Poster

PRECISE MEASUREMENT OF ELECTROSTATIC TIP-SAMPLE INTERACTION USING 3D-SFM MODE

I. Nieto, *J. Abad, J. Colchero*

Centro de Investigación en Óptica y Nanofísica (CIOyN), Dept. de Física, Universidad de Murcia Campus Espinardo, E-30100 Murcia

inc2@alu.um.es

For development of nanotechnological devices the precise determination of local electronic properties will play an important role. A very powerful tool for this kind of studies is the Scanning Force Microscope (SFM). A variety of SFM modes, in particular Electrostatic Force Microscopy (ESFM) as well as Kelvin Force Microscopy (KFM), have been developed to investigate nanoscale electrical properties in a variety of systems [1,3].

It has been shown that interpretation of data obtained by ESFM or KPM is not an easy task, accordingly, a variety of models have been proposed to describe electrostatic tip-sample interaction. Using appropriate models is a fundamental requisite for quantitative interpretation of data acquired by ESFM or KPM. In particular, in previous works our groups have proposed a model system for typical SFM setups that assumes a cantilever-tip system that is composed of three basic units: a macroscopic cantilever, a mesoscopic tip cone and a nanometer sized tip apex. For this geometry the electrostatic forces as a function of the distance d between the surface and the components of the tip-sample system can be calculated for the different units, leading to well-defined relations of the forces (F_{ev}, F_{cone}, F_{apex}) induced by each unit.[4]

An additional problem encountered in the quantitative evaluation of nanoscale electrostatic properties stems from the fact that different materials may have different contact potentials, which induce electrostatic fields that are "build into" the system. Moreover, in addition to electrostatic forces, also other forces, in particular Van der Waals type, will contribute to tip-sample interaction to further complicate data interpretation.

Recently a spectroscopic technique based on the simultaneous measurement of cantilever deflection, oscillation amplitude and frequency shift as a function of tip-sample voltage and tip-sample distance has been presented and shown to yield very promising results [4]. In this method, data is acquired at a fixed lateral position as interaction images with the bias voltage as fast scan and tip-sample distance as slow scan. Due to the quadratic dependence of the electrostatic interaction with tip-sample voltage the Van der Waals force can be separated from the electrostatic force. Using appropriate data-processing the Van der Waals interaction, the capacitance as well as the contact potential can be determined as a function of tip-sample distance. In order to describe experimental results, two different tip-radii R_{VdW} and R_{estat} as well as two different tip-sample distances d_{VdW} and d_{estat} are introduced, which describe how the tip interacts with the surface: electrostatically and due to Van der Waals forces.

In the present work, this spectroscopic technique is applied to study the electrostatic interaction between model surfaces –Platinum-Iridium as model for a metal surface and silicon as model for a semiconductor surface– in order to compare the experimental results with the behaviour that follows from the model discussed in Ref. [3] (see also fig. 1). Differences of between d_{VdW} and d_{estat} on the one side, and between R_{VdW} and R_{estat} on the other will indicate deviations from the ideal behavior described in ref.[3] and can be interpreted as due to band bending in the case of semiconducting surfaces, or due to the presence of (molecularly thin) dielectric films on the tip or on the sample.

References:

[1] K. L. Sorokina and A. L. Tolstikhina, *Crystallography Reports*, Vol.**49**, No.3 (2004) 476-499.
[2] B. Pérez-García, J. Abad, A. Urbina , J. Colchero and E. Palacios-Lidón, *Nanotechnology* 19 (2008) 065709
[3] E. Palacios-Lidón, B Pérez-García and J Colchero, *Nanotechnology* **20** (2009) 085707.
[4] J. Colchero, A. Gil, and A. M. Baro, *Physical Review B*, **64** (2001) 245403.
[5] E. Palacios-Lidón and J. Colchero, *Nanotechnology* **17** (2006) 5491–5500.

Figures:

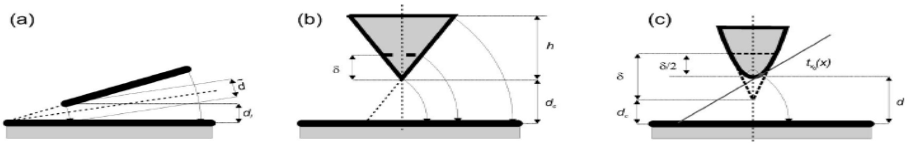

Fig 1. Model for a metal tip-sample system as proposed in Ref. [3] Auxiliary sketches of (a) the lever-sample, (b) the cone-sample, and (c) the tip apex-sample system showing the parameters that are relevant for the calculation of the corresponding forces.

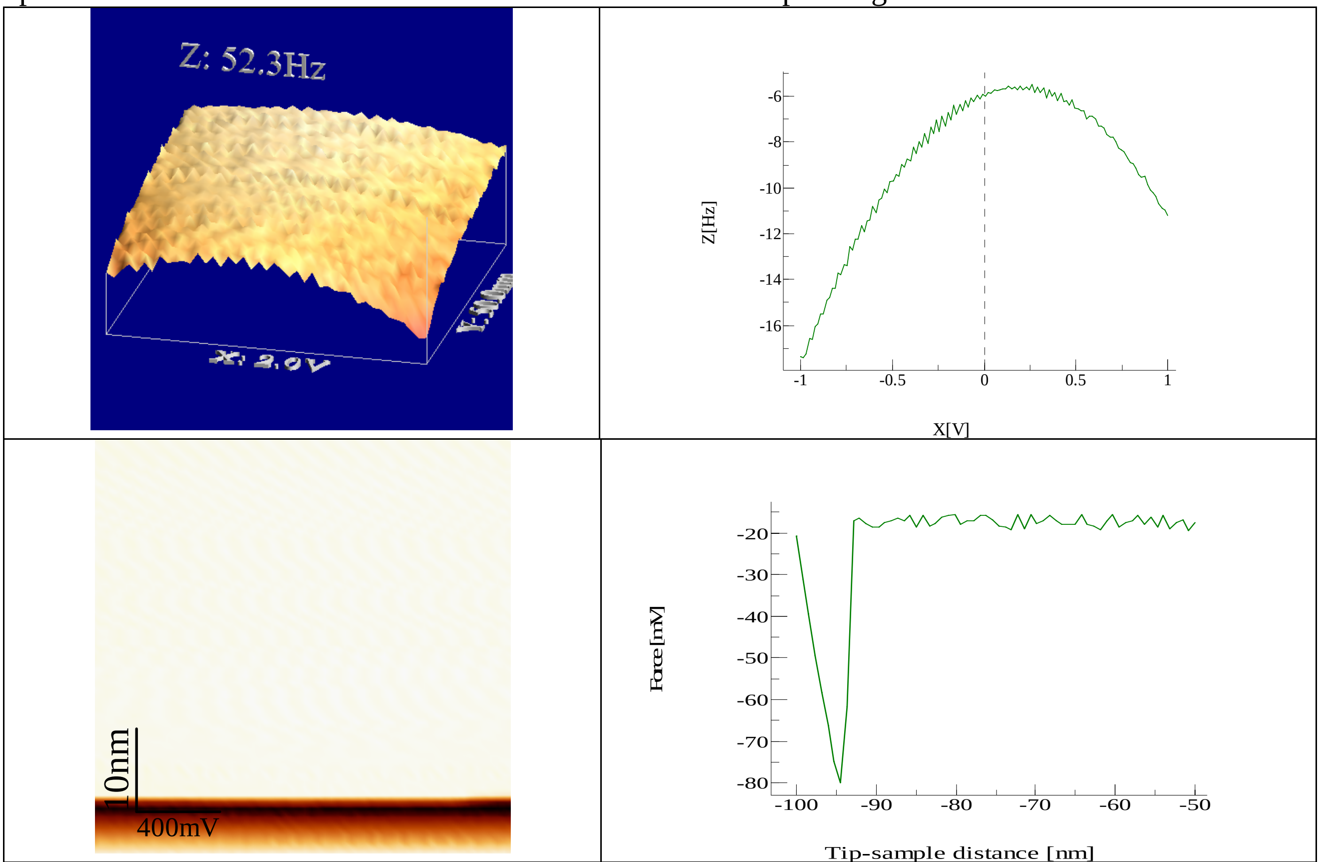

Fig 2. Top Left: Frequency "interaction" image taken using 3D-mode (fast scan "X": bias voltage; slow scan "Y": tip sample distance), were the quadratic dependence with the voltage is clearly appreciated. Also, as the tip-sample distance is reduced (smaller "Y" values, front of image) the curvature of the "interaction" image is larger, due to larger tip-sample interaction. Top Right: horizontal line through the "interaction" image (=interaction at constant tip-sample distance, but variable tip-sample voltage).
From an adjustment of the parabolic curves the precise tip sample interaction can be determined.
Down Left: Normal force "interaction" image. Down Right: typical force vs. distance curve calculated from the force "interaction" image shown down left.