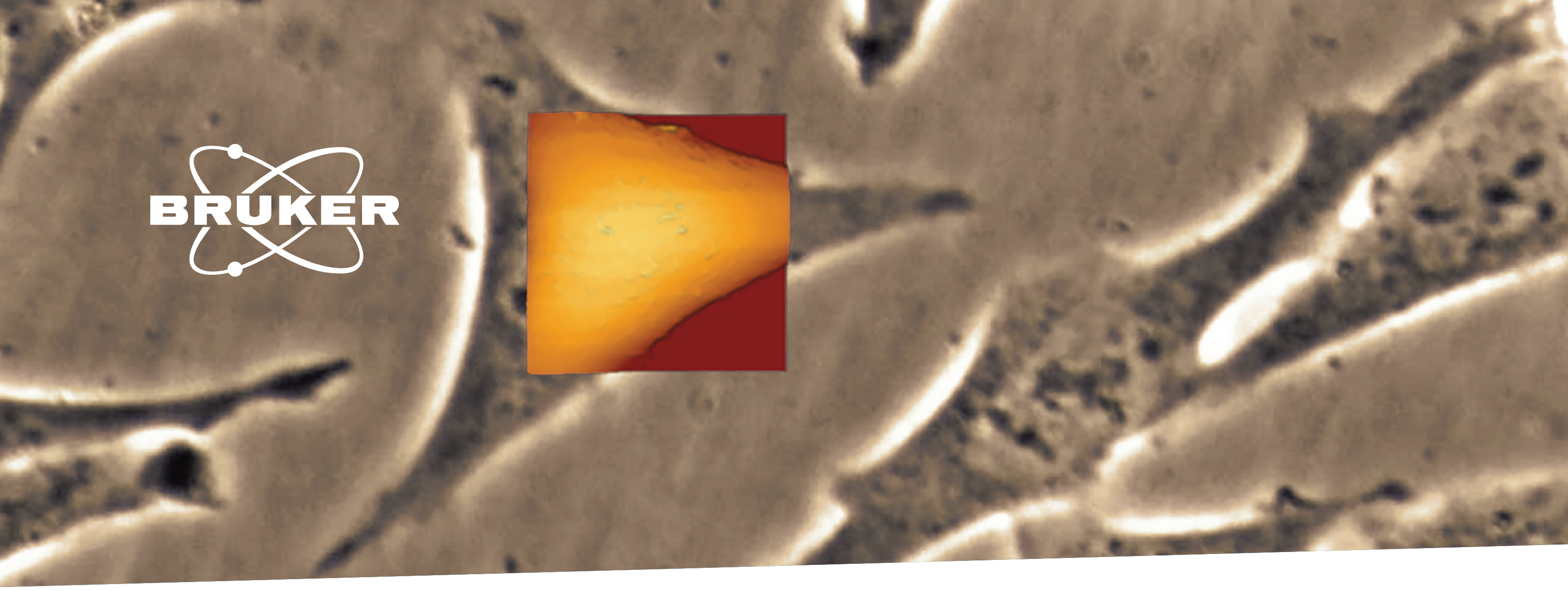


BIOAFM

ViscoDirect Software Module

Enhanced Analysis of Viscoelastic Behavior

Bruker's ViscoDirect software module for NanoWizard and CellHesion BioAFMs enables the automated, AI-assisted measurement of the viscoelastic properties of living cells, tissues, and soft matter. ViscoDirect extracts viscoelastic parameters from force-distance curves (FDCs) during an atomic force microscopy measurement to determine spatially resolved nanomechanical response across a sample.

Mapping Nanoscale Viscoelasticity

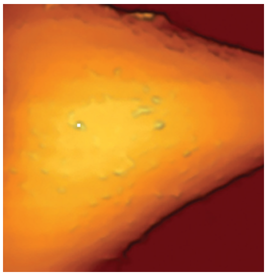
Biological samples and soft matter exhibit both elastic (solid-like) and viscous (fluid-like) behavior that determines how they sense and respond to mechanical forces. These viscoelastic properties play an integral role in such processes as morphogenesis, tissue formation, and metastasis.

Atomic force microscopy is a high-resolution, multiparametric, 3D imaging technique that quantifies the nanomechanical properties of samples. Viscoelastic matter exhibits distinct loading and unloading profiles during force measurements. Now, Bruker's ViscoDirect module extends a system's capabilities to include fast, automated measurement of a sample's elastic modulus and fluidity (viscosity), while accounting for sample thickness and force indentation.

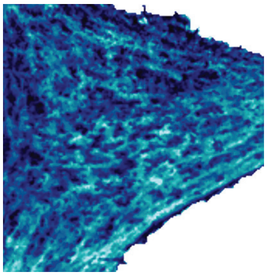
Only ViscoDirect delivers:

- Immediate viscoelastic analysis and online results during measurement
- Automated, AI-assisted FDC analysis
- Viscoelastic parameters from new and existing data
- Fast, straightforward acquisition of viscoelastic properties with minimal experimental effort

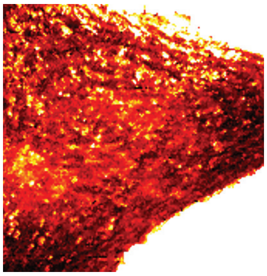
AFM contact point map shown as 3D topography (overlaid on optical phase contrast image in the header). Scan size 25 µm, Z-range 4.9 µm.



Scaling modulus map of a single cell derived using ViscoDirect analysis of the same scan region. Scan size 25 µm, Z-range 3 kPa.



Fluidity coefficient map of a single cell derived using ViscoDirect analysis of the same scan region. Scan size 25 µm, Z-range 0.4.



Modeling Viscoelastic Materials

The widely accepted power-law rheology (PLR) model uses only two parameters to describe the viscoelastic properties of soft materials:

E_0	Scaling modulus: the elastic modulus of sample at a time t_0
γ	Fluidity coefficient: quantifies the viscous response of the material. $\gamma = 0$ represents an elastic solid with Young's modulus E_0 $\gamma = 1$ represents a Newtonian liquid with viscosity $\eta_e = E_0\, t_0$

The relaxation function in power–law rheology is time dependent.

$$\Psi(t) = \frac{E_0}{\Gamma(1-\gamma)}\left(\frac{t}{t_0}\right)^{-\gamma}$$

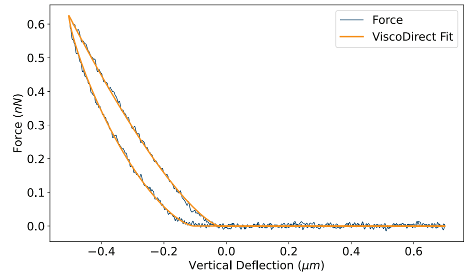
Bruker's proprietary* ViscoDirect fitting module significantly improves the speed and ease of BioAFM experiments in comparison to those using conventional fitting models. Using supervised machine learning (ML), it delivers faster, high-throughput results and enables automated analysis of complex viscoelastic materials during the measurement.[1,2]

Enabling a Diverse Range of Applications

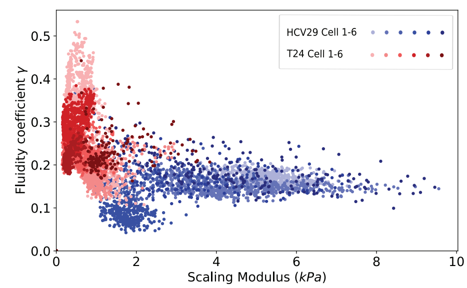
This validated fitting module uses ML regression to support a broad range of applications, including:

- Mapping of regional variations or mechanical gradients in samples with both liquid- and solid-like properties
- Determination of time-dependent behavior and viscoelastic response of hydrogels, polymers, gels, and colloids in soft matter physics
- Mapping of complex, multiscale cellular structures
- Identification of mechanical differences between healthy and cancerous or diseased cell lines
- Use of viscoelasticity as a label-free biomarker in predictive models of cell behavior

*Developed in collaboration with the group of Prof. R. Garcia and licensed from the Spanish National Research Council (CSIC).



FDC analysis with ViscoDirect: Representative force-distance curve acquired on a living cell, with the corresponding ViscoDirect model fit overlaid. The scaling modulus and fluidity coefficient are extracted by fitting the entire extend and retract movement.



Comparison of cell lines: Scatter plot of fluidity coefficient and scaling modulus as acquired on individual cells of different cell lines. Each point corresponds to a single force curve, and each color group represents a full map on a single cell.
Data courtesy of the group of Prof. M. Lekka, IFJ PAN, Poland.

References

1. The viscoelasticity of adherent cells follows a single power-law with distinct local variations within a single cell and across cell lines, Sanchez et al., *Nanoscale* 2021; 13: 16339–16348

2. High-Throughput Nanorheology of Living Cells Powered by Supervised Machine Learning, Tejedor et al., *Adv. Intell. Syst.* 2025; 7: 2400867

Bruker Nano Surfaces and Metrology

Bruker Nano GmbH, Bruker BioAFM
Berlin • Germany

productinfo@bruker.com

www.bruker.com/BioAFM