Lateral Manipulation of Atomic Size Defects on the CaF_2(111) Surface

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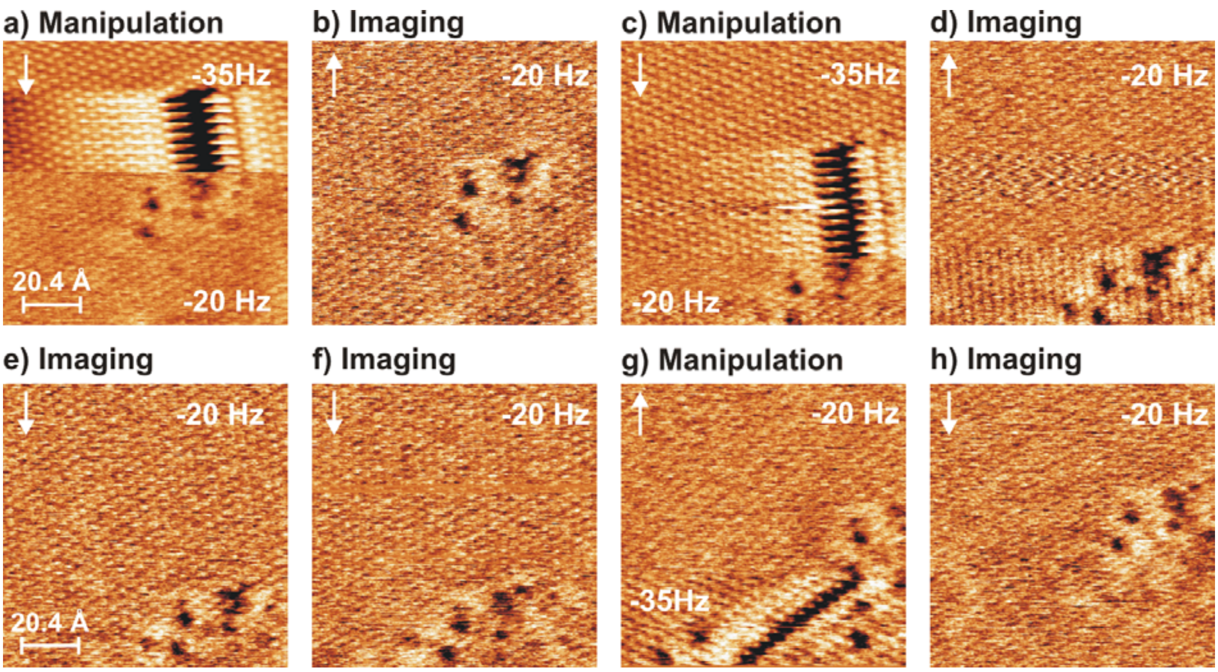
The lateral manipulation of atoms [1] and more recently large molecules [2] with a scanning tunnelling microscope operated at cryogenic temperatures is a well established method for the bottom-up fabrication of nanostructures. Recently, atomic manipulation with the dynamic force microscope has been demonstrated on semiconductor surfaces [3]. Here we describe a method where the dynamic force microscope operated in the non-contact mode is utilized to induce a directed atomic precision lateral movement of defects on an insulator surface, namely the (111) surface of CaF_2. Atomic size defects result from the exposure of the surface to the residual gas and are possibly hydroxyl groups as observed in studies where the CaF_2(111) surface has been exposed to oxygen [4]. Imaging and manipulation of defects is accomplished by scanning the surface at different levels of detuning. We find that it is possible to move defects when applying a high detuning of typically –35 Hz, while the defects are imaged and kept stationary in case the detuning is -20 Hz or lower. The figure shows a series of consecutively performed steps of manipulation and imaging of a group of defects. Frames d) to f) provide clear evidence that the observed movement is due to manipulation and not a result of thermal drift. During manipulation steps, the movement on the surface results in chain-like features with a periodicity of the CaF_2 surface lattice indicating stick-slip-motion. While the manipulation occurs primarily in the vertical direction, uncontrolled horizontal movements lead to an inclination of the manipulation path. From several series of experiments we find that the direction of the movement can be given a clear preferential direction and some modification of the direction can be enforced by increasing the scanning speed. Image analysis reveals a zigzag movement and positioning of defects at specific sites.



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3. N. Oyabu et al., *Nanotechnology* **16**, S112 (2005).
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