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Manufacture and calibration of high stiffness AFM cantilevers

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Background incl. aims

Atomic force microscopy (AFM) employs microfabricated cantilevers as sensing elements, which are used to measure surface topography and interaction forces. The flexible free end of a cantilever often presents either a pyramidal tip or a colloid probe particle. Force-displacement measurements have been applied to a wide variety of scientific and engineering disciplines, and across many industrial sectors. For many studies, the use of colloid probes or chemical functionalisation permits the selective study of a particular material/material interaction, often under non-ambient environments. Force-displacement measurements can provide information regarding sample mechanical properties, during tip/sample approach and contact, as well as adhesive properties, during the tip/sample separation. The spring constant is a measure of the cantilever stiffness, i.e. the resistance to bending. The spring constant of a rectangular cantilever can be estimated using Euler-Bernoulli beam theory. Once calibrated, the spring constant is used to convert normal (i.e. vertical) deflections into normal forces using Hooke's law.

Methods

The range of AFM cantilevers commercially manufactured means that spring constants in the approximate range 0.001 to 100 N/m are available. Deflections in the range 0.1-100 nm are typically measurable on the PSD, and hence forces can be measured in the picoNewton to microNewton range. Accurate control of the beam thickness during fabrication is particularly difficult to achieve, due to the nature of the etching process employed. The width and length of the beam are generally much more reliable and repeatable. Given the sensitivity of the spring constant to the beam thickness, typically proportional to the (thickness) cubed, accurate calibration is a necessity for accurate force-displacement measurements.

Results

We are currently calibrating 40 different designs of rectangular AFM cantilever, designed using Timoshenko beam theory, manufactured from Si. The various designs incorporate a range of widths, lengths, and thicknesses. These cantilevers are expected to exhibit spring constants in the range 100 to 10,000 N/m. This would afford researchers the opportunity to perform adhesion, indentation, and tribological testing with normal loads approaching 1 mN, whilst retaining the displacement resolution of the AFM.

Conclusion
We present the latest results of this project, including measured cantilever resonant frequencies and calculated spring constants, which are compared to analytic expressions and finite element models.

Keywords:

cantilever, load, microfabrication, spring constant