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AFM tip reconstruction with known tip characterizers, algorithms and applications in nanometrology

Andrea Giura, Alessio Cimma, Luigi Ribotta

In nanometrology, metrological AFMs are indispensable for achieving traceable, sub-nanometer accuracy in height measurements. However, lateral resolution is significantly limited by tip convolution artefacts, making precise tip characterization essential for quantitative analysis in semiconductor and biological applications.

This study investigates nanoparticles as candidate reference materials for *in-situ* tip reconstruction. We analyse stable samples, such as polystyrene spheres, rod-shaped Tobacco Mosaic Virus (TMV), and complex-shaped anatase TiO_2 nanoparticles.

We initially propose a 2D geometrical reconstruction algorithm based on known characterizer properties, such as nominal diameter and crystal angles. This approach is then generalized into a 3D framework. We employ a ray-tracing algorithm to generate ideal topographies of the characterizers, which are difficult to model mathematically, leveraging parallel CPU and GPU computing.

The final 3D tip shape is reconstructed using two developed methods: through morphological erosion of the measured topography by the generated ideal model or by applying the 2D geometrical approach generalized to 3D topographies. Our methods, developed in Python and CUDA, offer a robust and fast workflow for characterizing AFM tips using diverse nanostructures.

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