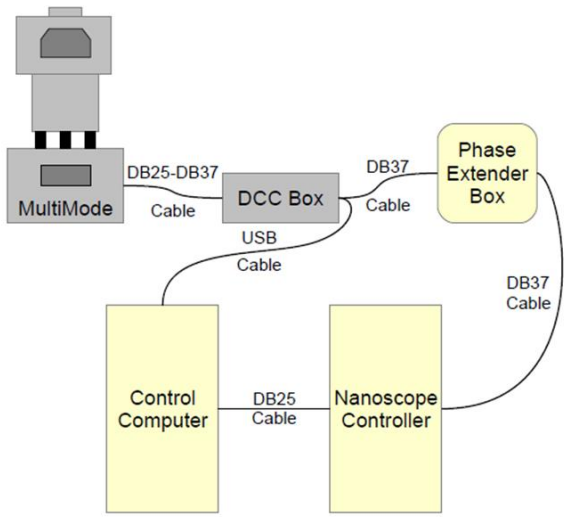
# Evaluation of AFM Probe Features and Their Imaging Capabilities

A microfabricated probe with a sharp apex plays a crucial role in providing a gentle and high-resolution imaging in AFM. The probe also serves as a sensitive force detector for measurements of local materials properties. The probe spring constant and tip sharpness define their use in different applications. The pyramidal shape tips with an opening angle of 35 degrees and apex with ~10 nm in radius are routinely made for Si probes. The spring constant is less defined, and it might vary within the same batch of probes. Therefore, it is valuable to measure the characteristics of individual probes installed in an SPM microscope. This opportunity for MultiMode™* and Dimension microscope is realized with the DCC accessory, which acquires the probe thermally-induced motion whose PSD contains the probe resonances of several orders. The analysis of 1st order resonance provides the probe spring constant, inverse optical sensitivity (IOS) and the noise level of optical beam deflection. These parameters are required for quantitative nanomechanical AFM measurements in different modes. Here we consider several probes with spring constants in the 2 N/m – 0.03 N/m range and their applications in tapping and contact modes. The geometrical dimensions of the rectangular Si probe define its spring constant *k* and most variations are caused by deviations of the probe thickness. Because of a large variety of commercial probes' names it will be rational to use their length (L), width (w) and thickness (t) in μm (L/w/t) for an approximate evaluation of their spring constant. A precise spring constant value is obtained with the DCC.

* - trademark of Bruker Corp



Dynamic Cantilever Calibrator Connection Diagram

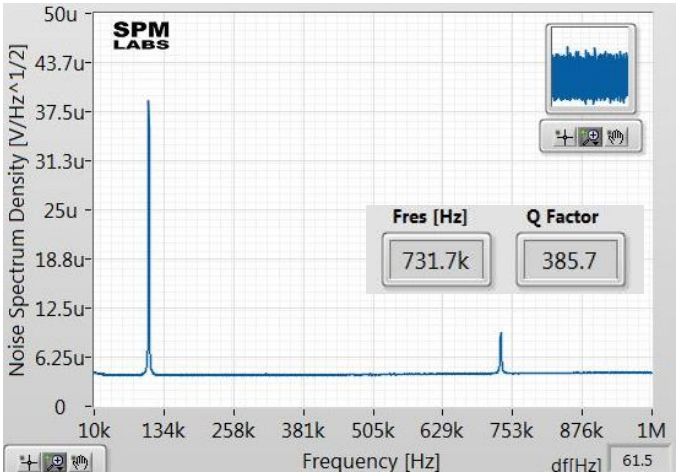


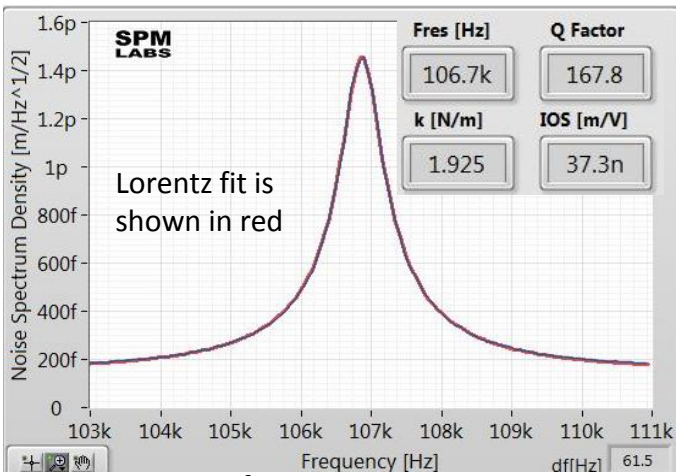

**Technical Specifications of Dynamic Cantilever Calibrator**

1. Acquired Signals : Normal/Lateral Deflections
2. Operational Band width: 250 Hz – 8 MHz
3. Sample Rates: Four ranges from 16 MHz to 1 MHz
4. Magnitude of Input Signals: Five ranges from 10 to 500 mV
5. Dimensions: 236 mm (L) × 106 mm (W) × 58 mm (T)

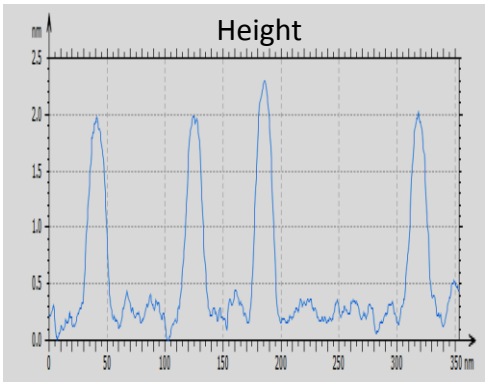
# Rectangular Si Probe:125/30/2

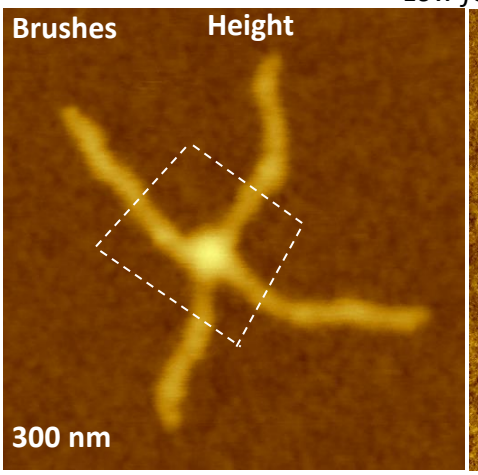
The first probe of our analysis is Si/.125/30/2 and the data obtained with this probe are collected in **Figure 1**. Its PSD in the 2 kHz – 1 MHz range (top, left) shows two resonances, and the analysis of 1st resonance (top, right) has provided *k* = 1.9 N/m and IOS = 37 of the instrument (MultiMode™). Below PSD graphs one can find height and phase images of brush macromolecules in a " spoke-wheel" arrangement. The images were recorded at low and high force levels , realized by choosing, respectively, the set-point amplitude close to amplitude of free oscillation and at its half value. With force increase the macromolecules' core and side chains moiety become evident in the height and phase images. A tip-induced depression is also obvious in the height profiles (left side), which were taken in the images on the segments marked with the white-dashed lines. The observed macromolecules are quite soft, and they were non-destructively imaged in contact mode only using the probes with *k* < 0.15 N/m

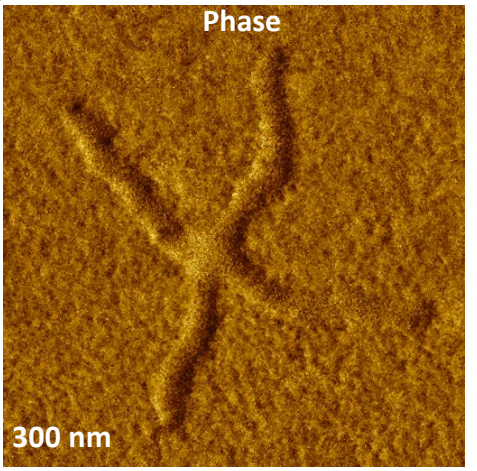


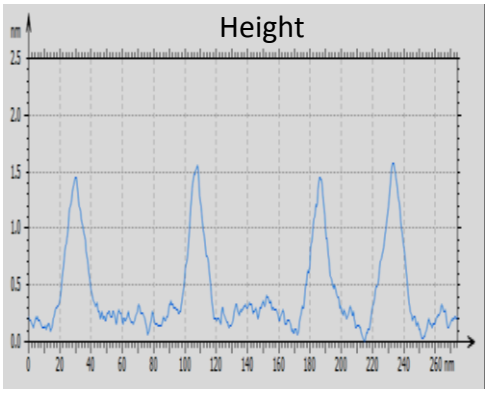

*Low force*

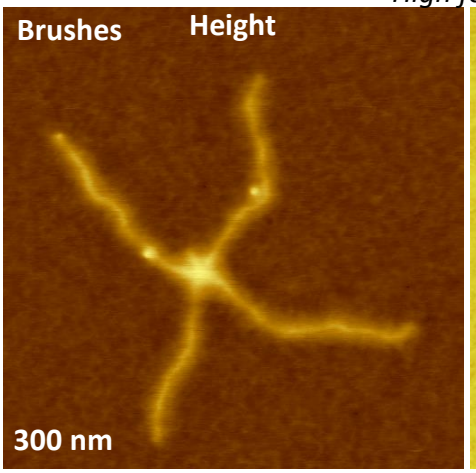



*High force*



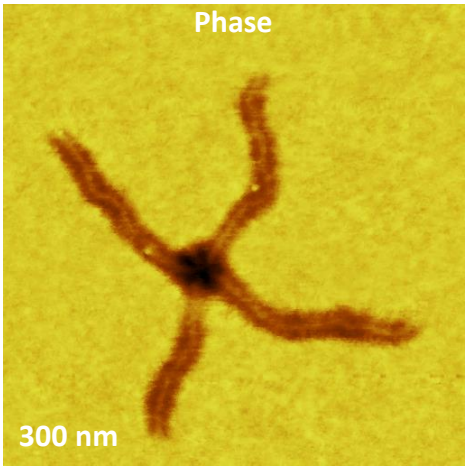
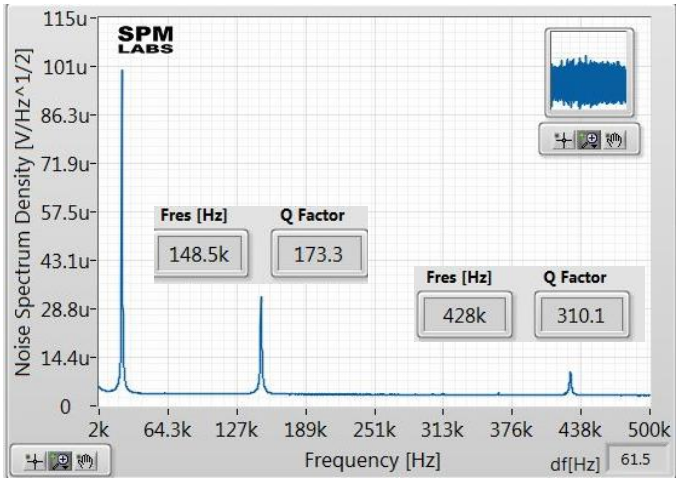
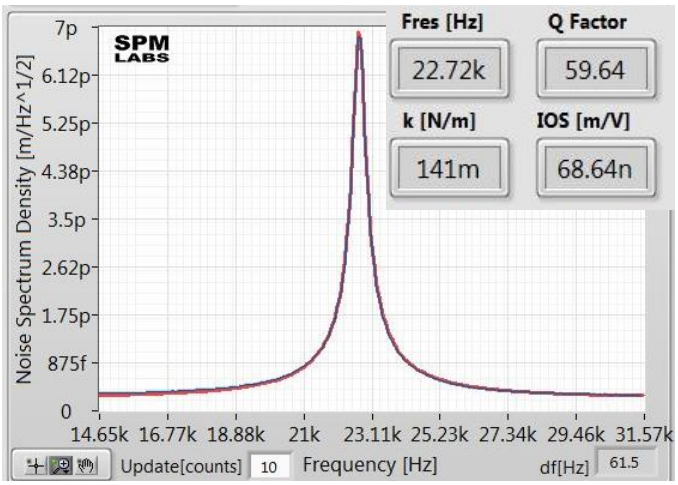




**Figure 1.**

Second probe, which was analyzed, is Si/225/30/1. Its PSD graphs in the 2kHz – 500 kHz range and around 1st resonance are shown in **Figure 2** (top left and top right). Three resonances are at frequencies <500 kHz, and these oscillations can be used for multi-frequency studies, which are developing in AFM. The interesting thing is that this relatively soft probe (*k*=0.141 N/m) can be applied in tapping mode, **Figure 2**. Soft probes are usually not used in this mode. The images of triblock copolymer PS-*b*-PB-*b*-PS (PS – polystyrene; PB – polybutene) were obtained in tapping and contact modes. The material is stiffer than the brush macromolecules, and it can be examined in contact mode even with stiffer probes (*k*~1-2 N/m). The tapping mode images of the brush macromolecules were obtained with this probe on various scales (bottom of **Figure 2**). Yet their core and side chains were not resolved even at high force because the probe in not strong enough to penetrate through the side chain moiety.

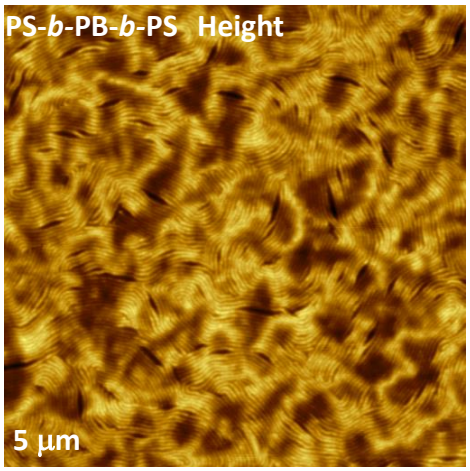


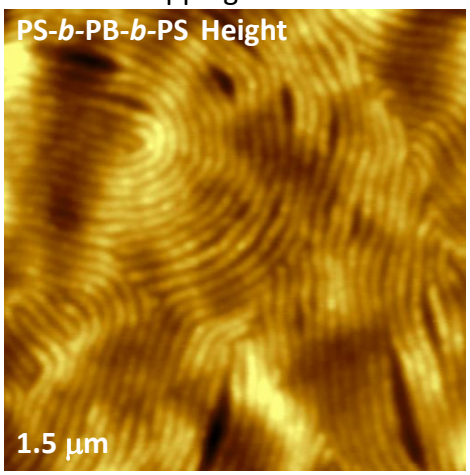

Tapping mode

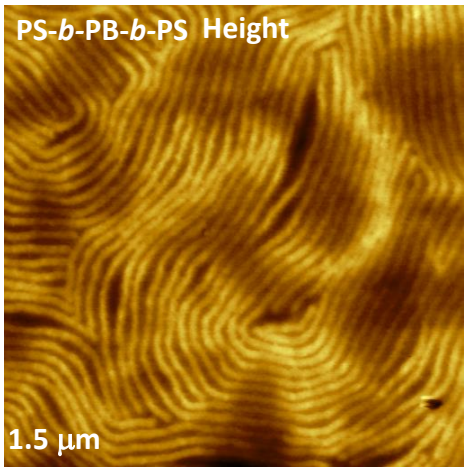



Tapping mode

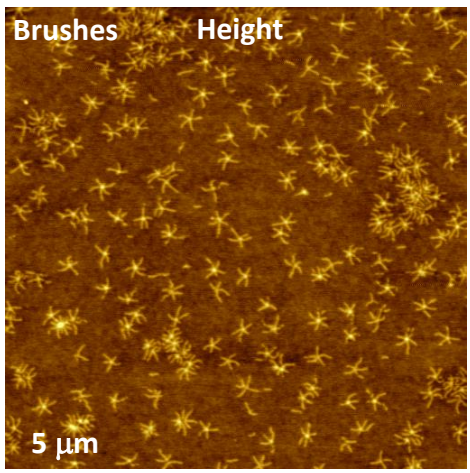
Contact mode

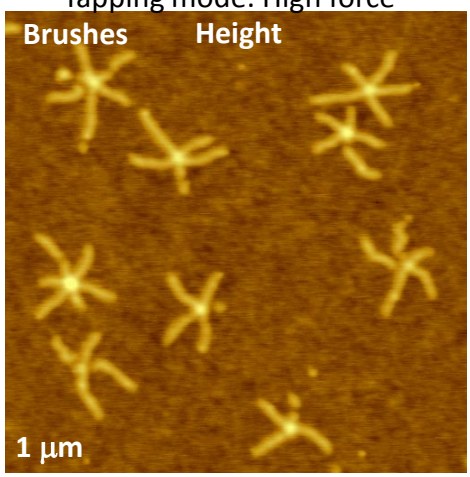



Tapping mode: High force



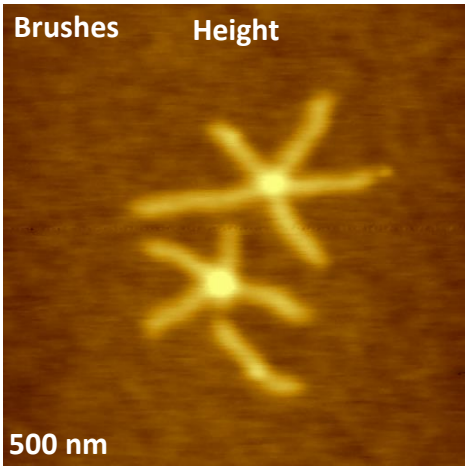
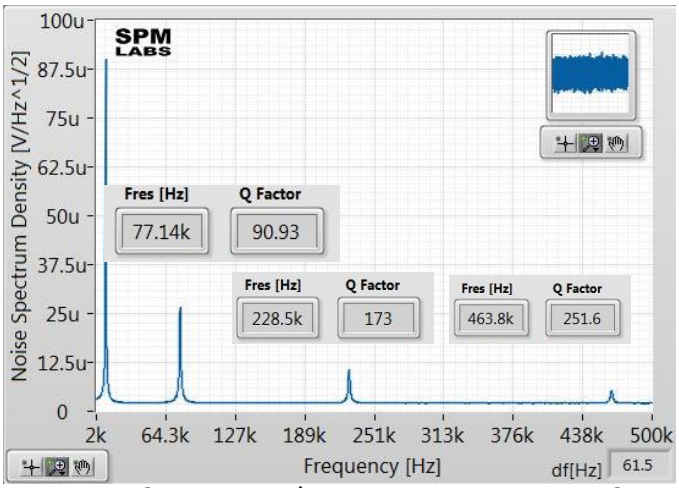
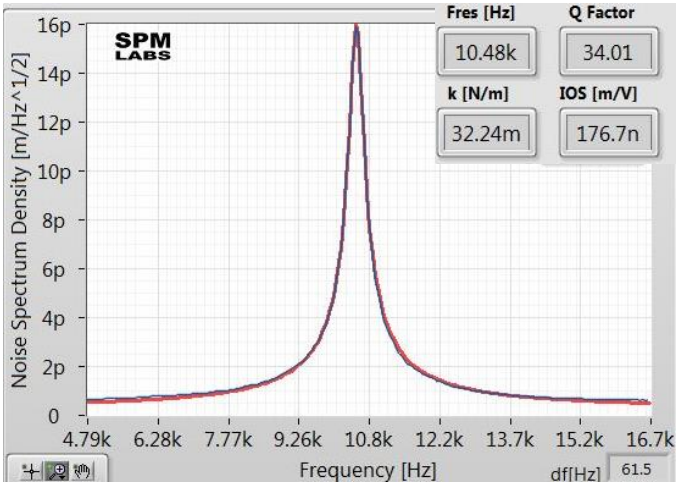




**Figure 2.**

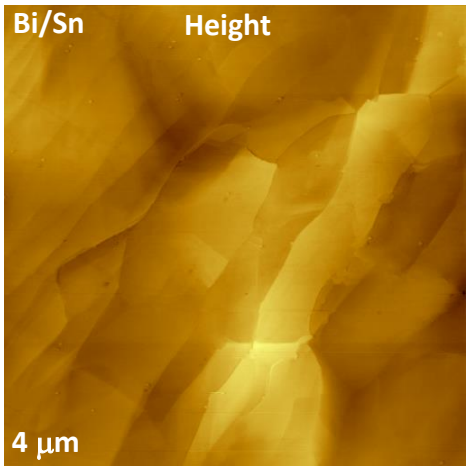
# Rectangular $Si_3N_4$/Si Probe: 230/35/0.6

Soft AFM probe are made of $Si_3N_4$ and some of them have Si pyramidal tips to ensure a better profiling of corrugated surfaces. Such rectangular hybrid probe $Si_3N_4$/Si/230/35/0.6 exhibits four resonances in the 2kHz – 500 kHz range (top left, **Figure 3**) and its spring constant is 32 mN/m (top right, **Figure 3**). This probe is applied mostly in contact mode studies of different materials: from metals to soft macromolecules. Several images of metal alloy Bi/Sn, polymer blends of PS with LDPE – low density polyethylene, PMMA - poly(methyl methacrylate), PB and block copolymer of PS and PMMA are shown below. Such soft probes have been successfully applied in the contact resonance measurements of various samples with DCC accessory. PSD of this probe, when it is in contact with a sample, shown several resonances with Lorenz shape profiles. These contact resonances depend on a nature of the tip location and they can employed for compositional AFM studies.

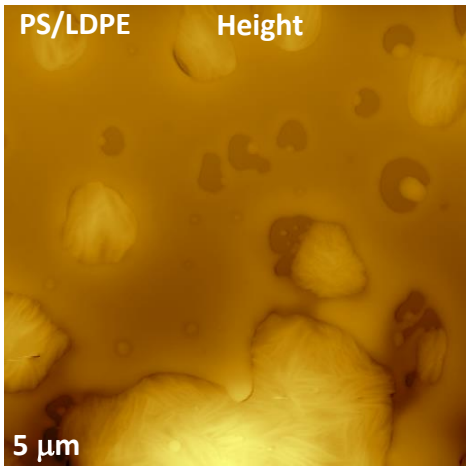


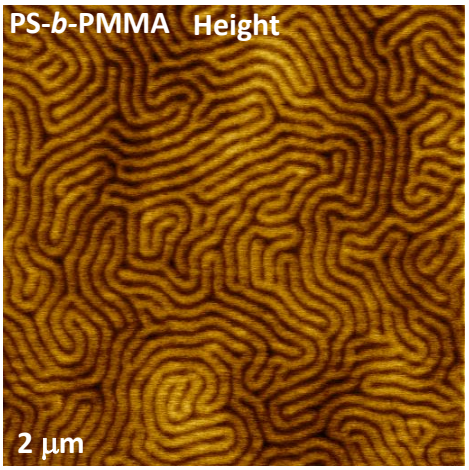

Contact mode




Contact mode




Contact mode

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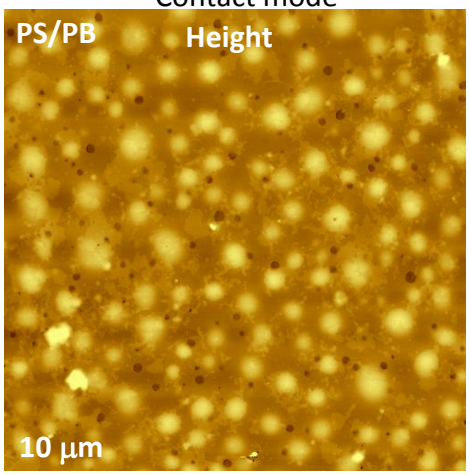


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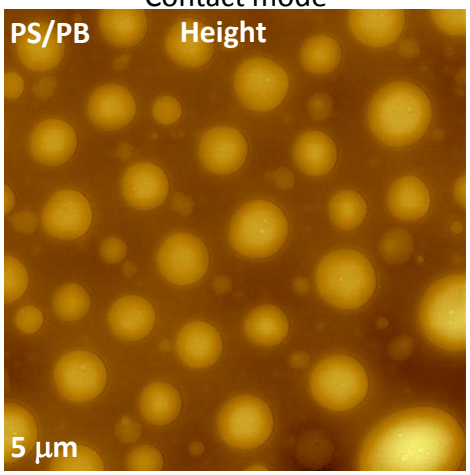


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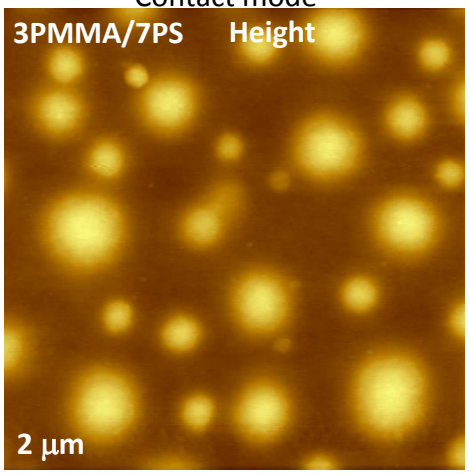


**Figure 3.**