Phase Imaging / Phase Detection Microscopy (PDM)

Phase Imaging of Sample Elasticity

Phase Imaging / Phase Detection Microscopy

Phase Imaging, also referred to as phase detection microscopy (PDM), is another technique that can be used to map variations in surface properties such as elasticity, adhesion, and friction. Phase imaging can be produced while an XE-series is operating in other modes, such as True Non-Contact AFM, intermittent-contact AFM (IC-AFM), or MFM mode. Phase imaging can also be collected while a Force Modulation image (FMM) is being taken.

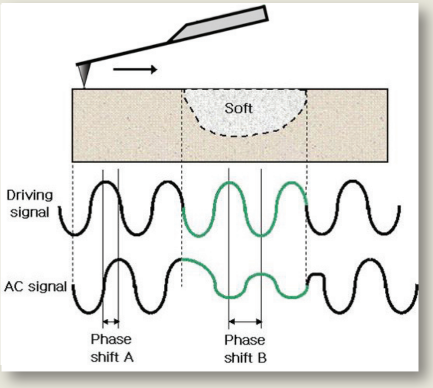

Figure 1.
The phase lag changes depending on the mechanical properties of the sample surface.

Phase imaging refers to the monitoring of the phase lag between the signal that drives the cantilever oscillation and the cantilever oscillation output signal, as shown in Figure 1. Changes in the phase lag reflect changes in the mechanical properties of the sample surface. The system's feedback loop operates in the usual manner, using changes in the cantilever's deflection or vibration amplitude to measure sample topography. The phase lag is monitored while the topographic image is being taken so that images of topography and material properties can be collected simultaneously.

One application of phase detection is to obtain material-properties information, especially for samples whose topography is best measured using True Non-Contact AFM rather than contact AFM (see True Non-Contact Mode). For these samples, phase imaging is useful as an alternative to force modulation microscopy, which uses contact AFM to measure topography. Figure 2 shows a topographic True Non-Contact AFM image (a) and a phase imaging (b) of block co-polymer. The phase imaging provides complementary information to the topography image, revealing the variations in the surface properties of the block co-polymer.

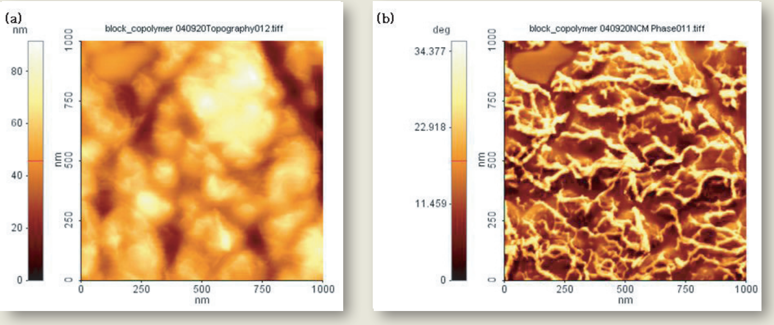

Figure 2.
(a) Non-contact AFM image and (b) phase image of block co-polymers, collected simultaneously. Field of view 1 μm × 1 μm.

When you operate True Non-Contact mode of the XE-series AFM, you monitor three signals: topography, NCM amplitude, and NCM phase. Consider a cantilever which oscillates in free space. When the cantilever approaches a sample, the amplitude decreases and the phase shift occurs relative to the oscillation signal in free space, as shown in Figure 3.

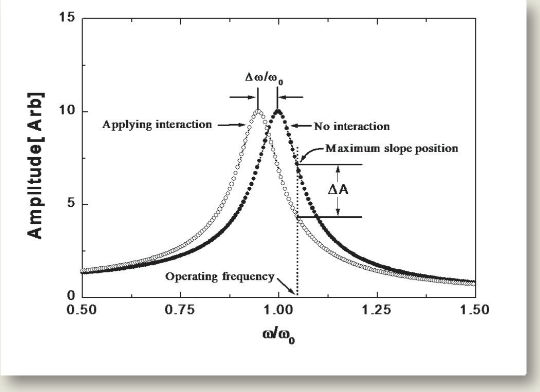

Figure 3.
Resonance curve of a cantilever oscillation shifts as it approaches a surface

To make a cantilever follow the surface topography in True Non-Contact mode, we can use amplitude or phase as feedback parameter. If you use amplitude feedback only, the amplitude change should be almost negligible, but the phase change becomes greatest during imaging. If you use both amplitude and phase to feedback the Z-scanner during imaging, you will compensate the phase change along with the amplitude change. As a result, the amplitude change could increase while the amount of phase change decreases relative to that of the amplitude feedback only. Since the True Non-Contact mode of the XE-series feedbacks both amplitude and phase, its phase image will be in highest contrast when its True Non-Contact AFM is in amplitude feedback only (a user can just turn on the amplitude feedback in NCM frequency sweep box). Figure 4 shows a topographic True Non-Contact AFM image (a) and a phase imaging (b) of OPV polymer.

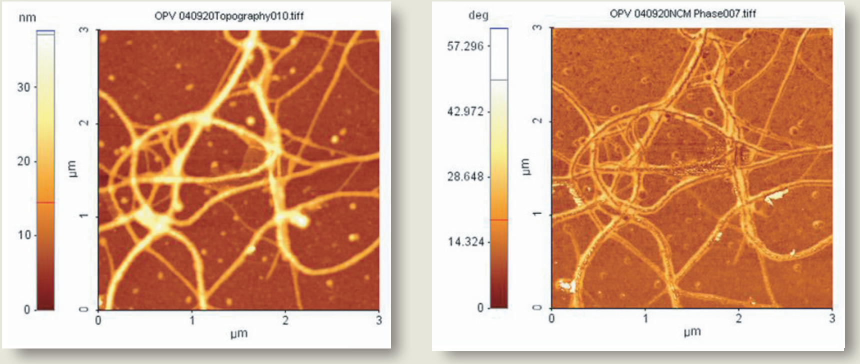

Figure 4.
(a) True Non-Contact AFM image and (b) phase image of OPV polymers, collected simultaneously. Field of view 3 µm × 3 µm.