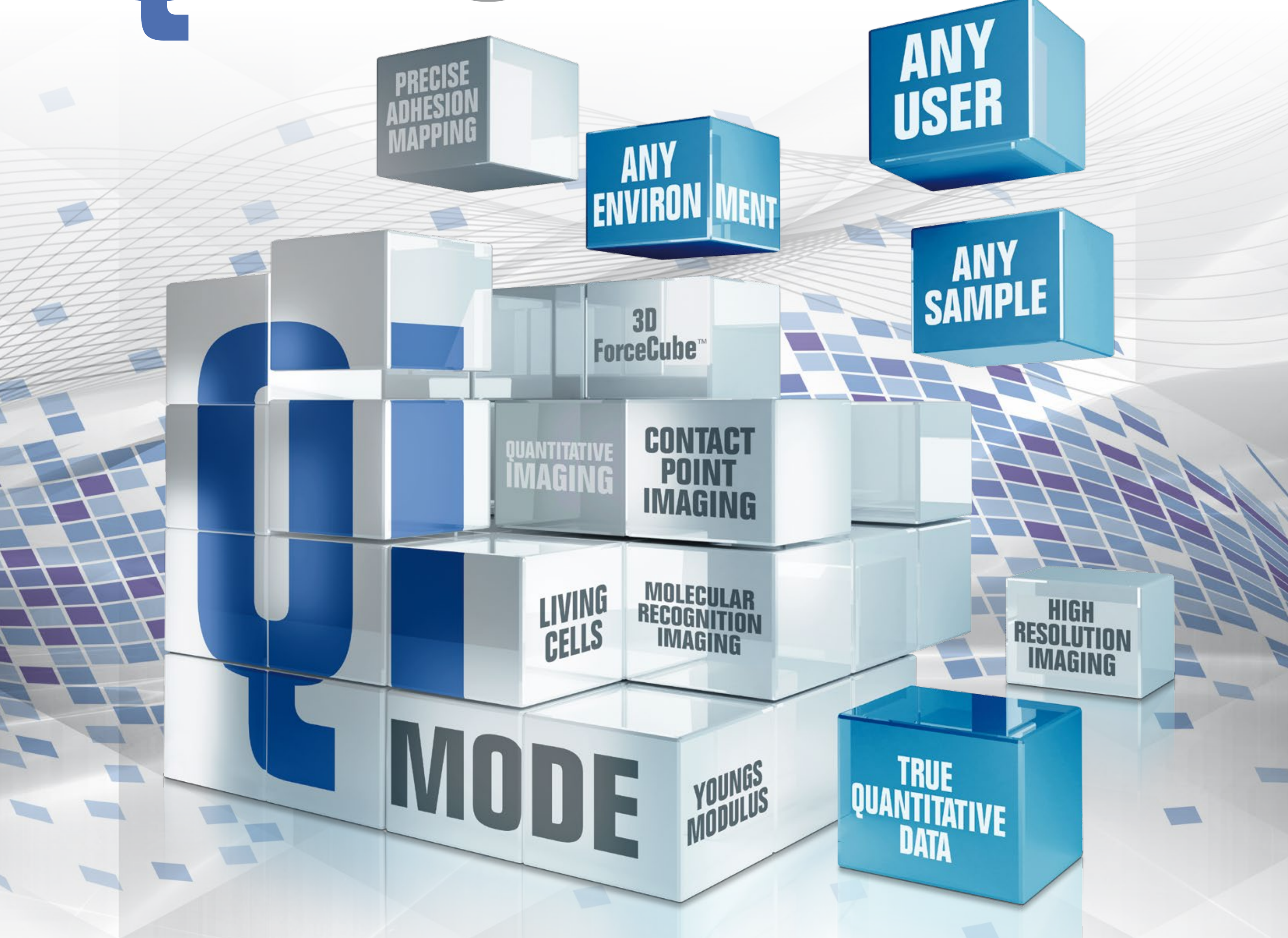
Quantitative Imaging Mode exceeds your expectations on how to operate an AFM

QI™ MODE



QI™ mode makes AFM **easy and intuitive** to operate for everybody

Precise force control – ideal for most fragile samples

High-resolution images with just "4 clicks" for any sample, particularly samples that are soft and sticky, loosely attached or have steep edges

Quantitative images with morphology, mechanical, chemical, optical, magnetic and electrical information such as modulus, adhesion, dissipation, conductivity and more

Molecular recognition imaging for localization of binding sites, **Contact Point Imaging (CPI™)** mode for true topography and **3D ForceCube™** for vertical gradient mapping

JPK Instruments

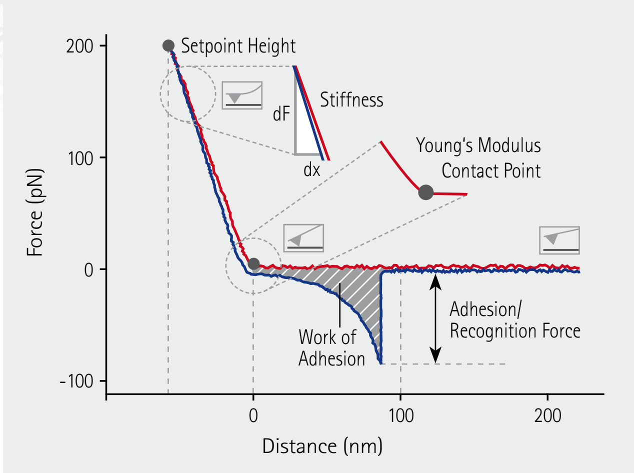
we have joined Bruker

BRUKER

QI™ MODE – GET RELIABLE DATA EASILY NO MATTER WHAT SAMPLE YOU MEASURE

QI™ MODE BECOMES THE STANDARD FOR ANY SAMPLE IN AIR, INERT-GAS OR FLUID

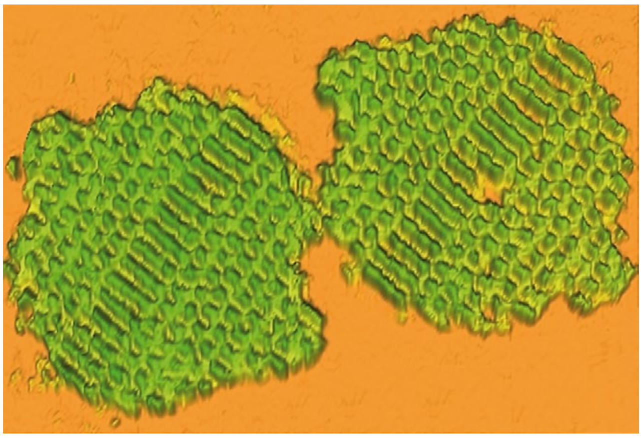
The new QI™ mode with its optimized accuracy and operation is able to reach the lowest peak forces down to **10 pN**. This ensures the lowest tip-sample interaction which preserves the tip and the sample from damage. Particularly for samples that are soft, sticky, brittle or loosely attached to a surface, QI™ mode is the imaging mode of choice. Highly corrugated surfaces e.g. from tissue, metal or plant samples are now easy to image because of the large Z-range. QI™ mode is superior to conventional AC imaging when studying deep and high-aspect ratio trenches/structures.



In QI™ mode a complete force-distance curve is recorded at each pixel. By analyzing the curves a comprehensive set of sample properties can be extracted.

PERFECT FOR NON-EXPERTS, BEGINNERS AND OCCASIONAL USERS

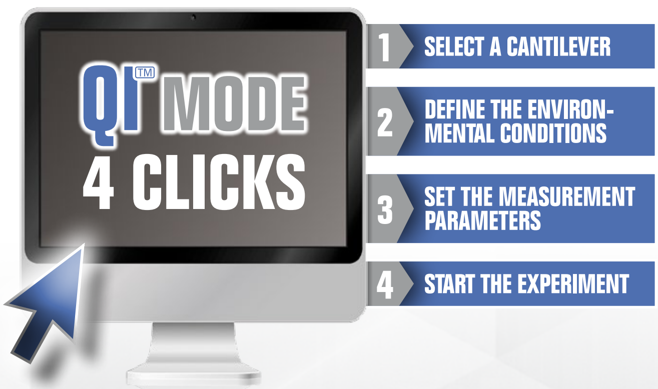
Whether in a multi-user facility, central microscopy laboratory or bio-imaging center, users want to obtain images and data quickly and easily. In such cases, QI™ imaging is the perfect measurement mode. No in-depth knowledge of AFM is needed to operate it and the intuitive, guided settings will save time to get high quality images within minutes. For more detailed sample analysis, simply switch to QI™-Advanced mode for a map of your sample's material properties. These are all available at a mouse-click - without compromising measurement speed.



DNA origami imaged in TAE-Mg buffer. Scan size: 150 nm × 200 nm, z-range: 2 nm. Sample courtesy of Dr. Meyer and Prof. Niemeyer, Karlsruhe Institute of Technology (KIT), Germany.

INTELLIGENT AND AUTOMATED IMAGING WITH JUST "4 CLICKS"

Usability is the key factor for an AFM nowadays. Ease of use includes for JPK a minimal operator input, auto optimization of scan parameters as well as real-time data channels. Measurements can be carried out in an uncomplicated yet reliable way without expert knowledge of the underlying technology. A few simple parameters are enough to set up and start a measurement.



Intelligent algorithms based on JPK's ForceWatch™ technology automatize the scanning process and control all parameters. However, JPK AFMs are no "black boxes". Advanced users can access all parameters and there is no hidden data processing. Transparency in data acquisition and handling is part of our philosophy.

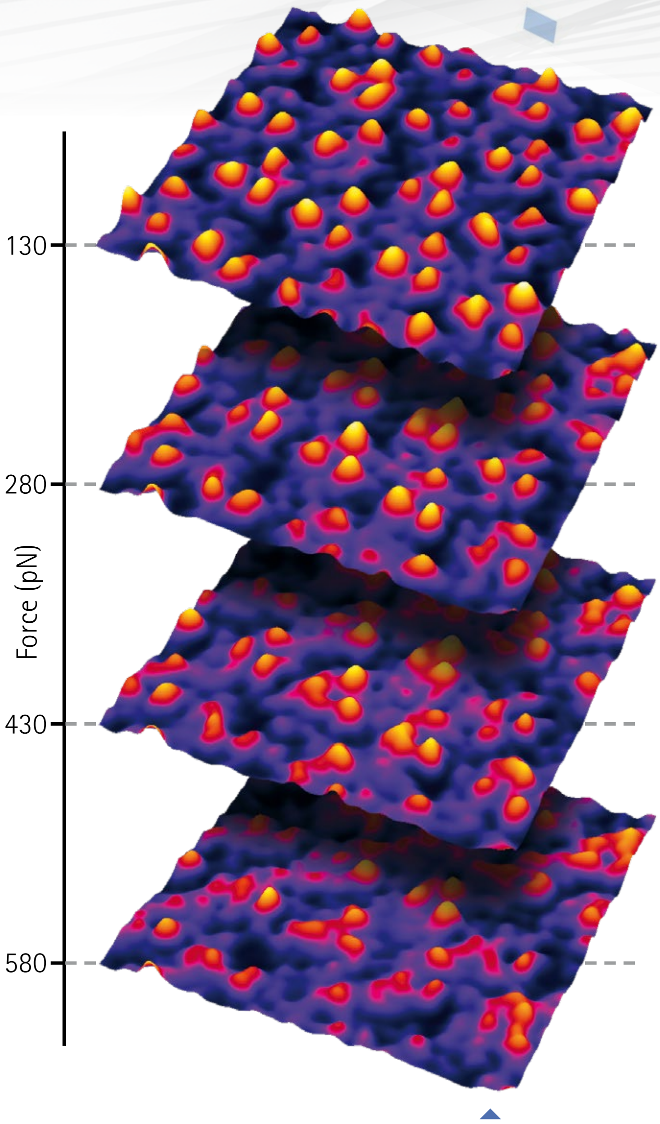
QI™ MODE TECHNOLOGY DELIVERS HIGH-QUALITY QUANTITATIVE DATA

REAL FORCE CURVES FOR RELIABLE DATA

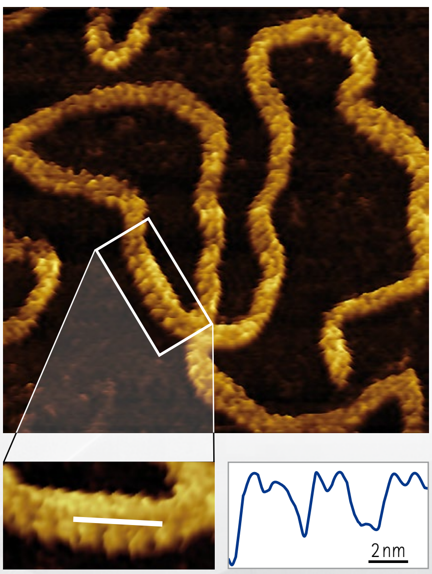
QI™ mode delivers real force curves in contrast to other methods using sinusoidal motion and is therefore the only way to get reliable quantitative data with highest resolution. Perfect direct force control by JPK's ForceWatch™ technology results in zero setpoint drift. The off-resonant QI™ mode with its linear motion with constant speed, compared to methods from other vendors, guarantees accurate values for stiffness and adhesion. A major advantage of QI™ is, that no lateral forces act on the sample during scanning. This preserves the sample and the tip and is in particular important when combining QI™ with other modes such as Conductive-AFM.

FOR EXACT QUANTITATIVE DATA THE MOTION OF THE CANTILEVER IS THE KEY

Constant cantilever speed to get real force curves (no continuous acceleration or deceleration, no sinusoidal oscillation) is the basic principle of QI™. This is significant for the detailed and quantitative analysis of sample materials, as many sample systems exhibit velocity-dependent properties. The calculation of absolute values, e.g., of the Young's modulus, and the unequivocal assignment of specific events occurring in adhesion measurements is therefore possible. For calculating the Young's modulus, the established modulus models are invariably based on constant speed of the measuring probe.



3D ForceCube™ images of bacteriorhodopsin membrane proteins measured in buffer solution. Scan size: 30 nm × 30 nm, z-range: 600 pm. Height images were calculated at different interaction forces to demonstrate the potential of topography reconstruction and tomography images.



Vector DNA on a poly-l-ornithine covered mica substrate measured in liquid and cross section of the marked region.

Major and minor grooves are clearly visible.

Scan size: 90 nm × 90 nm
z-range: 2 nm

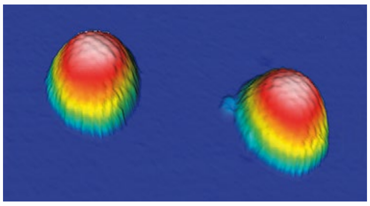
POWERFUL AND FLEXIBLE DATA PROCESSING

The full datasets of force curves per pixel are stored, thus enabling the use of data post-processing at any time automatically in a batch processing way. Mapping of quantitative nano-mechanical sample properties using different modulus models (Hertzian, Sneddon, JKR, DMT…) for the fitting of the force curves results in Young's modulus images. Additionally, modulus data can be overlaid on 3D topography or even with optical data by JPK's DirectOverlay™ mode.

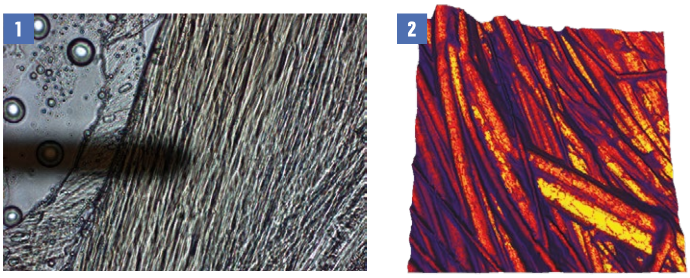
QI™ MODE IS PERFECT FOR BIO-SAMPLES

HIGH RESOLUTION IMAGING OF SINGLE MOLECULES TO CELLS AND TISSUES

QI™ mode ensures lowest forces in the pN range to protect soft and fragile samples. Getting high resolution images of bio-samples is easier than ever before. The use of very soft cantilevers is from great benefit.



Herpes Simplex Viruses on silanized glass slide measured in buffer solution. Virus capsid substructure can be resolved with highest resolution. Scan size: 300 nm × 600 nm. z-range: 150 nm.
Sample courtesy of Prof. Wouter H. Roos, Rijksuniversiteit Groningen, Netherlands.

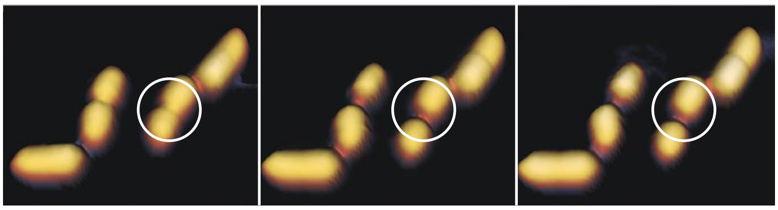


Untreated tendon tissue section of a patient suffering from diabetes measured in PBS buffer. **1** Optical image (40 × phase contrast) of measured tissue. **2** Overlay of 3D height image with Young´s modulus information. Scan size: 3 µm × 3 µm, color texture range: 1.5 MPa. Sample courtesy of Andrzej Mlyniec PhD, AGH-University of Science and Technology, and Krzysztof Tomaszewski MD PhD, Jagiellonian University, Krakow, Poland.

MECHANICAL PROPERTIES OF SOFT SAMPLES – FROM GELS TO CELLS WITH QI™-ADVANCED

To date, AFM analysis has yielded a deeper understanding of the nanoscale mechanical properties of (bio)-materials, proteins, cells, bacteria and tissues, supporting standard characterization and microscopy techniques (e.g., fluorescence microscopy) with quantitative data. QI™- Advanced mode is the next step in correlative microscopy. With its higher speed compared to force mapping and its large variety of data channels the user gets mechanical properties in one single scan. Comprehensive fitting routines support the user to get reliable quantitative data.

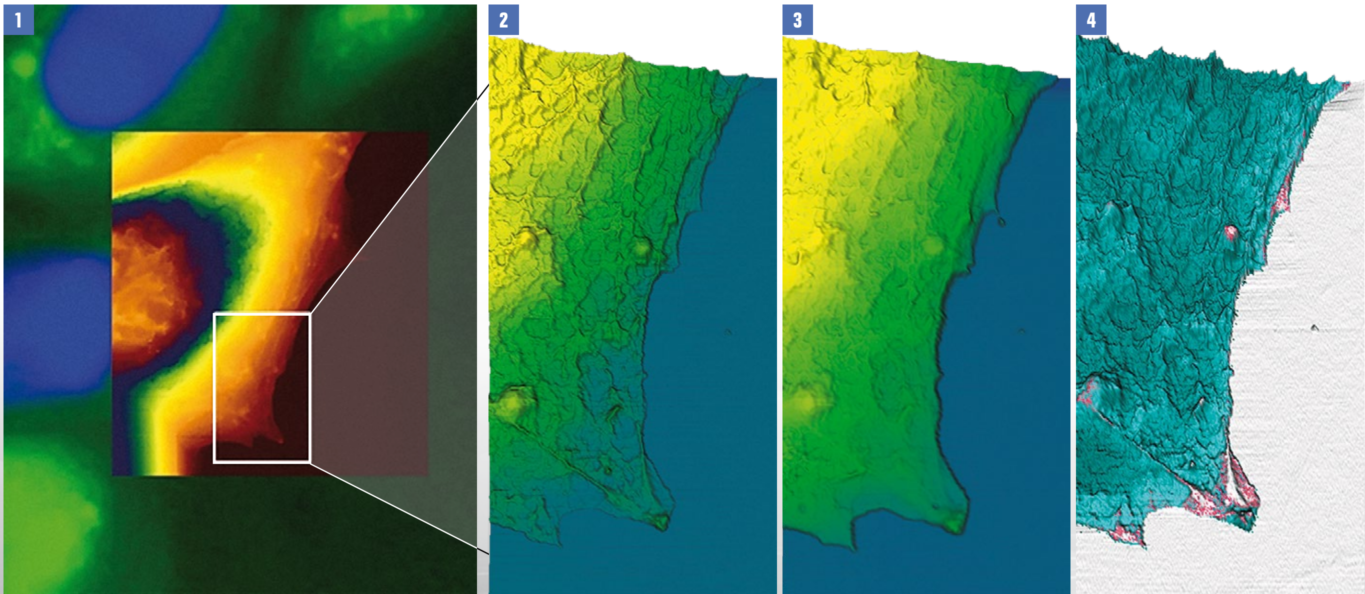
Living E-coli bacteria during cell division process. Four individual bacteria were analyzed over 1 h during division process using JPK Biocell™ at 30 °C. Three representative height images are shown (scan size 5 µm × 7 µm, z-range: 1.5 µm). Sample courtesy of Supriya Bhat and Prof. Tanya Dahms, University of Regina, Canada.



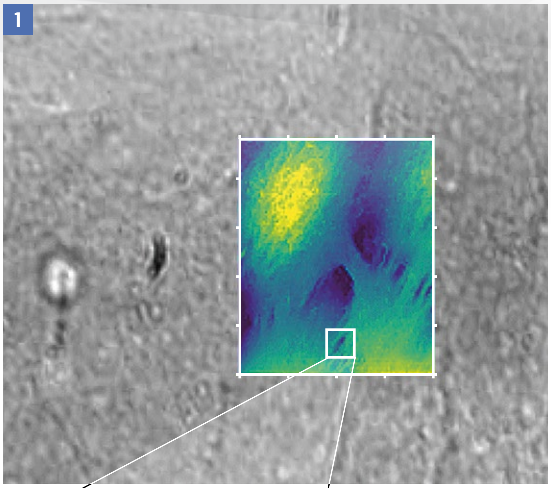
TRUE MORPHOLOGY WITH THE CONTACT POINT IMAGING MODE

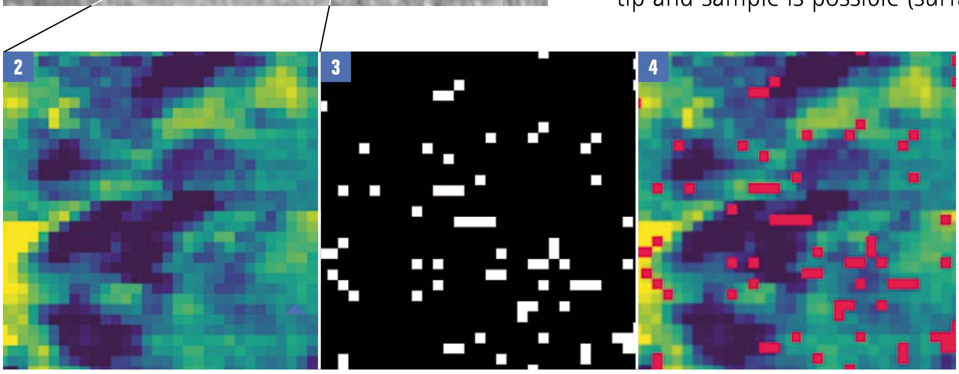
The newly developed CPI™ as a part of the QI™-Advanced package delivers the height values at zero force. This is a huge benefit particularly for living cells and soft gels if you want to measure the exact topography or the correct volume for example. A topography reconstruction at different interaction forces offers further unique information about your sample.

Living CHO cells were imaged in the JPK PetriDishHeater™ at 37 °C.
1 Cells were fluorescently labelled with Hoechst (blue nuclei) and fluorescein diacetate (green cytoplasm). After an overview scan, the marked region was selected for further analysis. **2** 3D height image of the marked region (setpoint: 1nN, z-range: 1.4µm). **3** Contact Point Image at zero interaction force (CPI, z-range: 2.4µm). The cell surface appears smoother and the reconstructed height is nearly twice as high as the height image at 1nN setpoint. **4** Young´s modulus image (range: 40kPa). Sample courtesy of Prof. A. Herrmann and Dr. T. Korte, Humboldt University, Berlin.



QI™ MODE QUANTIFIES BIOLOGICAL AND CHEMICAL INTERACTIONS





Recognition measurement to investigate distribution and the adhesive properties of binding events between desmosomal cadherins on living keratinocyte cells. Desmosomal cadherines are parts of desmosomes, which provide strong cell-cell adhesion to facilitate the integrity of tissues, but can also found extradesmosodal. The cantilevers were functionalized with recombinant Desmoglein 3 (Dsg3-Fc) using a PEG-linker. **1** Optical image (63 × brightfield) overlaid with topography image of different keratinocyte cells. Scan size: 25 µm × 30 µm, z-range: 2.5 µm.

Recognition data of cell border region:
2 Height image (z-range: 0.4 µm)
3 Identified recognition events
4 Overlay of height and recognition data. Scan size: 2.5 µm × 2.5 µm
Data courtesy of Dr. Franziska Vielmuth, Prof. Volker Spindler, Institute of Anatomy and Cell Biology, Ludwig-Maximilians-Universität Munich, Germany.

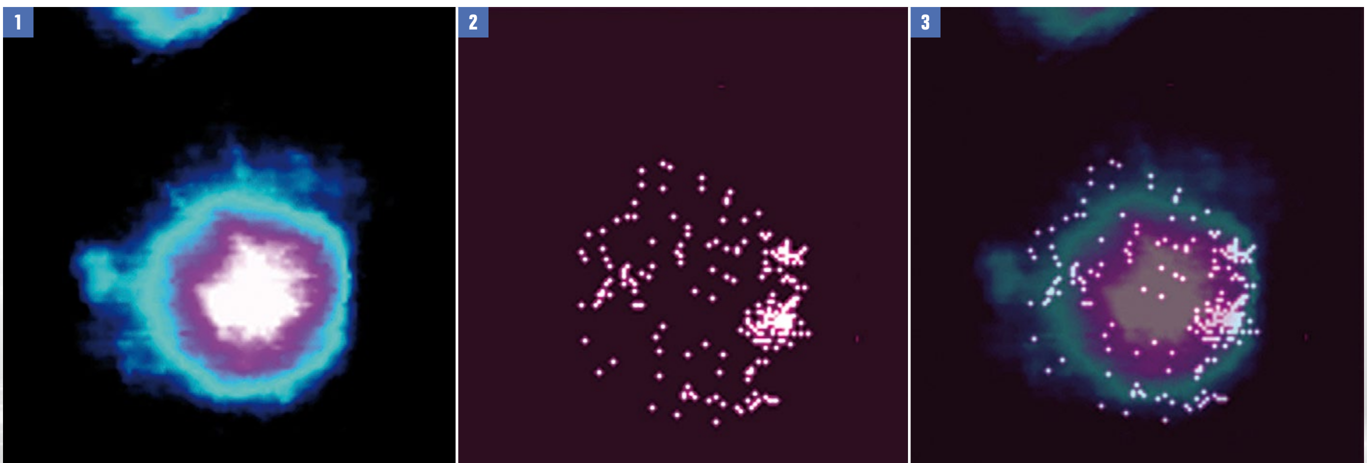
CHEMICAL FORCE MICROSCOPY RE-INVENTED

Chemical force microscopy (CFM) has been successfully applied to visualize the distribution of molecules in surface-adsorbed protein layers, DNA-protein complexes, antibody-antigen pairs and others. The ability of AFM tip functionalization with chemical groups and individual molecules, combined with the possibility to measure under physiological conditions, made AFM ideal to detect and quantify chemical and biological interactions on single molecule level. Due to QI™'s constant cantilever speed and the triangular cantilever movement (in contrast to a sinusoidal pattern), a variable contact time between tip and sample is possible (surface contact/retraction delay is variable). Moreover, linear loading/unloading rates are guaranteed to get accurate and reliable data for (un)-binding events. Molecular recognition can become a routine method under certain conditions with the intelligent peak finding routines adapted from JPK's proven ForceRobot®.

MOLECULAR RECOGNITION IMAGING NOW EASIER THAN YOU THINK

The ability to map the distribution of specific binding/unbinding sites of organelles or entire bacteria, yeast and mammalian cells or tissues leads to a new understanding of structure and function relationship of living matter. With the new QI™-Advanced mode this is now reliable and easy. The off-resonant motion of the functionalized cantilever together with the tunable amplitude, the variable number of taps per pixel and variable contact times per pixel make QI™-Advanced perfect for recognition applications.

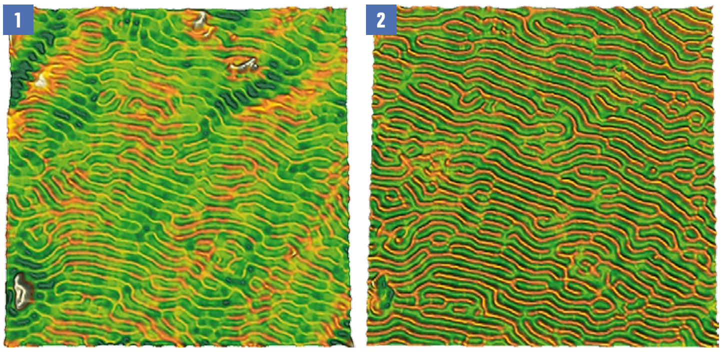
Recognition microscopy on biotin bead (diameter 200 nm) against streptavidin functionalized cantilever. Force-distance curves were processed to evaluate for the typical biotin-streptavidin binding signature for binary recognition image reconstruction. Scan size: 375 nm × 375 nm. **1** Height image (z-range: 50 nm). **2** Binary recognition image, bright spot indicates a binding event. **3** Overlay of height and recognition.

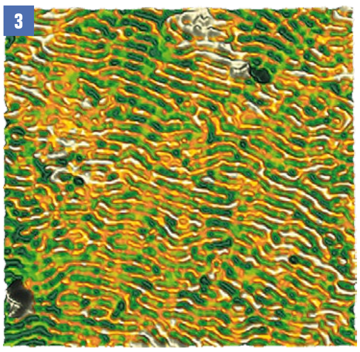


QI™ MODE PEAK PERFORMANCE FOR NANO-MECHANICS FROM POLYMERS TO ADVANCED MATERIALS

MAPPING LOCAL MATERIAL PROPERTIES WITH HIGHEST ACCURACY

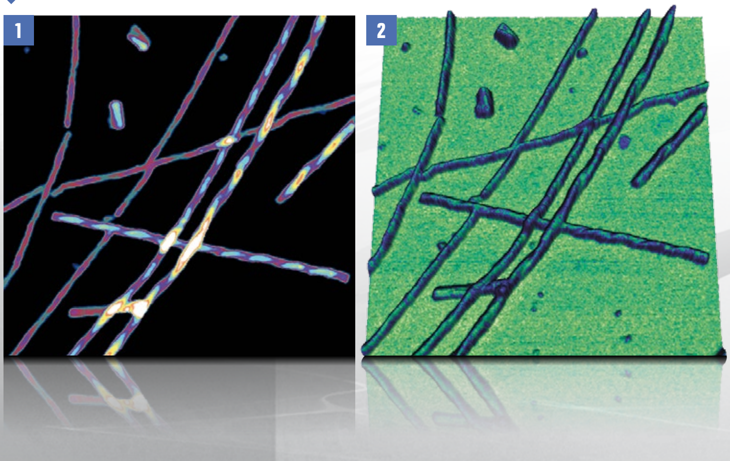
The development of new polymers and advanced materials for material and life science products is of great interest. Particular materials with strong (visco)-elastic properties and with nanoscale heterogeneities are in the focus of today's research. Evaluating the mechanical parameters of these materials plays an important role for future product reliability and quality. Besides topographic morphology, mechanical properties and features such as modulus, damping, adhesion and defects can be measured with QI™-Advanced quickly and accurately. The advantage of QI™ is the ability to measure sticky samples with large adhesion, brittle or loosely attached specimens with high spatial resolution. Studying thin films, nanocomposites, biomaterials, gels, polymer blends and brushes and self-healing polymers to get adhesion, Young's modulus, dissipation, and deformation is easy now.





Block-Co-Polymer thin section
1 Height image (z-range: 50 nm)
2 Adhesion image (range: 4.5 nN)
3 Elasticity image (range: 40 pN/nm)
Scan size: 2µm × 2µm
Sample courtesy: M. Menzel, Fraunhofer IMWF, Halle, Germany.

Twisted insulin fibrils. 1 Height image (z-range: 10 nm). 2 3D height image overlaid with elasticity information (color texture range: 2 N/m). Scan size: 3 µm × 3 µm. Sample courtesy of Dr. Claudio Canale, Nanophysics dept., Istituto Italiano di Tecnologia. Genova, Italy



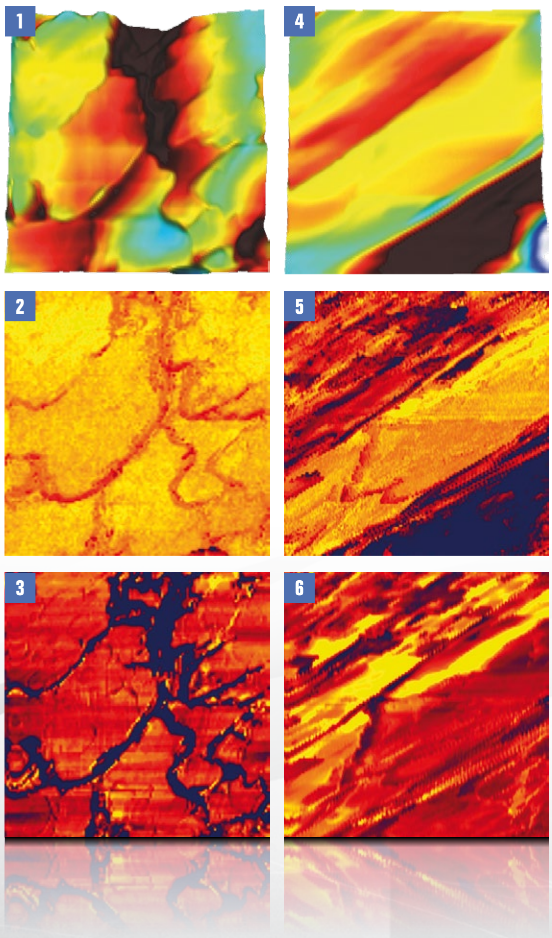
FOLLOW SAMPLE PROPERTY CHANGES EASILY

External stress acting on materials is responsible for changing the mechanical properties over time. Aging with loss of stability or elasticity, crack propagation, phase transitions, strain hardening: all these phenomena can be studied in-situ in gas or fluid environment under temperature control with QI™ mode. With JPK's StretchingStage, heating/cooling/cryo stages, fluid handling equipment or humidity control (see accessories handbook) the user can design experiments to follow the change of mechanical properties triggered externally.

Stretching of plastic Parafilm slide (typically film of 50:50 – Paraffin-wax and Polyolefin (Polyethylen). Using a JPK StretchingStage the sample was stretched about 75%. After stretching (4-6) the topography of the film changed dramatically, surface is softer and shows higher adhesion values than the untreated film (1-3).

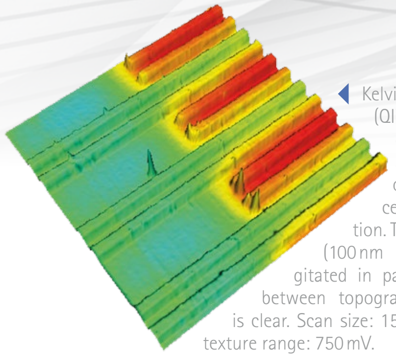
1 + 4 3D height image (z-range: 750 nm)
2 + 5 Young´s modulus image (range: 400 MPa)
3 + 6 Adhesion image (150 nN)

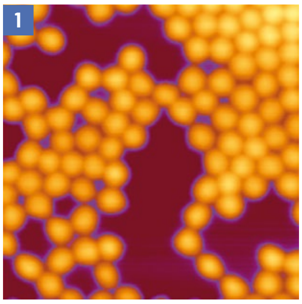
Scan size: 9 µm × 9 µm

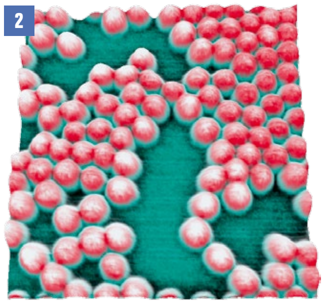


QI™ MODE COMBINED WITH HIGH PERFORMANCE CONDUCTIVE AFM, EFM AND KPM

Electrical characterization of objects, which are weakly attached to the surface or fragile has always been a challenge when using standard AFM imaging modes. Following this conventional technique, a multitude of errors may occur, including movement of the tip, the objects of interest, or lateral forces or vertical forces exceeding the limit to be acceptable for good results. This is especially the case for fragile samples such as conductive soft polymers, organic photovoltaic materials (OPV), conductive nanotubes, or delicate nanocomposites. QI™ mode eliminates lateral forces and exhibits controlled small vertical forces for controlled current flow making electrical experiments possible with a quality never reached before.







Electrostatic force microscopy (QI™-EFM) on NIPAM particles on silicon. 1 Height image (z-range: 90 nm) 2 Overlay of electrostatic force signal (color texture range: 15 mV) and 3D topography. Scan size: 4.5 µm × 4.5 µm. 3 3D ForceCube™ images, calculated at different distances between tip and sample. Sample courtesy of Prof. R. von Klitzing, TU-Berlin, Germany.

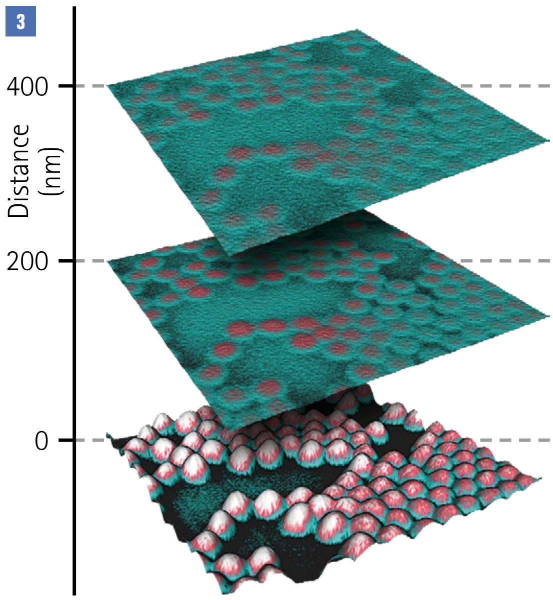
POWERFUL CORRELATION OF TOPOGRAPHY, MECHANICAL AND ELECTRICAL DATA

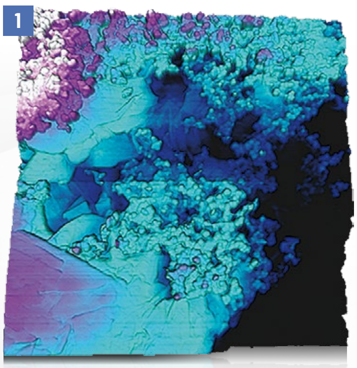
Multiparameter imaging is possible within one scan. The set of QI™ force distance curves offers nearly unlimited possibilities for analysis and post-processing. Electrical data can be directly correlated with topography or mechanical information to get, e.g., a better knowledge about edge effects, holes or layer defects in high resolution. This enlarges your perceptions and possibilities on sample analyses.

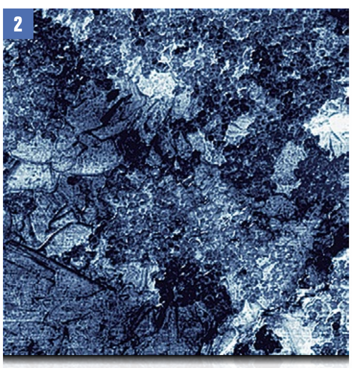
Kelvin Probe Microscopy (QI™-KPM) on an interdigitated electrode. 3D height image is overlaid with surface potential information. The raised electrodes (100 nm thick) are interdigitated in pairs, the separation between topography and potential is clear. Scan size: 15 µm × 15 µm, color texture range: 750 mV.

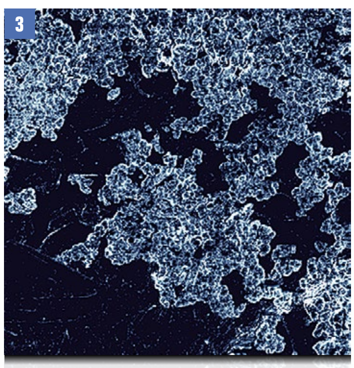
3D ForceCube™ – A NEW VIEW ON GRADIENT FIELDS

3D ForceCubes are a new way of visualizing of gradient fields. Electrical or magnetic fields or surface potentials are distance dependent. With the help of QI™-Advanced the relation between distances and forces can be easily measured within one scan and shown in a 3D ForceCube.









Conductive atomic force microscopy (QI™-CAFM) on battery electrode.
Scan size: 4.5 µm × 4.5 µm.

1 3D height image (z-range: 1 µm)
2 Adhesion image (range: 10 N/m)
3 Current image (range: 160 nA).

Sample courtesy of Prof. Dr.-Ing. A. Kwade, TU Braunschweig, Germany.

QI™ MODE BENEFITS

- Precise adhesion mapping
- Deformation information
- Accurate modulus data
- Dissipation information
- Chemical binding-site mapping
- Molecular recognition imaging

QI™ MODE

- Magnetic properties in 3D
- High-resolution conductivity mapping in 3D
- Electrical surface charge distribution mapping in 3D
- Easy cell imaging
- 3D ForceCube™ for vertical gradient mapping

JPK's proprietary Contact Point Imaging (CPI™) delivers true topography with zero forces, especially for exact volume measurements

PERFECT RESULTS WITH LEADING QI™ TECHNOLOGY FOR BEGINNERS AND EXPERTS

- Linear ramp motion of the probe relative to the sample instead of sinusoidal guaranties true quantitative data
- Lowest forces down to 10 pN acting on the sample due to JPK's TipSaver™ technology
- Ultra-robust and stable imaging over hours
- With QI™ you get rid of cantilever tuning, setpoint adjustment, and gain optimization, the system works autonomously
- Up to 5,000 lines per image possible
- Modulus range from sub-kPa to 100 GPa

QI™ mode comes with the NanoWizard® AFM as a standard. QI™-Advanced mode is an optional add-on software module for nanoscale material properties and can be easily upgraded.

GET THE QI™ ADVANTAGE

- High-resolution imaging in every sample environment especially for work in fluid
- Whole set of data with just "4 clicks"
- Non-destructive measurements due to zero lateral forces and lowest peak-forces
- Particularly great performance for soft, brittle, sticky, loosely attached samples
- Perfect mode for bacteria, cells and tissues
- Reliable data from topography to nanoscale sample properties
- QI™ and QI™-Advanced work with standard cantilevers

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