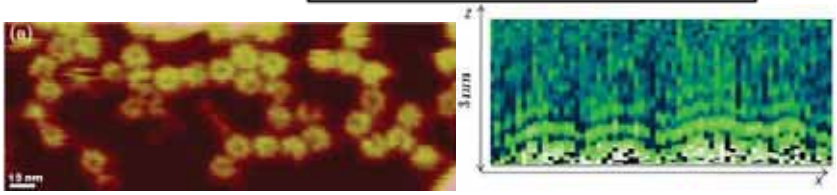

Figure 2. Bimodal AFM imaging of an array of GroEL proteins and the 3D mapping of the water layers on them.