ARTIFICIAL NEURAL NETWORKS APPLIED TO THE CHARACTERIZATION OF UNDETERMINED ELECTROSTATIC FORCE MICROSCOPY SETUPS

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Resumen

Electrostatic Force Microscopy (EFM) and its various implementations (capacitance, polarization, *Kelvin Probe*) are based on the electrostatic interaction between a biased *Atomic Force Microscope* (AFM) tip and a sample. Its high resolution and versatility have been used to analyze different properties of solid surfaces at the nanoscale[1,2] or the dielectric response of single nanowires. Single nanowires can be used to connect different parts of a circuit in nanoscale devices and will play an important role in future electronics.[3]

One of the main advantages of EFM and, in general, *Scanning Probe Microscopy* (SPM), is its potential to estimate relevant magnitudes of the sample quantitatively. However, an inverse problem has to be solved to obtain the values of the magnitudes from experimental data.[4] Following a standard approximation for the EFM interaction[5] we can consider the EFM signal S as a convolution of the Equivalent Surface Profile Z_{eff} and the Response Function RF: $S=Z_{\mathrm{eff}}(\boldsymbol{r}_s,\varepsilon(\boldsymbol{r}_s)) * \mathrm{RF}(\boldsymbol{r}_t,D)$ where Z_{eff} includes information both from the sample topography $\boldsymbol{r}_s$ and from the relative dielectric constant ε. The RF depends on the tip-sample distance D and the tip-cantilever geometry $\boldsymbol{r}_t$ (which includes information of the tip apex radius R_{tip} and the macroscopic shape of the tip).[6] Knowing RF, deconvolution techniques can be used to obtain Z_{eff}. Unfortunately, in EFM experiments, D and $\boldsymbol{r}_t$ are usually unknown, making the inverse problem undetermined. In previous works, R_{tip} has been obtained measuring the vertical force from a clean flat surface.[7] However, although R_{tip} is a key parameter in the electrostatic interaction, traditional techniques require that all the parameters included in RF must be known before any quantitative data is obtained from Z_{eff}. In this talk we show a technique that can solve the inverse problem and extract information from the sample without knowing the RF a priori.

We will analyze an EFM setup composed of a metallic tip over a metallic nanowire on a dielectric sample (see Fig. 1a). In this system, we will consider that both ε (one of the relevant parameters from Z_{eff}) and D (needed to determine RF) are unknown. In a typical non-contact AFM setup, D is difficult to measure because of the bending of the cantilever induced by the tip-sample interaction.[8] Working in humid environments, ε is also difficult to determine because it can be easily modified by the presence of water on the surface. First, we will use the Generalized Image Charge Method[9] (GICM) to obtain the force gradient F' (dF/dz where z is the vertical coordinate) as a function of D and ε. Then, using the F' curves obtained by the GICM as the training set, we estimate simultaneously D and ε with an Artificial Neural Network (ANN) from F' curves not presented during the training. Although both the GICM and ANNs have been used before to analyze and improve the resolution and system stability,[10] they have been never used to quantitatively measure and predict unknown magnitudes in SPM.

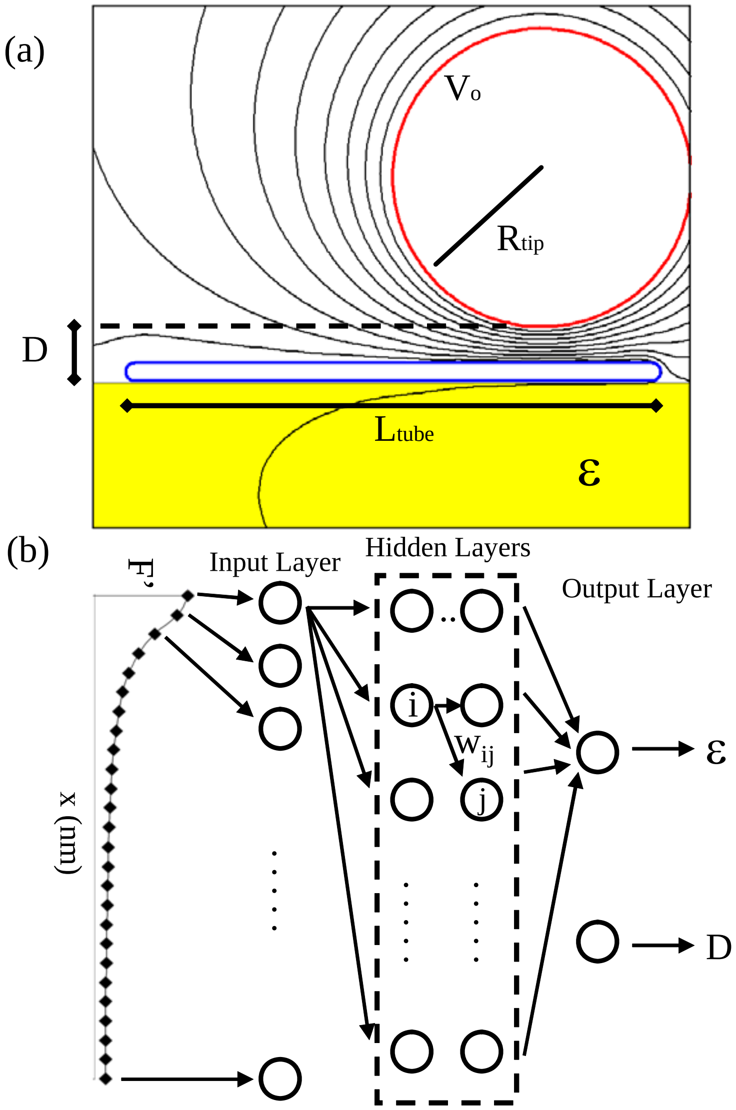

Figure 1: (a) Equipotential distribution calculated by the GICM for a spherical metallic tip scanning a metallic nanowire over a dielectric sample. (b) Scheme of the ANN (multilayer perceptron) used to obtain *D* and ε. The Input Layer (composed of 26 neurons) samples the gradient force (*F'*) curves at several lateral distances (*x*).

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