May the force be with you: using Atomic Force Microscopy to gain insights in chemistry

Peter Grutter
Department of Physics, McGill University, Montréal (Canada)

Understanding and pushing ultimate limits is one of the joys of Physics. Atomic Force Microscopy (AFM) is a well-established technique that can image individual atoms and thus determine the atomic structure of even insulating surfaces and molecules in almost any environment (Fig 1a,b). To gain fundamental insight into 'how stuff works' and to apply these insights to purposeful engineering one needs to go beyond structure and measure properties.

In the first part I will give a basic introduction to AFM. I will introduce how the measurement of electrostatic forces allows properties to be measured and will illustrate the resulting AFM capabilities with a few examples we have recently published. Specifically, I will discuss the characterization of atomic defects at the SiOx-Si interface (Fig. 1c) and the observation of random telegraph noise of a single trap by measuring the electrostatic forces between the AFM tip and the sample. When AFM is combined with a fast laser, we have demonstrated a temporal resolution of 100fs (limited only by the laser pulse length) by measuring the light induced non-linear polarization in the sample (Fig. 1d). This opens the exciting possibility of correlating the atomic scale structural and electronic properties of single defects in many materials on a 10fs time scale.

In the second part of the seminar I will focus specifically on electron charge transfer reactions. Using cryogenic AFM we measured Franck-Condon blockade of electron transfer in a single ferrocene molecules. This allows us to measure the electron-nuclear coupling strength and molecular vibration energy and thus the intermolecular reorganization energy with single molecule sensitivity. I will close by presenting some exciting initial results towards developing AFM to measure electron charge transfer in electrocatalytic environments. By carefully measuring force fluctuations we can investigate gas evolution reactions such as the hydrogen and oxygen evolution reactions occurring in water electrolysers. I will discuss our ideas of developing AFM to enable an atomic-level understanding of electrochemical phenomena occurring at the solid-liquid interface. Deeper understanding of this interface is key to advancing sustainable electrochemical energy technologies.

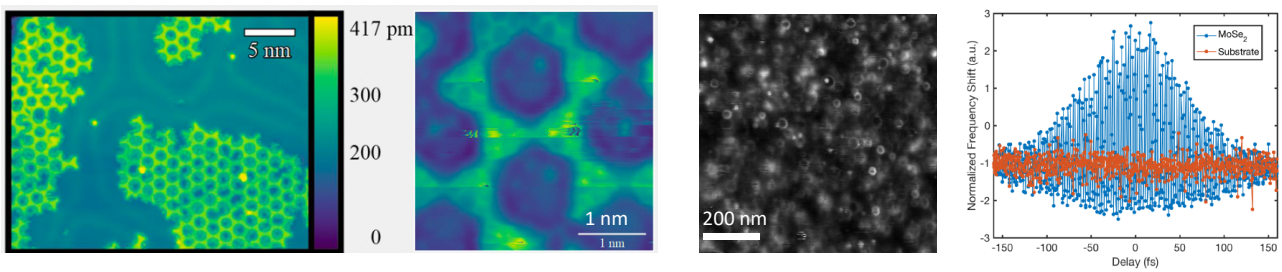

Figure 1 a) STM image of 2-dimensional π–conjugated polymer TBTANG on Au(111). b) Bond imaging of TBTANG polymer using a CO-terminated AFM tip. c) Electrostatic AFM imaging of defects at the SiOx-Si interface; each ring is a single defect. D) Optical intensity autocorrelation measured by AFM. Plotted is the AFM signal vs. the pump-probe delay time of a 100fs laser pulse, demonstrating ultrafast time resolution and local measurement of $\chi^{(2)}$ achieved by AFM.