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Beyond topography - enhanced imaging of cometary dust with the MIDAS AFM

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Abstract

The MIDAS atomic force microscope (AFM) on-board the Rosetta spacecraft is primarily designed to return the 3D shape and structure of cometary dust particles collected at comet 67P/Churyumov-Gerasimenko [1]. Commercial AFMs have, however, been further developed to measure many other sample properties. The possibilities to make such measurements with MIDAS are explored here.

1. Scanning probe microscopy

AFM is a type of scanning probe microscopy, a field which includes many different types of tip-sample interaction. Those relevant to MIDAS include:

1.1 Magnetic force microscopy (MFM)

MFM allows magnetic materials to be located and mapped to very high resolution by measuring the magnetic stray field of the sample. MIDAS was designed with MFM in mind, and 4 tips have been coated with a layer of cobalt and are therefore magnetic. The sensitivity of MIDAS is explored theoretically.

1.2 Force spectroscopy

Additional information can be gained during amplitude modulated AFM by studying the force-distance curve as the tip approaches and retracts from the sample. MIDAS already operates in a pixel-by-pixel mode, and so obtaining these data is straightforward, but results in a reduced scanning speed and higher data volume.

In principle information on the adhesion and Young's modulus can be obtained for each pixel in an image. For MIDAS the quality of such data are constrained by the accuracy of determining the tip and cantilever properties.

1.3 Phase imaging

In dynamic AFM the measured cantilever oscillations typically have a phase shift with respect to the driving frequency. This shift is related to the operating mode, but also to elastic dissipation in the sample. Therefore by imaging in this mode subtle compositional differences can be mapped that are not apparent in the topographic data.

2. Cantilever and tip properties

Most of the techniques described require a good understanding of the cantilever and tip properties. Since the behaviour of the materials after 10 years in flight is not fully quantifiable, these properties should be constrained using measurements on-board Rosetta wherever possible.

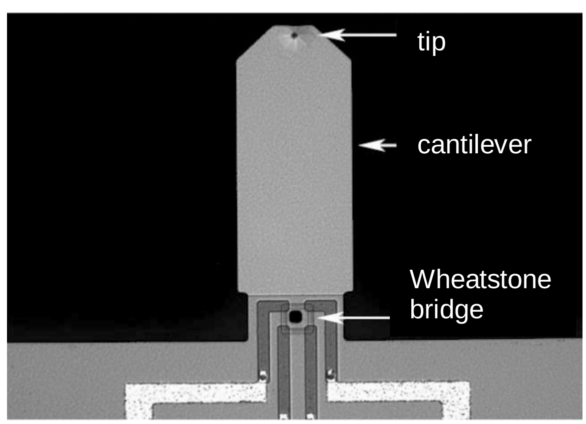

Figure 1: A MIDAS piezo-resistive cantilever, showing the tip and Wheatstone bridge.

2.1 Tip shape

The tip shape, and in particular the tip radius, determine the maximum lateral resolution for all images, and the contact area for force spectroscopy measurements. It can be measured by de-convolution of any image with regular features, such as those carried by MIDAS for calibration and non-linearity correction. In addition a tip-imaging sample containing a containing a series of sharp spikes can be scanned, to produce a 3D image of the tip.

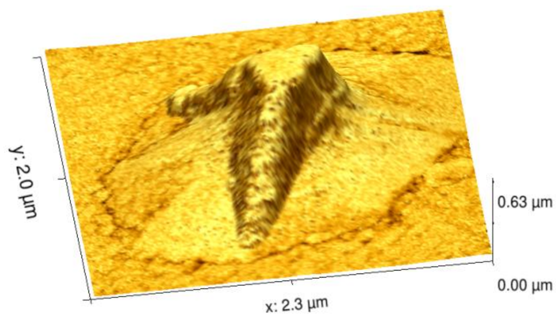

Figure 2: A blunt tip imaged on the MIDAS FS. The topography has been overlaid with the phase data.

2.2 Cantilever spring constant

To model any of the modes described here the spring constant *k* (N/m) of the cantilever must be known. In the laboratory the thermal noise power spectrum of the cantilever is measured [2], or a known mass is added to the tip and the shift in resonant frequency observed. The first of these is not possible due to the finite measurement bandwidth of MIDAS, and the second is not possible due to the lack of access to the instrument.

Alternatively, for a regular cantilever shape (e.g. “springboard”) the plan-view dimensions of the cantilever and measurement of the resonance frequency can be used to calculate *k* [3]. This method is strictly only valid for cantilevers with length/width ratios greater than 5, and so a finite element approach is used here to predict the spring constant.

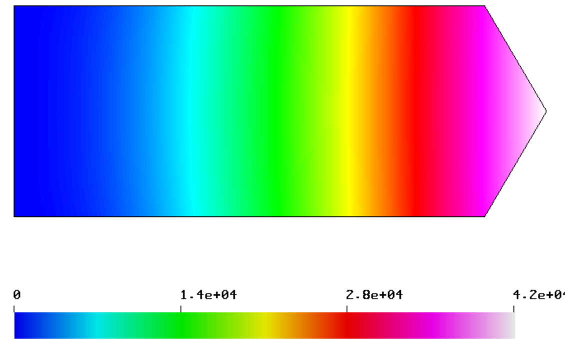

Figure 3: The first eigenmode of the modelled MIDAS cantilever, with arbitrary displacement scale.

3. Modelling tip-sample interactions

Knowing the cantilever properties defined above it is possible to model the dynamics of an oscillating cantilever, in the first instance using a forced harmonic point-mass model. By including appropriate tip-sample force models the feasibility and sensitivity of MIDAS to make the described measurements can be estimated.

First results are presented from these analyses, using a combination of analytical calculations and the VEDA dynamic AFM simulation tool to model the microscope dynamics [4].

References

[1] Riedler, W. et al.: MIDAS The Micro-Imaging Dust Analysis System for the Rosetta Mission, Space Science Reviews, 128, pp. 869-904, 2007.

[2] Hutter, J.L. & Bechhoefer, J.: Calibration of atomic-force microscope tips, Review of Scientific Instruments, 64(7), p. 1868, 1993.

[3] Cleveland, J.P. et al.: A nondestructive method for determining the spring constant of cantilevers for scanning force microscopy, Review of Scientific Instruments, 64(2), p. 403, 1993.

[4] Melcher, J., Hu, S. & Raman, A.: VEDA: A web-based virtual environment for dynamic atomic force microscopy. Review of Scientific Instruments, 79(6), p. 061301, 2008.