LATERAL MANIPULATION OF SINGLE ATOMS USING ATOMIC FORCE MICROSCOPY

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Engineering nanostructures on different surfaces by manipulating single atoms and molecules is an ultimate target in nanotechnology. Since the first time that atoms were individually arranged on a surface [1], the technique has reached a level in which it is possible to build a logic gate based on few molecules [2] or to set the initial stage of wiring a molecule [3]. Most of these impressive experiments, however, must be performed at cryogenic temperatures for avoiding diffusion and desorption of the atoms and molecules involved. An alternative strategy for the atom-by-atom creation of artificial nanostructures at room temperature (RT) would be highly desirable. Such strategy may allow to take a step forward towards a future application based on the bottom-up approach; especially if the nanostructures remain stable at the surface for relatively long periods of time.

The scanning tunnelling microscope (STM) [4] has proved, so far, to be the unique tool with all the necessary capabilities for laterally pushing, pulling or sliding [5] single atoms and molecules, and arranging them on a surface at will; this restricts such processes to conductive surfaces, and therefore excludes insulators – very important materials in actual technology – as possible templates. In this contribution, we will show that it is also possible to perform well-controlled lateral manipulations of single atoms using the atomic force microscope (AFM) [6]; a technique that provides access to insulating surfaces at atomic level.

An AFM operated using the frequency modulation detection method (FM-AFM) [7] in ultrahigh vacuum environment – also known as non-contact atomic force microscopy [8-10] – allows to probe metallic, semiconductor, and pure insulating surfaces with true atomic resolution. It has been, however, a really challenging task to achieve the needed force control to laterally manipulate single atoms considering the usual method for atomic resolution imaging: a tip placed at the end of a cantilever is oscillated at the cantilever's first mechanical resonant frequency with typical amplitudes of several nanometers driving the tip apex at a distance of only few ångströms above the surface.

In this contribution, we will describe the relevant experiments that led us to succeed in manipulating single atoms using FM-AFM [11-13]. We will present a method for the atom-by-atom creation, at RT, of artificial nanostructures of Sn atoms embedded in a Ge surface [13] (Fig. 1). This method basically depends on a proper alignment of the tip-scan direction and the tuning of the tip-surface interaction force. We will show that such artificial nanostructures remain stable at RT with an estimated minimum lifetime of 25 hours [13].

Atom manipulation using FM-AFM paves the way for the creation of artificial nanostructures on pure insulating surfaces. We will explore the possibility of manipulating single atoms on insulators; task that, nowadays, is a remaining feat in scanning probe microscopy.

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Figures:

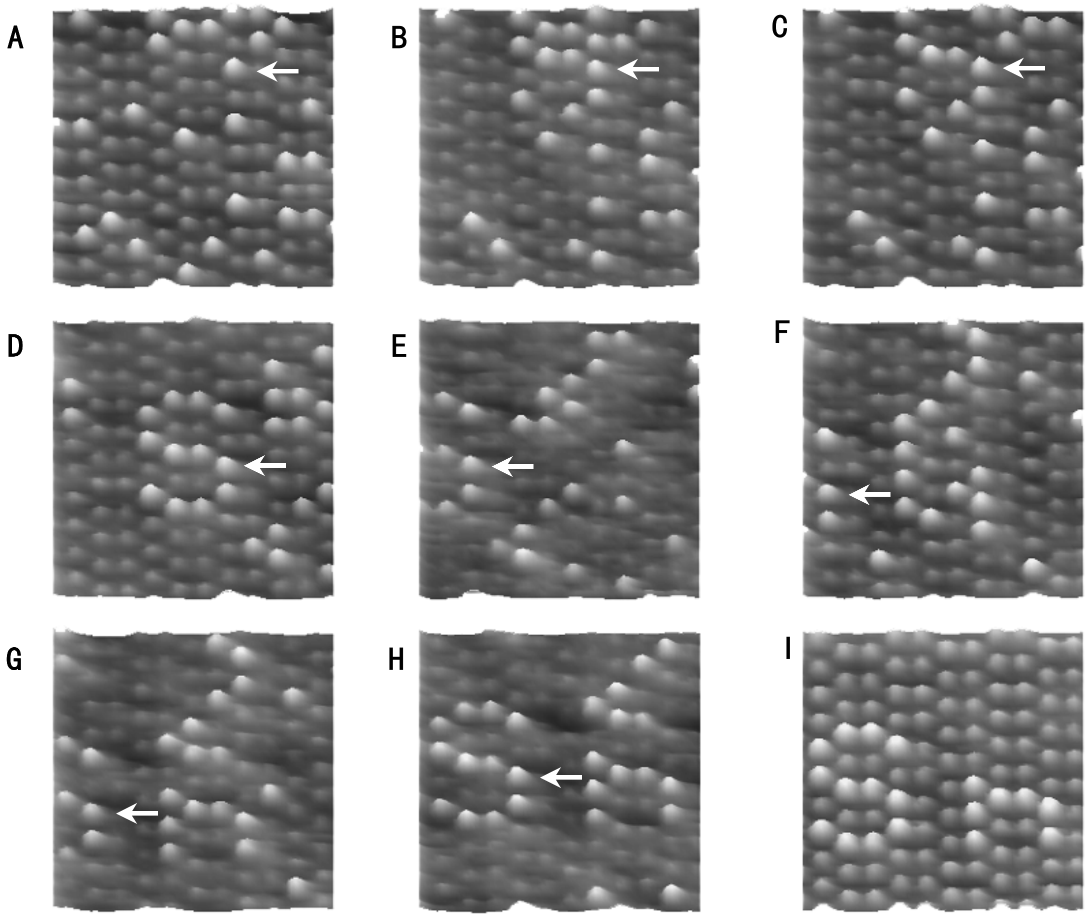

Figure 1: Sequence of topographic FM-AFM images acquired during the process of laterally rearranging single Sn atoms at a Ge(111)-c(2x8) surface for the construction, at room temperature, of the Tin symbol. The arrow indicates an Sn adatom that remain fixed during the whole construction process for clarity. Image size is (7.7 x 7.7) nm^2.