Coupling of conservative and dissipative forces in frequency modulation atomic force microscopy – a source of apparent damping

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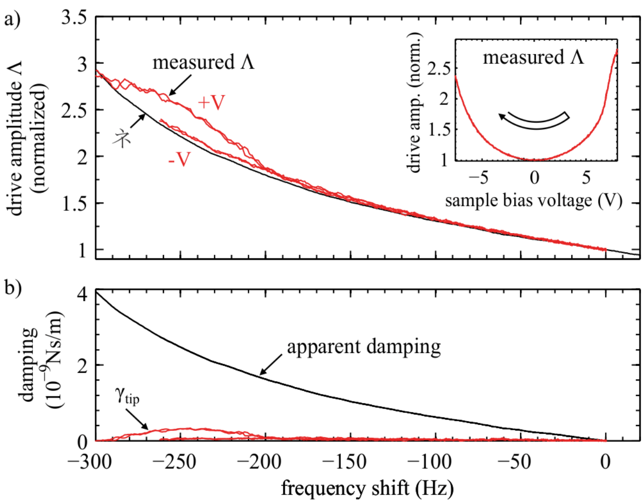
Experiments and theoretical calculations of dissipative forces in FM-AFM often disagree by several orders of magnitude. These discrepancies have repeatedly been attributed to instrumental artifacts, the cause of which remains elusive. We demonstrate that the frequency response of the piezoacoustic cantilever excitation system, traditionally assumed flat, can actually lead to surprisingly large apparent damping by the coupling of the frequency shift to the drive amplitude signal, typically referred to as the "dissipation" signal. Our theory [1], based on a recent derivation presented in the context of liquid environments[2], predicts problems in vacuum environments such as the large quantitative and qualitative variability observed in dissipation spectroscopy experiments, as well as contrast inversion in the drive amplitude signal observed at step edges and in atomic-scale imaging. The magnitude of apparent damping can escalate by more than an order of magnitude at cryogenic temperatures. We present a simple non-destructive method for correcting this source of apparent damping.



The normalized drive amplitude Λ was measured while sweeping the sample bias voltage twice as shown in the inset, and the same data is replotted *vs* measured frequency shift. The drive amplitude predicted for a conservative interaction (ネ) is plotted and shows that most of the measured drive signal is an instrumental artifact. b) The true damping was recovered (γ_{tip}) using the theory derivef in [1]. Assuming a flat piezoacoustic excitation transfer function would have resulted in additional apparent damping, also plotted, *and* the true damping (γ_{tip}) would have been overestimated by almost 3 ×.

[1] A. Labuda, Y. Miyahara, L. Cockins, P. H. Grütter, *submitted* (2011)
[2] A. Labuda, K. Kobayashi, D. Kiracofe, K. Suzuki, P. H. Grütter, H. Yamada, AIP Advances, *accepted* (2011)