

Tunneling Current Conductive AFM (TC-CAFM) module for low-conducting samples

The newly designed Tunneling Current Conductive AFM (TC-CAFM) module for NanoWizard® is designed to measure ultralow currents on low-conductive samples. The noise level allows to perform extreme sensitive experiments down to <math><100\text{fA}</math>. The JPK TC-CAFM module is perfect for lowest noise and highest performance current measurements even in combination with a controlled environment.

Apart from standard applications for Conductive AFM in material characterization new classes of materials being developed for example for green and low-cost electronics set a new benchmark for the characterization of electrical properties by AFM. Their mechanical properties make it impossible to apply conventional modes of conductive AFM imaging. With the new QI™ Advanced imaging mode coming with the NanoWizard®, JPK has developed a solution for the imaging of these kinds of samples. Aside from providing electrical data, this new imaging mode also allows the correlation of electrical and real mechanical data.

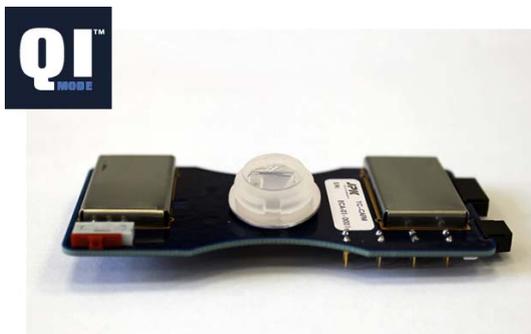


Fig. 1: TC-Conductive AFM module from JPK in combination with QI™ Advanced mode for highest performance current measurements in combination with mechanical sample properties

Setup description

As seen in **Fig. 1** the TC-CAFM module from JPK is a specially designed cantilever holder with integrated elec-

tronics. The standard version is made for experiments under ambient conditions. The version with environmental control has a closed cell that covers a volume of 140 μL approx. The transparent parts of the TC-CAFM environmental cell are made from polycarbonate.

In both cases the TC-CAFM module is equipped with a circuit board that needs to be very close to the cantilever for reliable lowest current amplification. All standard Conductive AFM cantilevers are compatible. The cantilever chip and the glass holder are held together with a mechanical gold clip that also collects the current from the tip.

Two different sample holders are available to support opaque or transparent samples. The sample size is variable. Sample diameters can go up to several cm. High NA objective lenses can be used to study the sample optically with inverted or upright microscopes.

In combination with the JPK TC-CAFM module (see **Fig.1**), the QI™ Advanced imaging mode is able to provide electrical information for a sample on the nanometer scale, while maintaining the highest topographic resolution. Besides being easy to use, another advantage of the force curve based approach is the capability to further analyze the conductive data in more detail at every pixel, which is not possible with data from conventional conductive AFM measurements.

The broad compatibility to other accessories for the NanoWizard® AFM series including the temperature and environmental control solutions as well as excellent optics enables the most sophisticated AFM experiments.

Fields of application

The TC-CAFM module is made for lowest range current mapping on the most fragile samples, down to the $\pm 10\text{nA}$ range.

Force spectroscopy applications also can be applied to TC-CAFM experiments when current flow is of interest depending on the force that is applied to the sample. Constant voltages or voltage ramps of different shape between +/- 10 V and down to millivolts in any case can be applied to the sample during an experiment.

The new QI™ Advanced imaging mode for NanoWizard® for conductive measurements is especially of benefit, but not limited to, the mapping of conductive properties on soft and brittle samples. Together with dedicated solutions for environmental and temperature control as well as the integration with optical techniques, a broad range of applications becomes available. Key examples include organic semiconductors such as organic photovoltaics, biosensors, displays and battery components. The investigation of the properties of graphene or CNTs is growing in importance.

Also for the measurement of rather stiff samples, the QI™ Advanced imaging mode is advantageous, as it eliminates lateral forces and therefore tip wear. Tip wear is of major concern when performing conductive AFM due to potential abrasion of the conductive coating of the cantilever.

Typical applications include:

- **(Organic) semiconductors and compounds**
- **Low-conducting polymers and polymer coatings**
- **Light emitting polymers**
- **Graphene**
- **Nanotubes**
- **Dielectric and ferroelectric thin films**
- **Lithium ion battery components**

Specifications

- Highest-performance lowest current conductive AFM experiments
- Also recording local I/V curves

- Bias voltage range ± 10 V
- Different current ranges available
 - **Current range** with a gain $1 \cdot 10^9$ up to ± 10 nA with a noise limit 100fA RMS in imaging bandwidth
 - **Other current ranges** on request (see JPK Conductive AFM module product note)
- Sample holder for opaque samples (standard)
- Sample holder for transparent samples works with all inverted optical microscopes
- Optional version with closed sample volume for experiments in defined atmosphere with a volume of 140 μ L
- The TC-Conductive AFM module is compatible with all NanoWizard® AFM's
- In combination with QI™ Advanced mode and NanoWizard® mechanical and electrical data can be correlated on the nanoscale in a single scan
- With QI™ Advanced high resolution and low noise current mapping on fragile, brittle and loosely attached samples, virtually no tip wear due to eliminated lateral forces
- Parameters such as start and end voltage of the ramp, ramp-direction or rate can be easily chosen in the user interface. The software can either record a single spectrum or average over multiple spectra. With the ExperimentPlanner™ software module the user has the absolute freedom of designing individual measurement procedures
- Compatible with JPK heating/cooling stages (see JPK accessories handbook)
- For experiments under controlled gas atmosphere the setup is compatible with the JPK glove box solution (see product note)