AFM lab

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Abstract

In this lab an Atomic Force Microscope (AFM) is employed to image a sample polymer and carbon nanotubes (CNTs).

1 Questionnaire

1.1 AFM

The micrograph used is a tabletop atomic force microscope. The AFM works by raster scanning a nano-sized tip attached to a cantilever across the surface of the sample. The tip is made of silicon, and sharpened to an approximate diameter of 20nm at it's end. The tip is scanned across the surface at a variable speed, in this exercise scanning speeds of 0.5Hz and 1Hz were used (i.e. lines scanned per second in the selected area). After the laser and tip had been calibrated, all adjustments were made directly in the computer software, greatly simplifying the imaging process.

1.2 Operating mode

Both contact and non-contact mode were used on the polymer sample, while only non-contact mode was used on the CNTs. The choice is mostly determined by the hardness and smoothness of the sample. On smooth and hard samples contact mode works well, but as soon as larger bumps or steps are prevalent in the sample non-contact mode is used. This is the case for the CNTs, because contact mode would not be able to tackle the large z-variation they represent.

1.3 Images

The two images below show some dispersed CNTs including the height curve across a separated nanotube. The image on the left shows an overall view with sides of $5\mu m$, and bears a certain resemblance to a SEM or TEM image of the tubes. In the image to the right the magnification has been increased, and the image has sides of $551nm$. The scanning speed has been decreased in image on the right due obtain higher resolution, but the resolution of AFM is reaching it's limits at this magnification. From the height curves it can be seen that the nanotubes vary in diameter, from about 20-60nm in the ones sampled here. The shape is roughly round, but due to the tip not being long and sharp enough, the side of the tip makes contact with the CNTs first, and causes the cantilever before the end of the tip actually makes contact with the nanotube. This gives the height profile an elliptic quality. Note that the scale on the x-axis and y-axis is different on the height profile, causing the profile to appear rounder than it really is.

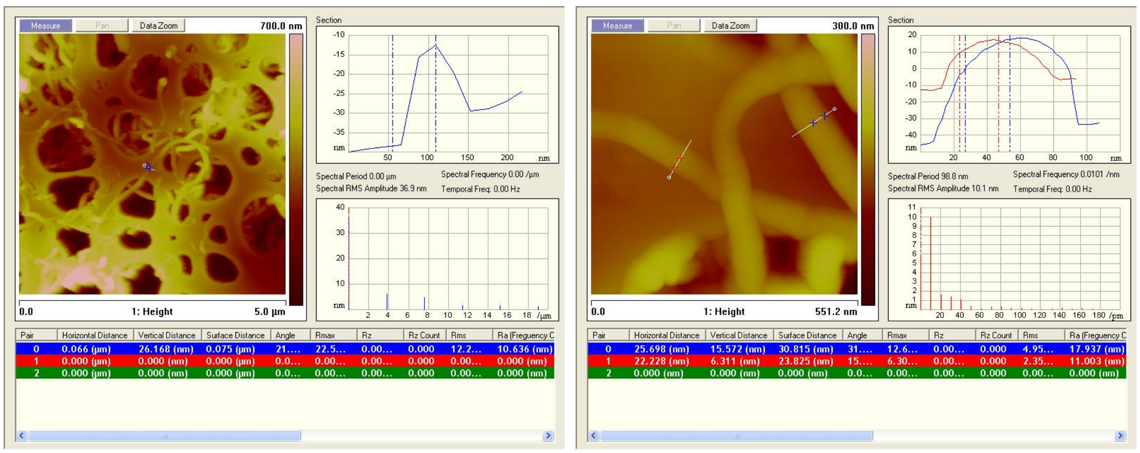

Figure 1: Images of CNTs at $5x5\mu m$ and $551x551nm$ including height curves.

1.4 Resolution

The spatial resolution of the AFM is limited by several factors; The shape and size of the tip limits the tracking of the CNTs, as mentioned above concerning the height curves. Ambient noise, such as vibration from the ventilation system and talking also will limit the resolution to a certain extent. The closer the tip is to the sample the higher resolution can be obtained, but this also increases the interaction force, which can cause the nanotubes to move or distort. Contamination of the tip or sample will severely limit the resolution.

Compared to electron microscopes the AFM gives an equivalent lateral resolution, but the real strength of the AFM is it's extreme z-resolution. Images at lower magnification bear resemblance to SEM, du to a similar lateral resolution and both having a 3D quality to the image. At higher magnification HR-TEM shows more details concerning the build-up and diameter of the CNTs in the xy-plane, such as wall thickness and layering, but gives no information in the z-direction (height). Here AFM complements well. Together SEM, TEM and AFM give us a lot of information about the CNTs. SEM and AFM give an useful overview of the fibers of CNTs, their alignment compared to each other, and their aggregation. SEM, TEM and AFM give information about the three-dimensional structure of the tubes, while TEM alone as the microscope with highest resolution gives us most information about the wall structure and residual iron particles from the synthesis.