THE SUPERIORITY OF CONICAL TIPS IN ATOMIC FORCE MICROSCOPY (AFM)

A conventional atomic force microscopy (AFM) probe consists of an almost atomically sharp tip at the end of a microcantilever, which is raster scanned over a sample surface. The forces arising between the tip apex and the sample enable an image of the surface to be built up.

It's likely that tip sharpness is the first characteristic that enters a researcher's head when they think about AFM tips. Both the sharpness of the tip apex and the aspect ratio of the tip (microscale sharpness) are important considerations in surface imaging because they determine image resolution. The aspect ratio of the tip is determined by its microscale shape whereas the sharpness of the tip apex should be independent of it, if suitable sharpening processes have been applied during fabrication.

Naturally, to resolve a surface feature, the tip apex should be sharper than the size of the feature being imaged. When a surface is imaged using the tip, each point imaged is a spatial convolution of the shape of the tip and the imaged feature. If the microscale sharpness of the tip is large, steep edges will appear broadened because each point imaged becomes dominated by the shape of the tip. Furthermore, the uniformity of the tip shape will impact on whether there is imaging consistency in different scan directions. If the sidewalls of the tip are not the same, symmetrical images will not be obtained.

The three most common shapes of AFM tips are conical, pyramidal, and tetrahedral.

The aspect ratio of pyramidal and tetrahedral tips is limited by their fabrication process, which requires etching along the crystallographic planes of the

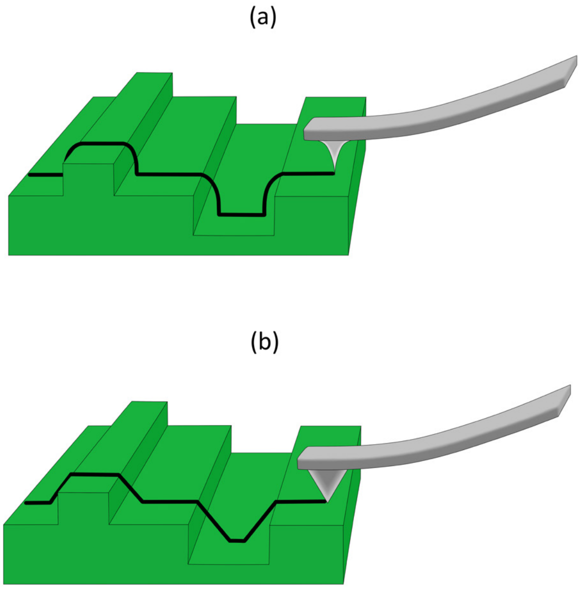

Figure 1: Trace (black line) of AFM probe with (a) conical and (b) pyramidal tip as it moves along a sample surface

material from which they are manufactured.

Therefore, their sidewalls interact with steep edges on the surface of a sample, which leads to artefacts such as shadows around these features. This is evident in the trace of a pyramidal tip as it moves over a surface with steep-edged features in Fig. 1(b), where the features appear broadened. In this case, it is the tip being imaged rather than the surface feature. Furthermore, these tips often have irregular geometries because they are fabricated using wet-etching techniques, which leads to asymmetry in different scan directions.

Conical tips are superior to pyramidal and tetrahedral types in many ways. Firstly, they can be fabricated with higher aspect ratio because etching along a particular crystal orientation is not required for their fabrication. The trace of a conical tip over a surface with steep-edged features is shown in Fig. 1(a). It is evident that the conical tip more closely resolves the “real” profile of such a surface. Secondly, they are manufactured using dry-etching, which allows for geometrical uniformity. This means that with conical tips, the image will look identical regardless of scan direction.

NuNano provides probes with conical tips to provide these advantages over probes fabricated with pyramidal or tetrahedral tips. They have allowed for high resolution imaging of, for example, semiconducting nanofibers on silicon and C60 on gold (https://www.nunano.com/gallery/).