Lateral Force Microscopy (LFM)
Mapping of the Frictional Force

Lateral Force Microscopy

The principle of Lateral Force Microscopy (LFM) of the XE-series is very similar to that of contact mode AFM. Whereas in contact mode we measure the deflection of the cantilever in the vertical direction to gather sample surface information, we measure the deflection of the cantilever in the horizontal direction in LFM. The lateral deflection of the cantilever is a result of the force applied to the cantilever when it moves horizontally across the sample surface, and the magnitude of this deflection is determined by the frictional coefficient, the topography of the sample surface, the direction of the cantilever movement, and the cantilever's lateral spring constant. Lateral Force Microscopy of the XE-series is very useful for studying a sample whose surface consists of inhomogeneous compounds. It is also used to enhance contrast at the edge of an abruptly changing slope of a sample surface, or at a boundary between different compounds.

Since the LFM of the XE-series measures the cantilever movement in the horizontal direction as well as the vertical one to quantitatively indicate the surface friction between the probe tip and the sample, it uses a PSPD (position sensitive photo detector) that consists of four domains (quad-cell), as shown in Figure 1. Generally, in AFM, to measure the topography of a sample surface, a "bi-cell" signal of the quad-cell PSPD is used, the commonly called "A-B" signal. This signal is related to the difference between the upper cells (A+C) and the lower cells (B+D) of the quad-cell PSPD, as shown in Figure 1.

$$Topographic\ information = (A+C)-(B+D)$$

The LFM signal, which is related to the change in the surface friction on a sample surface, measures the deflection of the cantilever in the horizontal direction and can be represented as the difference in the signals recorded in the right cells (A+B) and the left cells (C+D).

$$Frictional\ information = (A+B) - (C+D)$$

Figure 1.
(top) The PSPD of AFM and (bottom) LFM

Figure 2.
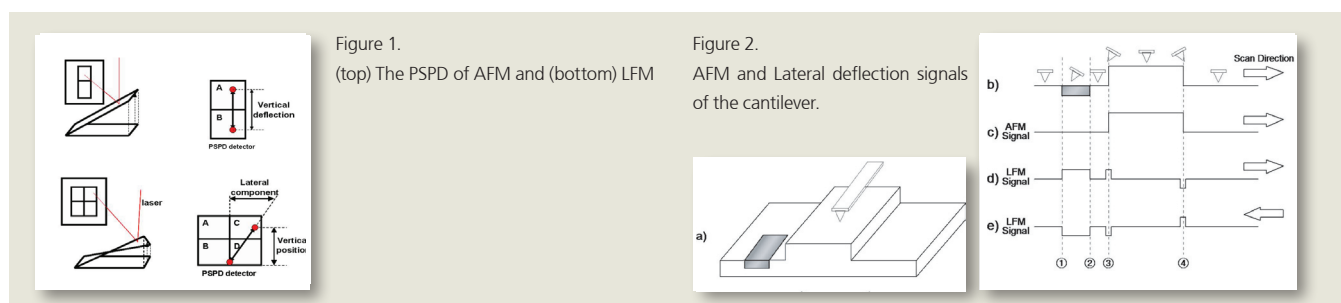AFM and Lateral deflection signals of the cantilever.

Figure 2 (a) shows a surface structure with a centrally located step with low, smooth areas on either side. The flat part on the left contains a domain with a relatively high frictional coefficient. **Profile b** indicates the cantilever's deflection as it encounters topographic features as well as different frictional coefficients as it scans from left to right. **Profile c** is an AFM image of the surface topography and structure; it is represented by the change in the vertical deflection of the cantilever which does not include the horizontal deflection. **Profile d** and **Profile e** show the LFM signal which indicates the horizontal deflection of the cantilever. When scanning left-to-right, the surface structure of a sudden peak will instantaneously twist the cantilever to the right. This results in a lateral force signal with a convex shape as seen in Figure 2 (d) at point③. The opposite occurs when the probe encounters a sudden downward step as depicted at point④.

The region between point① and point② indicates an area on the sample surface where there is a material with a higher surface frictional coefficient compared to the surrounding area. There are no distinguishable surface features that will allow the user to differentiate this region utilizing the topography signal. Even though the topographical information is the same between point① and point② , there will be a conspicuous difference noticeable in the LFM signal. When the cantilever scans this area from left to right, an increase in relative friction will cause it to tilt to the right, thus producing an increase in the LFM signal.

Figure 2 (e) shows the LFM signal when the scan direction is reversed. If the cantilever scans direction as indicated by the arrow, there will be no change in the LFM signal at point③ and point④ which are related to the topographic features of the sample surface. However, when the scan direction is reversed, the cantilever will now tilt to the left in the area where the frictional coefficient between point① and point ② is larger, yielding a decrease in the LFM signal in this area.

LFM results contain information of both surface friction and topography. Hence, when you analyze the result of the LFM measurement, it is necessary to distinguish the information due to difference in the frictional coefficient from the information due to the change in the sample surface topography via comparison with the topography image. Figure 3 shows (a) AFM topography and (b) LFM image of a human hair (20 μm scan size). One can clearly observe the difference in frictional areas of keratin protein in Figure 3 (b).
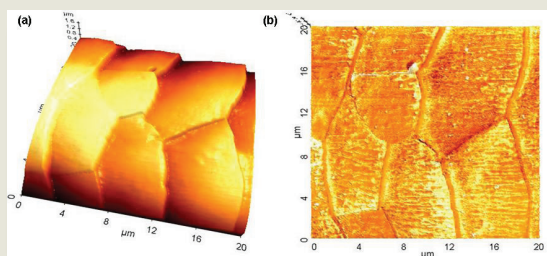

Figure 3.
(a) Topography and (b) LFM image of human hair. (20 μm scan size)