Mass and viscoelasticity of single cells

Dr. Marco Portalupi, Nanosurf AG
AFM – how does it work?

Scanner position is readjusted to maintain constant interaction strength.

Feedback controller aims at maintaining constant interaction strength.

Change in interaction is detected.

Tip-sample interaction.

Data visualization and instrument control.

Software.
CleanDrive photothermal excitation

Bio-compatible 785nm NIR laser source
No "forest of peaks" in any environment
Reliable automatic tuning
Ultra stable excitation
Secondary structure of dsDNA
DriveAFM as a table-top system...

Stage mounted on Isostage 300 active vibration isolation

...or on an inverted optical microscope

A variety of stages for different inverted optical microscope brands is available.
AFM + optical microscopy

Super-resolution techniques challenge AFM in the biosphere

Mechanical interaction → other insights than just structure
Mass measurements

Viscoelasticity measurements
Mass measurements of single yeast cells

Advancing the original technology

Increasing mass resolution, improving optical microscopy

Cuny, Sapra, Martinez-Martin, Fläschner et al., Nat. Commun. 2022
Mass measurements of single yeast cells

Two measurement modes:

• Continuous mode
• Sweep mode
Mass measurements of single yeast cells

Increasing mass resolution
Mass measurements of single yeast cells

Increasing mass resolution, improving optical microscopy
Single budding yeast cells (S/G2/M phase) increase total mass in multiple linear segments sequentially.

Viscoelastic measurements

Materials exhibit only elasticity

→ Reactive force: $F_{\text{elasticity}}$

→ All compression energy is stored

→ From $F_{\text{elasticity}}$ and probe geometry: $E_{\text{Youngs}}$
Viscoelastic measurements

Materials exhibit elasticity and internal friction

→ Some energy is stored, some lost
→ Two force components: $F_{\text{elasticity}}$ and $F_{\text{friction}}$
→ Analogous to $E_{\text{Youngs}}$: $E_{\text{storage}}$ and $E_{\text{loss}}$
Calibration

Amplitude $A_{\text{free}}$ and phase $\phi_{\text{free}}$ characterize the cantilever behavior in absence of conservative and dissipative forces of the sample (i.e. stiffness and viscosity of the sample).
Characterization

Go in contact. Stay there. Modulate.

Using the same “driving” of the cantilever, the oscillation of the cantilever changes, characterized by its new amplitude $A_{\text{sample}}$, and phase $\phi_{\text{sample}}$. 
Calculation

Dynamic sample stiffness:

\[ k_{\text{sample}} = k_{\text{cantilever}} \left( \frac{A_{\text{free}}}{A_{\text{sample}}} - 1 \right) \]

Loss tangent:

\[ \tan(\delta) = \tan(\phi_{\text{sample}} - \phi_{\text{free}}) \]

→ Use contact models to extract \( E_{\text{storage}} \) from \( k_{\text{sample}} \)

→ With \( E_{\text{storage}} \) and \( \tan(\delta) \) get \( E_{\text{loss}} \)

*L.M. Rebelo et al. Soft Matter 10 (2014) 2141*
Acknowledgements

Biophysics lab, ETHZ, Basel
Prof. Daniel Müller
Dr. Nico Strohmeyer
Dr. Michele Nava
Dr. Laura Gonzales
Giulia Ammirati

Computational biology lab, ETHZ, Basel
Prof. Jörg Stelling
Dr. Andreas Cuny

School of Biomedical Engineering, University of Sydney
Dr. David Martinez-Martin

Nanosurf AG, Liestal
Dr. Jonathan Adams
Dr. Gotthold Fläschner
Hans Gunstheimer
Thank you for your attention

For more information visit or email us
www.nanosurf.com/DriveAFM
info@nanosurf.com

Follow Nanosurf on

[Social media icons]