Mechanical Vertical Manipulation of Single Atoms on the Ge(111)-c(2x8) Surface by Noncontact Atomic Force Microscopy

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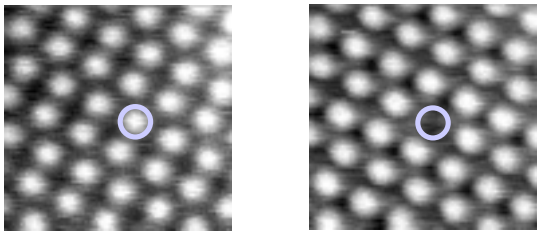
Recently, noncontact atomic force microscopy was used for performing controlled mechanical vertical manipulation of selected single atoms on a surface for the first time [1]. In that work a soft and controlled nanoindentation of a Si tip on selected positions of the surface was used for the extraction of single adatoms, as well as for the deposition of single atoms in a previously created vacancy on the Si(111)-(7x7) surface. However, those experiments were performed using constant excitation mode for driving the cantilever oscillation, making the analysis of the interaction force involved in the vertical manipulation process difficult. In the present contribution, we report on the mechanical vertical manipulation of selected single atoms of the Ge(111)-c(2x8) surface, but using constant amplitude mode. Manipulation experiments removing single atoms from the surface, and depositing single atoms coming from the tip in a previously created vacancy on the Ge(111)-c(2x8) surface using a semiconductor tip will be presented. To apply the inverse procedure proposed by Giessibl [2] to the frequency shift vs. tip-surface distance curves associated with the manipulation processes allows us to obtain information and present a discussion about the forces before and after the manipulation event, and the energy dissipated in the process.

[1] N. Oyabu *et al.*, Phys. Rev. Lett., **90**, 176102 (2003)

[2] F. J. Giessibl, Appl. Phys. Lett., **78**, 123 (2001)



Topographic images before (left), and after (right) the mechanical vertical manipulation of a single Ge adatom highlighted by a circle. Experimental parameters were (8.5x8.5) nm^2, A = 16nm, Δf = -17Hz, and 80K tip and sample temperature.