Determination of the spring constants of the higher flexural modes of microcantilever sensors

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Microcantilevers are widely employed as probes not only in atomic force microscopy [1], but also as sensors for mass [2], surface stress [3], chemical identification [3], or in measuring viscoelastic properties of cells [4]. Small changes in the oscillation properties of the flexural modes of the cantilevers can be exploited to quantify properties such as masses or forces provided the corresponding spring constants are known. Most of the applications currently make use of the first flexural mode only.

Use of the higher flexural modes of microcantilever sensors is an area of current interest due to their higher Q-factors and greater sensitivity to some of the properties probed [2]. A pre-requisite for their exploitation, however, is knowledge of the spring constants [5]. None of the existing cantilever calibration techniques can calibrate the higher flexural modes easily. Current calibration techniques have certain difficulties and disadvantages: some of them are destructive or risk damaging the cantilever in the calibration process. Others rely on a requirement for accurate knowledge of the cantilever dimensions, its mass, density, or elastic modulus. Chemically modified cantilevers or cantilever sensor systems for biomedical research, require a simple yet reliable calibration method which can be performed in situ and which does not bear the risk of affecting the quality of the modified cantilever.

We present a method that allows for the determination of the spring constants of all flexural modes. A flow of gas from a microchannel interacts with the microcantilever (see Figure 1) causing a measurable shift in the resonance frequencies of all flexural modes [6]. As such the method is non-invasive and does not risk damage to the microcantilever. From the magnitude of the frequency shifts the spring constants can be determined with high accuracy and precision. Experimental data for the response of the first four flexural modes of microcantilever beams used in AFM with spring constants in the range of ~0.03-90 N/m will be shown.

The resulting spring constants of the first mode are compared to those obtained with the Sader method [7]. Finite element analysis CFD (Computational Fluid Dynamics) simulations of the experimental setup are used to provide an insight into the interaction of the flow with the microcantilever (see Figure 1).

References

Figure 1. Schematic of the setup used to determine the spring constants of the higher flexural modes of microcantilever sensors.