

## **Traceable characterisation of AFM probes: new ways to reconstruct tip shape and calibrate cantilevers**

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Atomic Force Microscope (AFM) is a widely used technique to measure topographies at the nanoscale. AFM images are due to the convolution of the sample shape, the tip shape and the tip-sample-substrate interactions. While AFM height measurements can achieve sub-nanometer resolution and accuracy, lateral resolution is influenced by several factors, the most significant is the tip shape.

The study of the shape and size of AFM tips is essential in several fields: (1) dimensional characterisation: it helps in examining the critical dimensions of nanoparticles in a robust way; (2) biological applications: it enables traceable nanomechanical measurements of biological and soft materials, which can contribute to the early diagnosis of cancer; (3) nanofabrication: in nanoelectronics and semiconductor industries there are increasing challenges in measuring nanostructures, becoming smaller and more complex in 3D shapes.

Several methods for AFM tip reconstruction are presented in literature, and we focused on in situ characterisation using known tip characteriser for 2D and 3D reconstruction of the tips. AFM technique can also be seen as a spring dynamometer, since the AFM tip is attached to the extremity of a cantilever, which bends according to the interatomic forces between the tip and the sample surface.

Here, we present a procedure for the nanoscale force traceability. Due to the impossibility to provide direct traceability to force at the nanoscale level, we indirectly extract nanoforce values from the spring constants of the cantilever. By using Laser Doppler Velocimetry measurements, resonant frequencies and the corresponding damping of free oscillations are measured, deriving the elastic properties of cantilevers according to Sader's approach. To conclude, this study contributes to fully characterize the "multipurpose metrological AFM" under development at INRiM, in order to obtain an instrument directly traceable to the SI both for dimensional and force measurements.