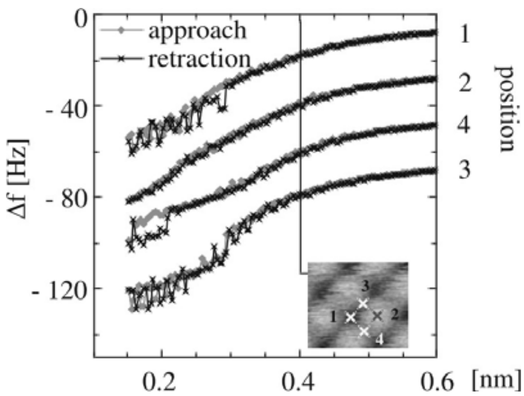
Manifestations of Rare Atomic Hops in Dynamic Force Microscopy

R. Hoffmann[1,2], A. Baratoff[1], H. J. Hug[1,3], H. R. Hidber[1], H. v. Löhneysen[2] and H.-J. Güntherodt[1]
[1]NCCR Nanoscale Science and Institute of Physics, University of Basel, Switzerland
[2]Physics Institute and Center for Functional Nanostructures, University of Karlsruhe, Germany
[3]Swiss Federal Laboratory for Materials Testing and Research, Dübendorf, Switzerland
r.hoffmann@physik.uni-karlsruhe.de

Over the past ten years, dynamic force microscopy has achieved genuine atomic resolution on a variety of samples [1]. Dissipation ΔE reaching ~ 1 eV per cycle upon approach has been attributed to atom hops repeated in every oscillation. This should produce concomitant jumps in Δf and ΔE at the distance where the corresponding force hysteresis appears [2]. Thermal agitation is predicted to smear such jumps [3]. In the present sequel to recent work [4], we report and interpret a puzzling novel behavior which has been found at smaller distances in Δf versus distance measurements. Below a critical distance we observe a sequence of jumps in Δf which appear to lie on two limiting envelopes at positions marked in the inset to fig.1. The average dissipation gradually rises to ~ 0.02 meV per cycle after jumps appear. We attribute both phenomena to infrequent hops between two conformations with energies ε_A , ε_B separated by a low barrier near the apex of the probing tip. The hopping rates γ obey detailed balance. We show that the change in $\varepsilon_A - \varepsilon_B$ is approximately equal to the change in the difference U_A - U_B of the tip-sample interaction energies in the two configurations. The same difference also provides an upper bound on the average energy dissipated per hop at the minimum approach distance. We propose a plausible two-level system which should exhibit the conjectured distance dependence of ε.



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