Capillary effects in Tapping mode Force Microscopy: Phase contrast, Adhesion and Hydrophobicity Maps

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Scanning Force Microscopy (SFM) has become a standard tool to image and manipulate surfaces with nanometer resolution. In order to minimize sample deformations due to the tip interaction, in particular when dealing with soft samples, the SFM images are usually taken by using different dynamic operation modes [1]. Intermittent contact or "tapping" is the most widely used operation mode for investigating various biological materials [2].

Phase contrast images, obtained by simultaneously recording the phase lag of the cantilever oscillation relative to the driving signal, often provides significantly more contrast than the topographic image. The origin of the phase contrast in force microscopy is related to the existence of energy dissipation processes due to tip-sample interactions. When working in air ambient condition, the phase contrast is strongly influenced by capillary forces [3–5]. Capillary force maps would be particularly interesting for biological applications, where the recognition of different species is frequently based on their hydrophilic or hydrophobic nature [3, 5]. However, most of the phase images are purely qualitative, mainly due to the absence of simple relationships relating phase changes with specific surface properties.

In this work we study the influence of capillary forces on phase contrast in tapping operation. Based on a simple model, we predict a quantitative relation between the phase images in tapping mode and adhesion maps. In air ambient conditions, where the adhesion is dominated by capillary forces, phase contrast images are shown to be proportional to the cosine of the contact angle. Under appropriate conditions, phase images of biological samples in air could then be regarded as surface hydrophobicity maps.

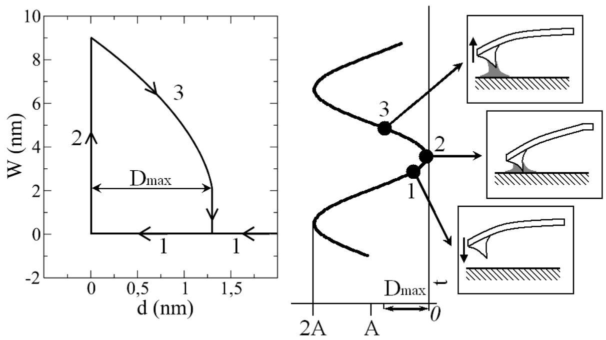

FIG. 1: (a) Width W of the capillary induced water neck versus tip-sample distance d. (b) Sketch of the neck formation and rupture cycles as the tip slightly "tap" the sample: As the tip touch the sample a water bridge condenses by capillarity (1); as the tip retracts, the water neck elongates and finally breaks at a critical elongation D_{max}.

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*URL: `http://www.uam.es/mole`