Support Note 013-000-000

Bruker AFM Probes:
Force Calibration Cantilevers

1. Introduction

This Support Note describes the Bruker AFM Probes Force Calibration Cantilevers (model CLFC). These probes are pre-calibrated by Bruker using our best-known practices and serve as calibration devices to used in the calibration of other probes.

Important: Retain this document! It contains the calibrated values for the individual CLFC probes included in your shipment (see Appendix).

This Support Note includes the following:

2. Physical Description of CLFC Probes

The CLFC force calibration probes are silicon probes with three rectangular cantilevers. Special processing methods are used to ensure that the cantilevers have uniform rectangular cross-sections. The nominal probe characteristics are given below:

	Length (µm)	Width (µm)	Thickness (µm)	Frequency (kHz)	Spring Constant (N/m)
Cantilever A	97	29	2	293	10.4
Cantilever B	197	29	2	71	1.30
Cantilever C	400	29	2	18	0.157

Even though the processing conditions are closely controlled, the actual dimensions and properties do vary slightly from these values. For that reason, the spring constant of every CLFC probe is individually calibrated at Bruker. The calibration method is described in the following section. The actual spring constants for your probes are given in the Appendix: Calibration Certificate for CLFC Probes.

3. Calibration Method Used for CLFC Probes

The CLFC force calibration probes are calibrated by Bruker using the thermal tune method, also known as the thermal noise method. This method was first proposed by Hutter and Bechhoefer, who noted that the spring constant of a cantilever could be related to its thermal energy by the equipartition theorem,[1] resulting in the equation

$$\frac{1}{2}k\langle z_c^2\rangle = \frac{1}{2}k_B T,$$

where k is the spring constant, k_B is the Boltzmann constant, T is the absolute temperature, and $<z_c^2>$ is the mean squared displacement of the cantilever's thermal motion. Butt and Jaschke[2] later noted that a small correction is required to compensate for the fact that cantilevers do not act as perfect simple harmonic oscillators. This correction yields the final equation:

$$k = 0.971 k_B T / \langle z_c^2\rangle .$$

An additional correction is required if the method is implemented on an AFM using the normal optical lever cantilever deflection detection technique because it detects cantilever inclination rather than true cantilever displacement.[2] The details of these corrections as well as a comprehensive review of several other calibration methods is available as a Bruker Applications Note.[3]

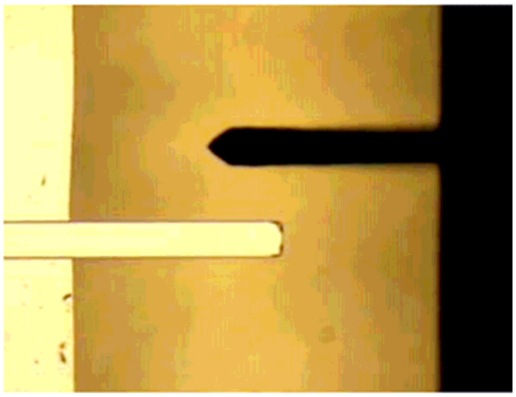
Recently, however, research at Bruker showed that the thermal tune method could be readily implemented on a laser Doppler vibrometer.[4] Laser Doppler vibrometry is an interferometric technique for measuring velocity and displacement based on the Doppler shift of laser light reflected by a moving object. The instrument is capable of measuring very small displacements with very low uncertainty, which makes it ideal for the thermal tune method. Using this technique, we have demonstrated uncertainly in the calibrated spring constants approaching about 5%.[4] This is the method that we now use for calibration of the CLFC force calibration probes.

4. Method for Transferring Calibration to Other Probes

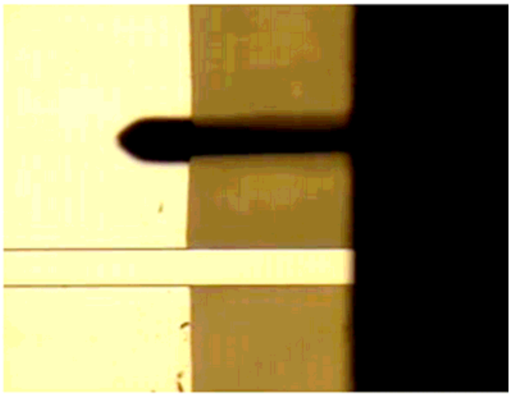
Other probes are calibrated by transferring the known spring constant of a CLFC cantilever using the reference cantilever method.[3] This is done using the following simple steps:

1) Select the appropriate CLFC cantilever by comparing the nominal spring constant of your unknown cantilever, k_{nom}, to the known spring constants of your CLFC cantilevers, k_{ref}. For best accuracy, select a CLFC cantilever with spring constant such that $0.3\ k_{ref} < k_{nom} < 3\ k_{ref}$.

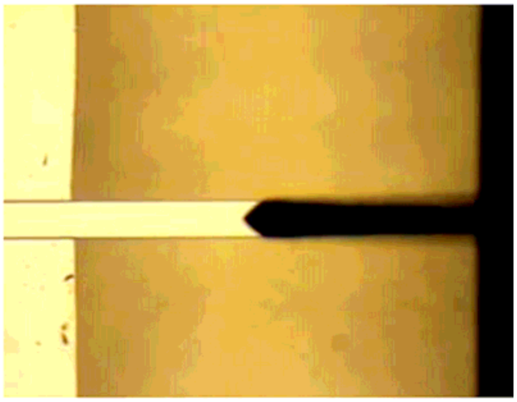
2) Mount the CLFC probe on a sample disc using double-sided tape. Align the CLFC cantilever on the AFM sample stage such that its long axis is aligned with the cantilever to be calibrated, but facing the opposite direction, as shown below where the CLFC cantilever is shown on the left and the unknown cantilever is on the right.



3) Align the cantilever to be calibrated over the substrate of the CLFC probe, as shown below, and engage normally in contact mode. Measure the deflection sensitivity in ramp mode. The exact method will vary depending on your microscope and software, so please refer to your operating manual if you are unsure of the procedure. It is good practice to keep the vertical deflection signal near 0V and measure the deflection sensitivity over about 100nm of deflection. Repeat the deflection sensitivity measurement a few times and average the values to obtain the average hard surface deflection sensitivity, S_{hard}. You should obtain a value somewhere in the range of 10 – 200 nm/V, where shorter cantilevers have lower deflection sensitivities.



4) Withdraw and realign the cantilever close to the end of the CLFC cantilever as shown below. Engage normally in contact mode and repeat the deflection sensitivity measurement. Take care that the vertical deflection signal is near the same value as for the last measurement and measure the deflection sensitivity over the same range. Again, take several measurements and average the results to obtain the average deflection sensitivity on the CLFC cantilever, S_{ref}.



5) Measure the offset of the tip from the end of the reference cantilever. This is most conveniently done by using the top down optics of the AFM. You can use the length of the reference cantilever, L, as a standard to calibrate the optical view. The offset is designated by ΔL.

6) Calculate the spring constant of the unknown cantilever using the following formula:

$$k = k_{ref}\left(\frac{S_{ref}}{S_{hard}} - 1\right)\left(\frac{L}{L - \Delta L}\right)^{3}$$

Uncertainty in the calibration is dominated by error in determining the deflection sensitivity values. The accuracy of the deflection sensitivity calibrations can be improved by operating ramp mode with closed-loop Z if that is supported by your AFM.

5. References

1. J.L. Hutter, J. Bechhoefer, "Calibration of atomic-force microscope tips", Rev. Sci. Instrum. 64 (1993) 1868-1873.

2. H.-J. Butt, M. Jaschke, "Calculation of thermal noise in atomic force microscopy", Nanotechnology 6 (1995) 1-7.

3. B. Ohler, “Application Note 94: Practical Advice on the Determination of Cantilever Spring Constants”, http://www.Bruker.com/library

4. B. Ohler, “Cantilever spring constant calibration using laser Doppler vibrometry,” Rev. Sci. Instrum. 78 (2007) art. no. 063701.

6. Appendix: Calibration Certificate for CLFC Probes

Wafer number: ____

Date of calibration: ____

Probe	Lever	Frequency (kHz)	Spring Constant (N/m)
1	Long		
	Medium		
	Short		
2	Long		
	Medium		
	Short		
3	Long		
	Medium		
	Short		
4	Long		
	Medium		
	Short		
5	Long		
	Medium		
	Short		