Master internship project

Temperature-dependence of the spring constant of a scanning thermal microscopy cantilever

Location: Centre d'Energétique et de Thermique de Lyon (CETHIL), UMR 5008 CNRS - INSA de Lyon, France
Duration: 6 months
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Research project

Context and goal.

Scanning thermal microscopy (SThM) is one of the most promising technique for the thermal measurement of materials and systems at the nanoscales. Our SThM instrument is based on an atomic force microscope (AFM) (Figure 1.a.) for the accurate positioning of a nanometric in size resistive metallic sensor at the surface of the investigated sample [1]. This sensor can be used as a thermometer to measure the sample's surface temperature (passive mode) or, while heated by Joule effect, as both a thermometer and a very small heating source for characterizing the sample thermophysical properties (active mode). Whatever the experiment configuration, the probe is then heated: by the sample in passive mode, by Joule effect in active mode [1].

Thermal sensor is located at the tip of a silicon nitride AFM's cantilever (Figure 1.b.) of which deflection depends on the tip-sample force but also on the probe deformation as a function of temperature due to bi-material effect[1] for instance. An optical method is used to measure the cantilever deflection from which the tip-sample force can be derived provided that the cantilever spring constant is known.

The knowledge of the tip-sample force can be crucial in the estimation of sample properties as the size of the probe - sample contact area, which depends on this force and is an important input parameter of the model then used.

The goal of this research project is to characterize and assess the temperature dependence of the cantilever spring constant of SThM probes. To date this temperature-dependence has been often neglected in the approaches of SThM measurements. This project will provide new information for a better management of experiment conditions and an improved modelling of the probe-sample interaction.

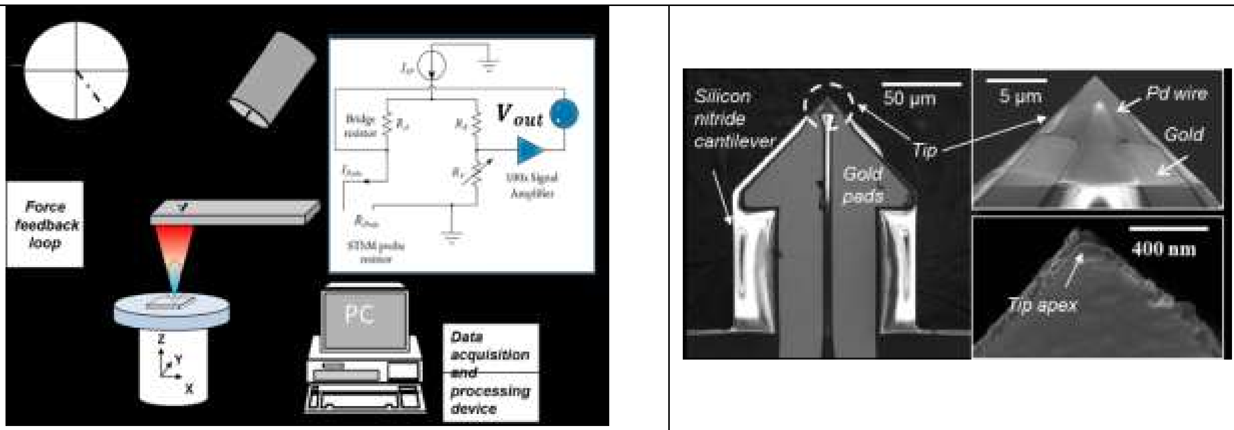

Fig. 1. a. Schematic of our AFM-based SThM setup. **b.** SThM probe

[1] Bi-material effect is a thermomechanical effect that arises when two materials of superimposed layers have different thermal expansion coefficients.

Master internship Program. The work plan includes the following six main steps.

1. Understanding the project goals through bibliography research and learning to use the SThM instrument.
2. Performing the measurement of probe cantilever spring constant in ambient air environments using the thermal noise [2] and Sader's (resonance) [3] methods (implemented at CETHIL [4]) in different experimental configurations while:
   - the probe is self- heated by Joule effect,
   - the sample is heated.

   In this step, the optimisation of the experiment design is comprised.
3. Adapting a 3D numerical model available in the laboratory for simulating the temperature field in the probe, the air surrounding the probe and at the sample surface during experiments.
4. Analyzing experimental results with modeling simulations as a function of the probe heating source and its temperature.
5. Writing of the report.

References:

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[2] H.-J. Butt, B. Capella, M. Kappl, *Force measurements with the atomic force microscope: Technique, interpretation and applications*, Surface Science Reports 59 (2005)

[3] J. E. Sader et al. Spring constant calibration of atomic force microscope cantilevers of arbitrary shape, Rev. Sci. Instrum. 83, 103705 (2012)

[4] C. Acosta, CETHIL Internal report on different techniques for spring constant estimation (05-2023)