Mechanical atom manipulation using atomic force microscopy at room temperature

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The manipulation of individual atoms and molecules at surfaces is of great importance for future nanoscale devices, as well as for the investigation of fundamental physical and chemical phenomena occurring at the atomic scale. The ability to construct multifunctional nanostructures with desired properties on the atomic scale has important consequences for a number of important applications, including catalysis, quantum computing devices, and functional nanomaterials. The formation of such specially designed nanostructures has been demonstrated utilizing the atomic manipulation capability of scanning tunneling microscopy (STM) at cryogenic temperatures [1, 2]. It has been shown that fine control of the tip target atom interaction force is required for delicate positioning of individual atoms to a specified location in STM manipulation [3]. The interaction force in a STM experiment can be estimated indirectly by the tunneling conductance. On the other hand, the invention of atomic force microscopy (AFM) has extended the unique capability for atom manipulation on surfaces that are inaccessible to STM [4], and more importantly, provides an opportunity to directly measure the forces [5] involved in the atom manipulation process [6-8].

Here, we present an investigation of the effect of the tip on lateral manipulation using AFM at room temperature. The atom hopping probabilities associated with different manipulation processes as a function of the tip-surface distance are investigated by means of constant height scans with various tips, the interaction of which with surface atoms are evaluated by force spectroscopic measurements. We demonstrate that the efficiency for manipulation is extremely dependent on the nature of the tip-apex chemical properties.

[1] D.M. Eigler and E.K. Schweizer, Nature **344** (1990) 524.
[2] A.J. Heinrich, C.P. Lutz, J.A. Gupta, and D.M. Eigler, Sicence **298** (2002) 1381.
[3] S.-W. Hla, K.-F. Braun, and K.-H. Rieder, Phys. Rev. B, **67** (2003) 201402.
[4] I. Yi, R. Nishi, M. Abe, Y. Sugimoto, and S. Morita, Jpn. J. Appl. Phys. **50** (2011) 015201.
[5] M. Lantz, et al., Science **291** (2001) 2580.
[6] M. Ternes, et al., Science **319** (2008) 1066.
[7] Y. Sugimoto, et al., Phys. Rev. Lett. **98** (2007) 106104.
[8] Y. Sugimoto, et al., Science **322** (2008) 413.