# Characterizing contact formation at the atomic scale: A combined Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM) study

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We are investigating contact formation at the atomic scale, in particular the interplay of forces and conductivity. It is well known that the contact geometry in scanning probe microscopy plays a key role in understanding tunneling junctions [1,2], molecular electronics junctions [2] and dissipation[3]. In order to investigate these phenomena, we use a combined ultra high vacuum (UHV) scanning tunneling microscope (STM) and atomic force microscope (AFM) to measure metal-metal junctions between STM tips and metallic STM samples. In addition to obtaining the simultaneous tunneling current (STM) and force (AFM) information we are also able to image the STM tip before and after the experiments with field ion microscopy (FIM) [4]. All these methods are applied in situ in the same microscope. Therefore we see atomic changes of the STM tip that happen during scanning and distance spectroscopy.

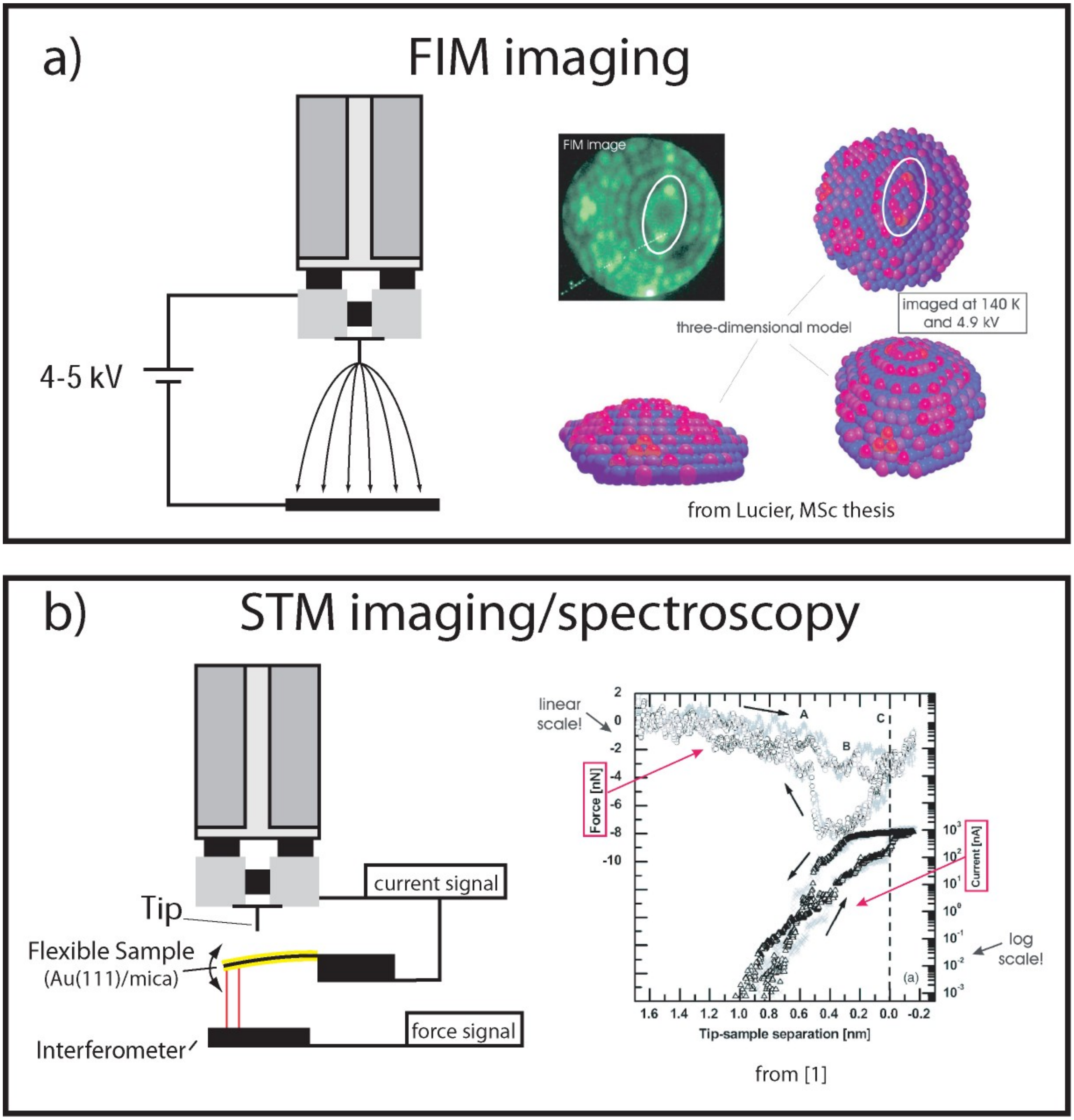
There are many possible ways to make use of our setup. The most obvious would be to use it to make atomic contacts (the contact between an atomically sharp STM tip as one electrode and an atomically flat STM sample as counter electrode). This is the aim of the current work.

Figure 1 shows our setup and the way we are using the system to do atomic contact experiments. We use FIM to image the STM tip (part a). The STM tip is facing a screen unit. Both of them are biased at several kV in opposite polarity while the tip has to be on posivitve potential to ionize the imaging gas (He). The ionized He follows the field lines between screen and tip and produces a magnified image of the tip on the screen. The image we obtain consists of bright spots representing the atoms at the edges of crystalline planes. By identifying the crystalline orientation the hole STM tip can be reconstructed as a ball model. Therefore we know the real space structure of our tip. After the tip imaging we introduce the sample and approach the tip towards the sample as shown in figure 1 b). We take care not to crash the tip during the approach. Once the tip is in tunneling contact, we do STM scans and approach curves with various distance ranges.

These distance ranges refer to different processes:

- contact formation: few nm of tip sample separation to contact (tunneling current saturates and cantilver shows onset of linear force distance relation (Hook's law)) [1]
- nano indentation: from contact to 3 nm further in (see [5])
- dissipation: the hole range that shows a hysteresis in the force channel and structure changes of the STM tip (future work)

[1] Sun et. al. PRB 71 193407, 2005
[2] De Menech et. al. PRB 73, 155407, 2006
[3] Ghasemi et. al. PRL 100, 236106 2008
[4] Lucier et. al. PRB 72, 235420, 2005
[5] Cross et. al. Nature Materials vol 5, p. 370, 2006



from Lucier, MSc thesis

from [1]

Figure 1: The UHV STM/AFM with FIM capability. (a) shows the FIM process and (b) shows how we acquire simultaneous STM/AFM data