

Lateral Force Microscopy using Nanomanipulation

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The scanning probe microscope (SPM) is a high precision measurement research equipment that enables one to obtain images of a sample's surface topography at the nano-level using atomic force microscopy (AFM) techniques. In addition to its imaging capabilities, the SPM can also be used to obtain material characteristics such as surface electrical charges, magnetic properties, vertical/lateral force, and friction. Surface force data, represented through force curves, can be generated by different methods of SPM tip and surface interactions. The most common and well developed method of force measurement using SPM is vertical force microscopy. Force measurements in the lateral direction have also been conducted but results have mainly been qualitative. The scope of this research is to develop an SPM technique that would enable lateral forces to be quantified just like vertical forces.

One motivation for this research involved incorporation of the technique with medical research. Complex structures contained within human cells are encapsulated within a lipid bi-layer known as the cell membrane. The cell membrane acts as a gateway between the internal cell structures and the external environment regulating what enters and exits the cell. Exposure of a cell to internal or external stimuli such as mutation or non-ideal physiological conditions can cause changes in the physical properties of the cell membrane. Past research in a similar area have shown that a direct correlation exists between a sample's surface vertical forces and its viscosity^[1].

The Bruker Catalyst AFM system will be used to develop the multi-axial force measurement technique. The new lateral force technique incorporates a variety of the system's existing functions including the existing topographical scanning functions and an add-on nanomanipulation function known as the NanoMan. Two different methods have been proposed to conduct the force measurement in the lateral direction to generate lateral force curve data. The two methods involves pushing against the sample's internal and external structure to induce a twist in the cantilever that would mimic a lateral approach by the AFM tip. The two methods are presented in figure 1 and will be achieved through the Catalyst AFM's nanomanipulation NanoMan function.

The multi-axial force microscopy technique will be tested on a variety of samples of different hardness consisting of hard, medium, and soft samples. The hard sample chosen was an AFM calibration grid with depth of 200nm and pitch of 10um. The pushing force method will be conducted on the sidewall of the pits. The soft sample consisted of DOPC (1,2-dioleoyl-*sn*-glycero-3-phosphocholine) lipids prepared with the method discussed by Johnson *et al*^[2] to form liposome membranes. Liposomes have been used by a multitude of researchers, including Schönher *et al*^[3], to simulate a real cell membranes. The liposomes are laid down on a layer of muscovite MICA through natural attraction forces. Muscovite MICA was chosen for the material's relatively smooth surface. A topographical image and profile of the soft sample is presented in figure 2. The medium hardness sample to be tested is still to be determined.

Over the last decade, researchers have well defined vertical force measurement techniques. Vertical force curves can be easily generated using built in functions in almost all SPM systems. The anticipated results

of the research involves producing lateral force curves, using a combination of nanomanipulation and force measurement techniques, that will to a certain extent produce the same results produced by a lateral force curves generated on the same sample.

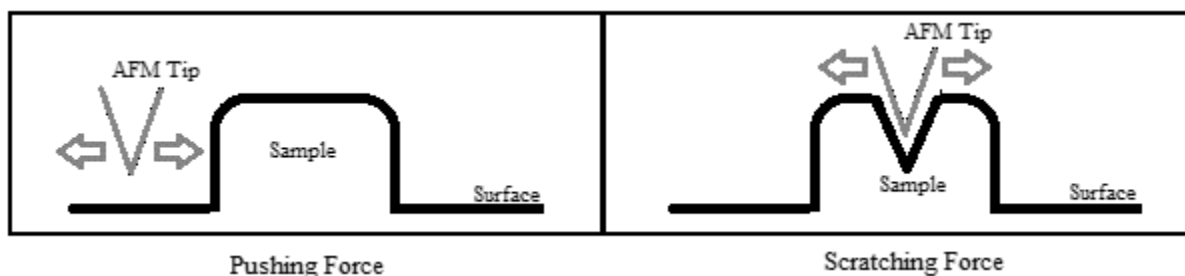


Figure 1. Multi-axial force measurement lateral force measurement methods conception. The pushing force method (left) consists of the AFM tip pushing against the side of the sample and the scratching force method (right) consists of AFM tip puncturing into the sample surface and pushing left and right in the lateral direction.

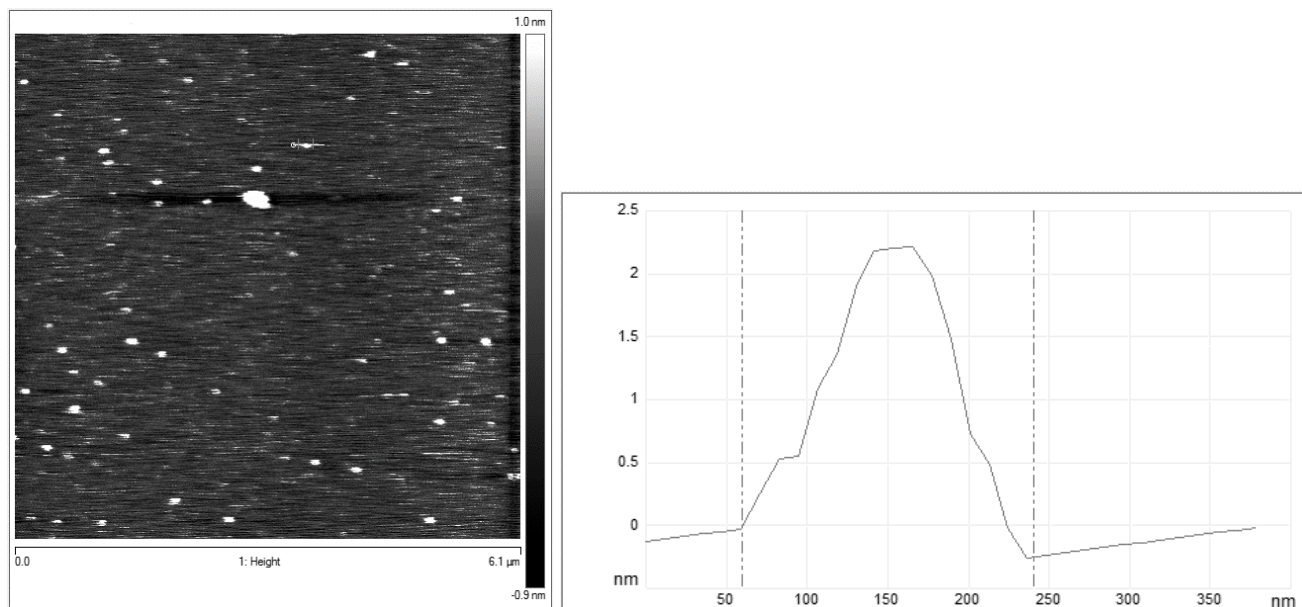


Figure 2. Soft sample AFM topographical scan (left) and profile (right). The soft sample consists of a MICA surface with DOPC liposome bilayers (seen in white) attached. The topographical profile (right) depicts the height and length measurements of one of the DOPC liposome bilayer seen on the topographical scan marked on the top right section of the image.

References:

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- [2] Johnson, Joseph M., Taekjip Ha, Steve Chu, and Steven G. Boxer. "Early Steps of Supported Bilayer Formation Probed by Single Vesicle Fluorescence Assays." *Biophysical Journal* 83.6 (2002): 3371-379.
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