ENERGY DISSIPATION DUE TO CAPILLARY INTERACTIONS: HYDROPHOBICITY MAPS IN FORCE MICROSCOPY

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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 biological samples, the SFM images are usually taken by using different dynamic operation modes [1]. 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. At fixed feedback amplitude, phase shift variations are directly linked to energy dissipation processes [2-4]. However, most of the phase and energy dissipation images are purely qualitative, mainly due to the absence of simple relationships relating phase changes and energy dissipation with specific surface properties.

As a general approach, power dissipation in AM-AFM is naturally considered synonymous of energy dissipated per cycle. Assuming that the dissipation takes place in each oscillation cycle, it would be proportional to the oscillation frequency, $\nu_{0,}$ i.e. $P_{dis}=\Delta E\nu_0$, being ΔE the energy dissipated in the contact process. In striking contrast to this apparently natural argument, we show that the time-averaged dissipated power is not always proportional to ΔE due to a beating phenomenon where the interaction is occasionally dissipative [5,6].

In air ambient condition, the phase contrast is strongly influenced by capillary forces [5]. When the tip approaches the sample, water condensation from the humidity can induce the formation of a nanometer-sized water bridge. In this work we analyze the energy dissipation process involved in the formation and rupture of a nanometer-sized capillary-condensed water bridge (see Fig. 1). With the help of numerical simulations, dissipation contrast in AM-AFM is shown to be a result of a non-trivial interplay between the energy dissipated in each rupture process and the bi-stable motion of the cantilever. In the repulsive regime (see Fig. 2), the dissipated power is approximately constant and independent of the amplitude as expected. In contrast, in the attractive regime, after the contact process, the cantilever, which has lost energy, will not reach the same amplitude as before the contact, and the tip may not hit the sample surface during the next swings. The power dissipation is then lower than expected.

In the repulsive regime, the dissipated power is a function of the tip and sample contact angles being independent of the elastic properties of the system. Working in this regime, energy dissipation images in air can be regarded as surface hydrophobicity maps.

References:

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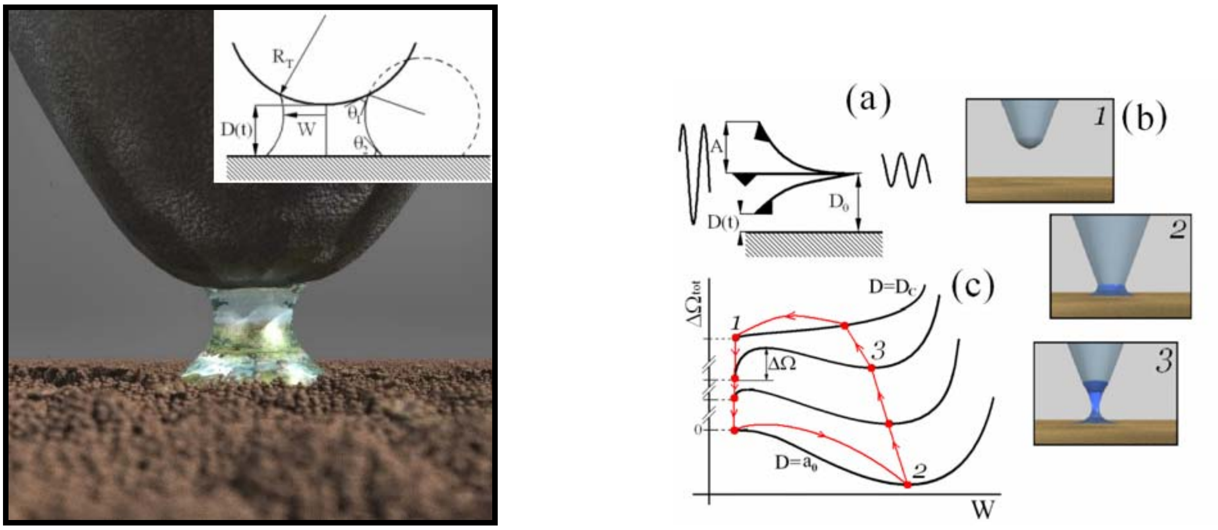

***Figure 1**: Left: chematic representation of the tip-neck-substrate system.
Right: **(a)** Tip-cantilever-driver system. **(b)** Graphic representation of water neck formation/rupture. **(c)** Schematic representation of the formation/rupture process in tapping mode. (After Sahagún et al. [5]).*

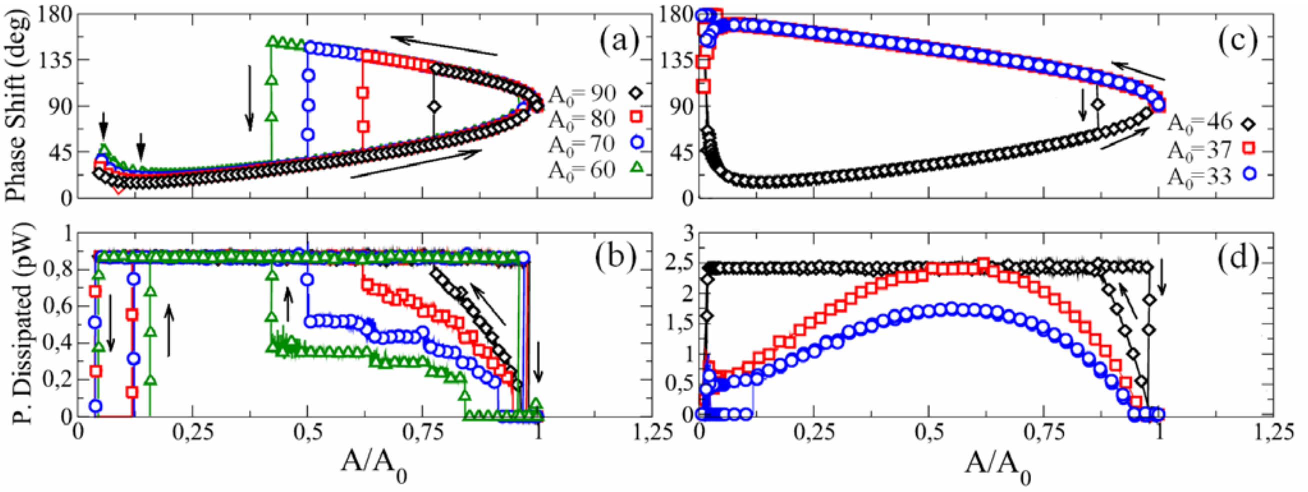

***Figure2** : Phase (a) and power dissipated (b) vs normalized amplitude. (c) and (d) are the same but corresponding to different cantilever constants*
(After Sahagún et al. [5]).