On the use of Artificial Neural Networks in Electrostatic Force Microscopy

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We present different applications of Artificial Neural Networks [1] in Electrostatic Force Microscopy [2] [3]. First, a detailed analysis of the electrostatic interaction between an Electrostatic Force Microscope tip and a thin film is presented. By using Artificial Neural Networks, an equivalent semiinfinite sample has been described as an excellent approximation to characterize the whole thin film sample. A useful analytical expression has been also developed. In the case of very small thin film thicknesses (around 1nm), the electric response of the material differs even for very high dielectric constants. This effect can be very important for thin materials where the finite size effect can be described by an ultrahigh thin film dielectric constant.

The second application we present is a technique to calculate electrostatic magnitudes such as force and potential in Electrostatic Force Microscopy setups [4]. This technique combines Artificial Neural Networks and the Generalized Image Charge Method [5] to overcome one of the main problems of traditional numerical simulations: the need of many parameters that are difficult to estimate and depend on the geometry of the experimental setup. Using Artificial Neural Networks, our technique is able to estimate the internal parameters of the algorithm and automatically obtain the electric magnitudes with a very high accuracy. This technique has been implemented in the freely distributed software winGICM. [6] The automatic configuration of the software by an Artificial Neural Network allows the users to handle it without being specifically trained in the theoretical background underlying the algorithms.

Finally, a technique that combines a theoretical description of the electrostatic interaction and Artificial Neural Networks (ANNs) is used to solve an inverse problem in Scanning Probe Microscopy setups. [7] Electrostatic interaction curves calculated by the Generalized Image Charge Method (GICM) are used to train and validate the ANN in order to estimate unknown magnitudes in highly undetermined setups. To illustrate this technique, we simultaneously estimate the tip-sample distance and the dielectric constant from a system composed of a tip scanning over a metallic nanowire. In a second example, we use this method to quantitatively estimate the dielectric constant in an even more undetermined system where the tip shape (characterized by three free parameters) is not known. Finally, the proposed method is validated with experimental data.

References

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Figures

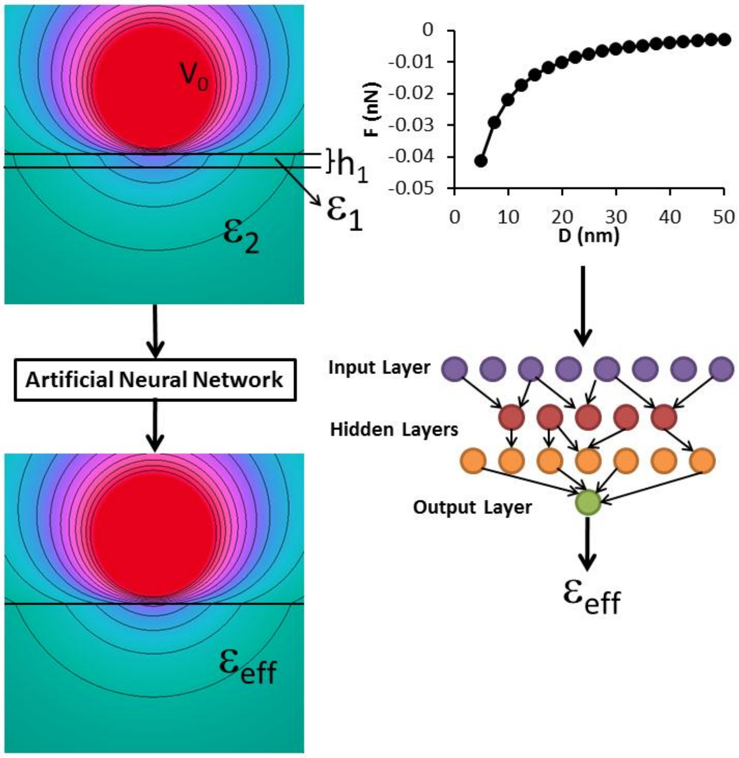

FIG. 1.Scheme of the method to obtain the effective dielectric constant of a thin film sample. The electrostatic force of a system composed by a thin film over a dielectric substrate (equipotential lines shown at the top) is used as the input of an Artificial Neural Network. The output value is the effective dielectric constant of an equivalent sample composed by a semiinfinite dielectric substrate (equipotential lines shown at the bottom).