IMPROVING IMAGE RESOLUTION WITH HIGH ASPECT RATIO AFM PROBES

The spatial resolution of surface imaging by atomic force microscopy is determined by two properties of the tip: the radius of its apex and the aspect ratio. In this article, the focus will on aspect ratio and for which types of samples it proves most useful.

The aspect ratio is defined as the ratio between the height and width of an AFM tip. Standard AFM probes, made from silicon, have conical-, pyramidal- or tetrahedral-shaped tips. Conical-shaped tips can be manufactured to have a relatively higher aspect ratio. However, these conventional probes are unable to accurately resolve the topography of highly non-planar features such as deep and narrow trenches, common in semiconductor device processing.

This is because the height and width of the probes is shorter than the height of the sidewalls and wider than the spacing between the sidewalls of the structure, respectively. Consequently, the tip apex is unable to reach the bottom of the trench, as shown in Figure 1.

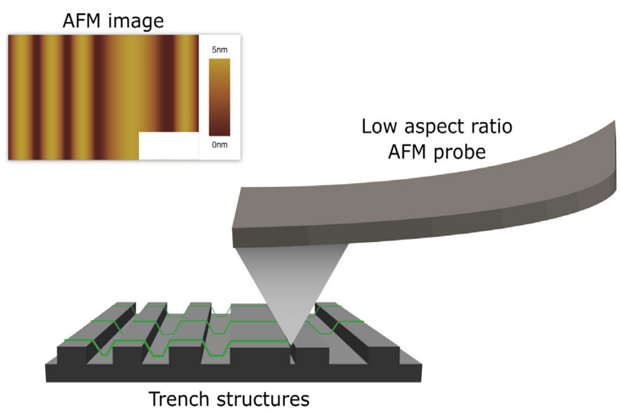

Figure 1: Trace of a low aspect ratio AFM probe scanning over a surface of trench structures. Inset: Obtained AFM image.

Furthermore, these conventional probes are unable to image tall particles, cells, or pillars with high resolution because the tip apex cannot access the bottom corner of the feature next to its steep edge and thus, cannot trace out the shape of the structure accurately [1].

It follows that the width of the tip should be reduced, and its length increased i.e., it should have a higher aspect ratio in order to fit inside the trenches and produce high-resolution images of these types of features, as demonstrated in Figure 2.

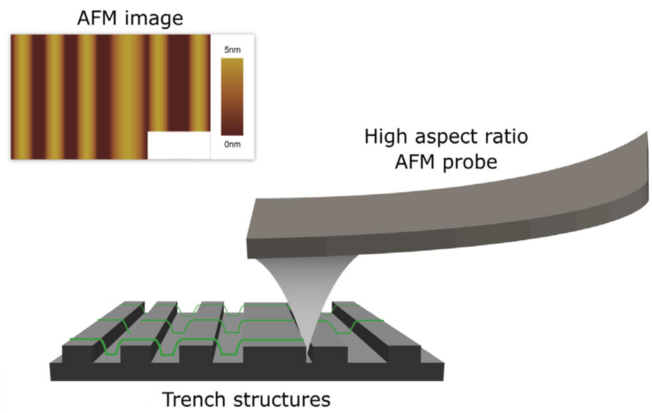

Figure 2: Trace of a high aspect ratio AFM probe scanning over a surface of trench structures. Inset: Obtained AFM image.

Since the height of these features is typically not more than 1 μm, only part of the tip needs to have high aspect ratio, extending from the tip apex to slightly longer than the sidewall height of the trenches or tall structures under investigation.

High aspect ratio of the tip can be achieved in a few different ways. Firstly, the silicon can be chemically or plasma etched, or milled by an ion beam to remove part of the tip sidewalls. This decreases the cone angle of the tip. Secondly, high aspect ratio materials can be grown onto or attached to the apex of the tip such as carbon nanotubes [2] or silicon nanowires [3]. Carbon nanotubes also serve to increase tip robustness because of their high strength. However, it should be noted that silicon nanowire tips are generally easier to fabricate than their carbon nanotube equivalent and that ultimately, removing existing material from the tip is favoured over attaching/growing new material on its apex.

NuNano have produced high aspect ratio, silicon AFM probes with a cone angle of < 15° over the final 1 μm of the tip.

References

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[3] B. A. Bryce, B. R. Ilic, M. C. Reuter, and S. Tiwari, "Silicon nanowire atomic force microscopy probes for high aspect ratio geometries," Applied Physics Letters, 100(21), 213106, 2012.