

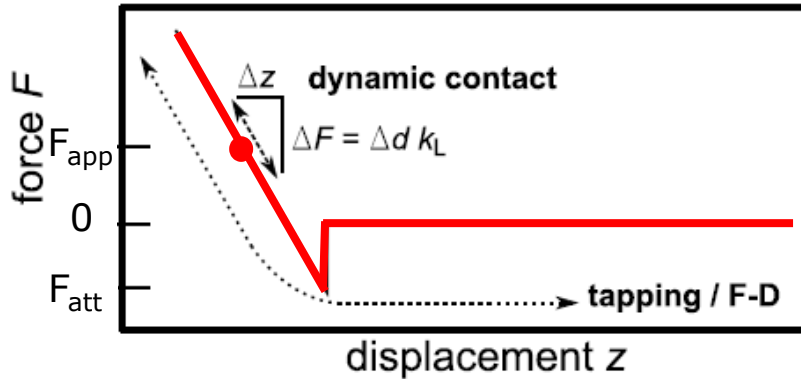
03.06.2019

EUSPEN Stakeholder Workshop „Micro-Probes“

FORCE DISTANCE CURVES (FDC) & CONTACT RESONANCE (CR) MEASUREMENT MODES FOR MECHANICAL PROPERTY MEASUREMENTS

Sebastian Backes, Brunero Cappella

Force Distance Curves (FDC) & Contact Resonance (CR)



Hurley, Killgore / Scanning Probe Microscopy in
Industrial Applications
First Ed., John Wiley & Sons

CR („new“) vs. FDC („established“)

CR advantages:

- Fast
- High lateral resolution
- Stiff materials (100s MPa to 100s GPa)

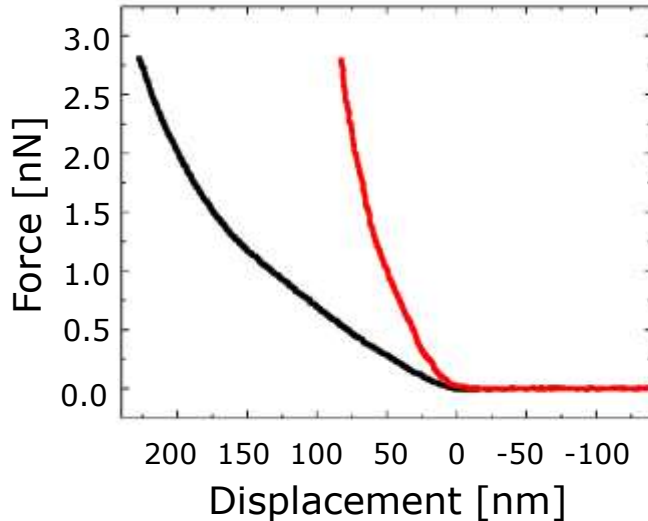
FDC advantages:

- High precision
- Analysis well understood
- Additional mechanical properties

Comparison: FDC & CR with identical cantilevers and samples

Stiffness:

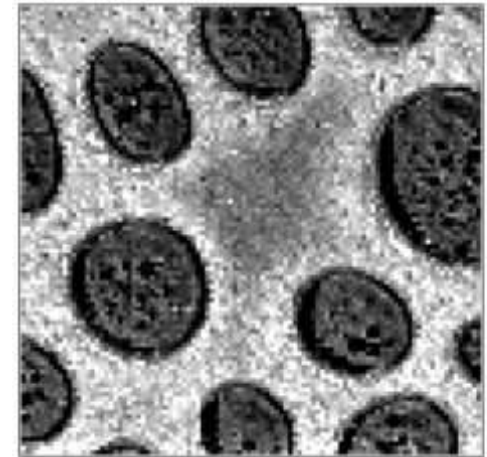
red stiffer than black



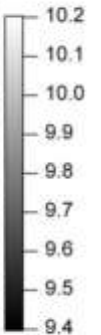
Models:

- Hertz (no adhesion)
- JKR (adhesion)
- DMT (adhesion)
- Maugis (adhesion)

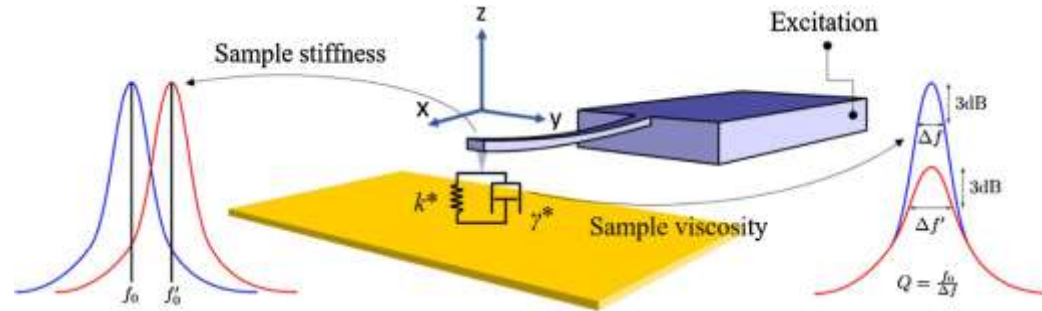
Force Volume



Elastic
Modulus
[GPa]



PS film on PnBMA



Bertke et al. / Sensors and Actuators A 279 (2018) 501

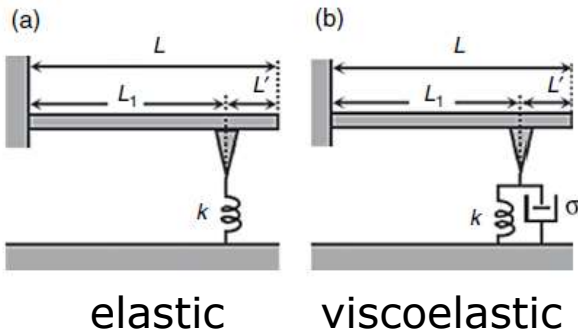
Measurement modes:

- Qualitative scanning
- Quantitative point measurements
- Quantitative scanning

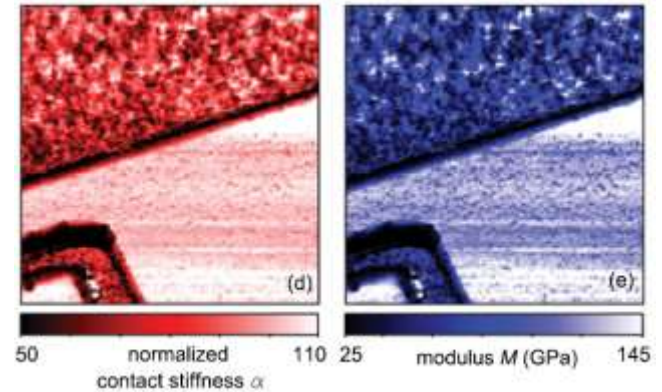
Quantitative CR Scanning

- Phase Locked Loop (PLL)
- Dual AC Resonance Tracking (DART)

Analysis:



- Frequency
- Contact stiffness
- Elastic modulus



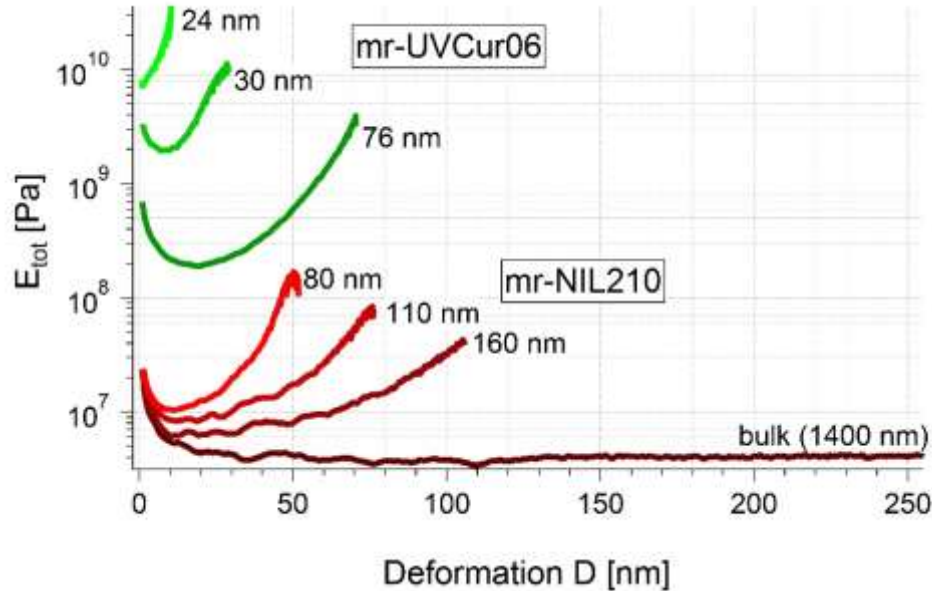
Nb Film on SiO₂

Hurley / Applied Scanning Probe Methods Vol. XI, Springer Verlag
Hurley, Killgore / Scanning Probe Microscopy in Industrial Applications
First Ed., John Wiley & Sons

Examples: FDC vs. CR

Samples of Photoresist with Thickness Variation

FDC:

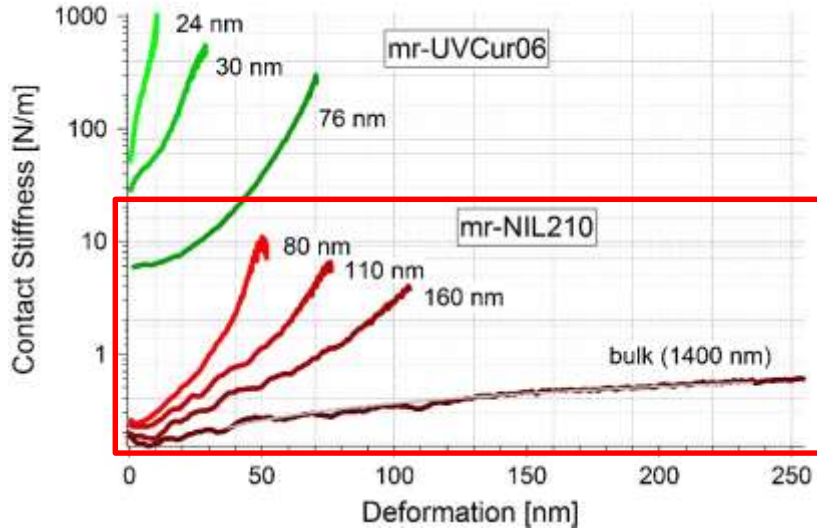


4 orders of magnitude!

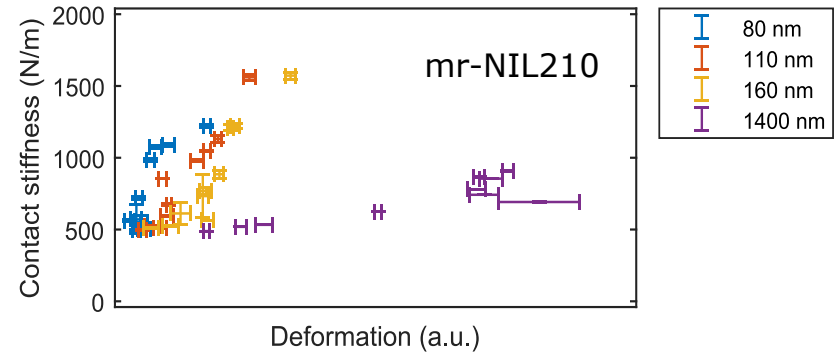
Examples: FDC vs. CR

Samples of Photoresist with Thickness Variation

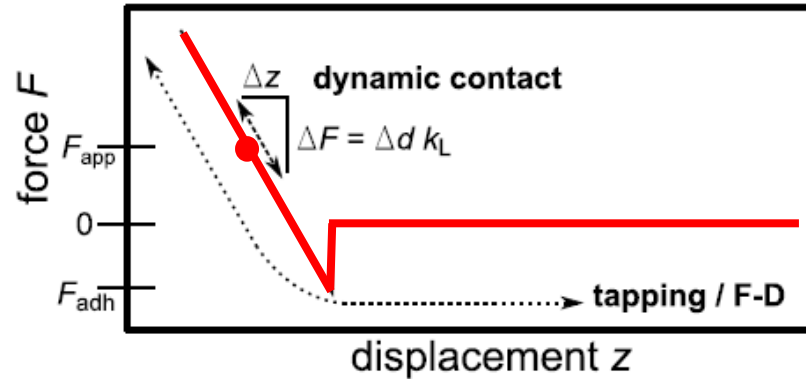
FDC:



CR:



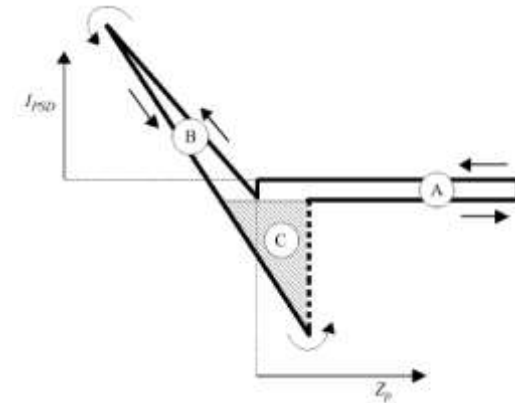
Qualitative agreement



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CR:
unclear

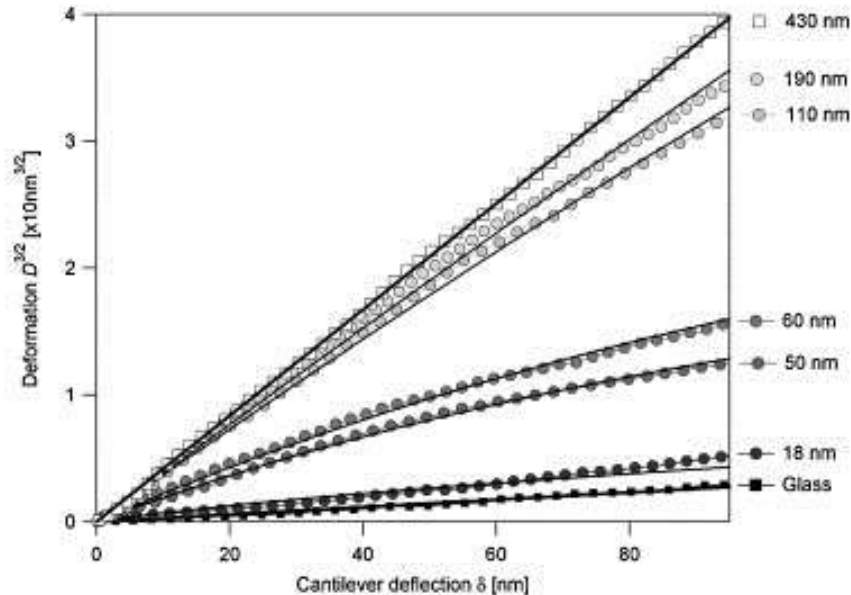
FDC:
precisely accessible



FDC - Detection of Coatings

Example: Thin Polymer Films on Glass

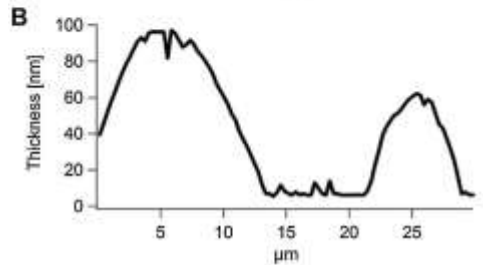
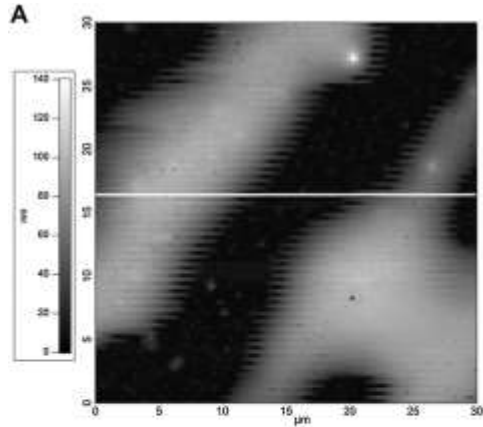
Determination of thickness using FDC



Silbernagl, Cappella / Scanning 32 (2010) 282

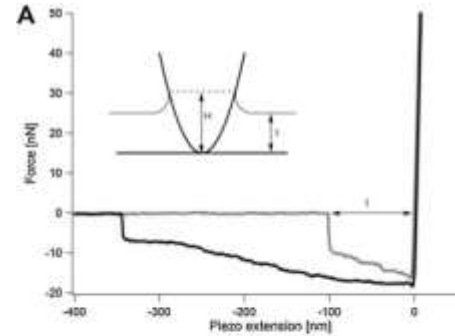
- **Bulk:**
Slope determined by polymer
- **Substrate:**
Slope determined by glass
- **Thin films:**
Polymer dominant for low deflection
Glass dominant for high deflection

FDC - Detection of Lubricants

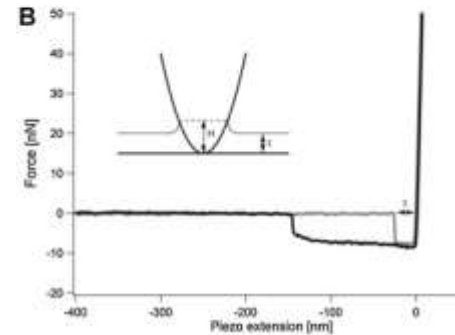


Cappella / Micron 93 (2017) 20

Thickness through total indentation

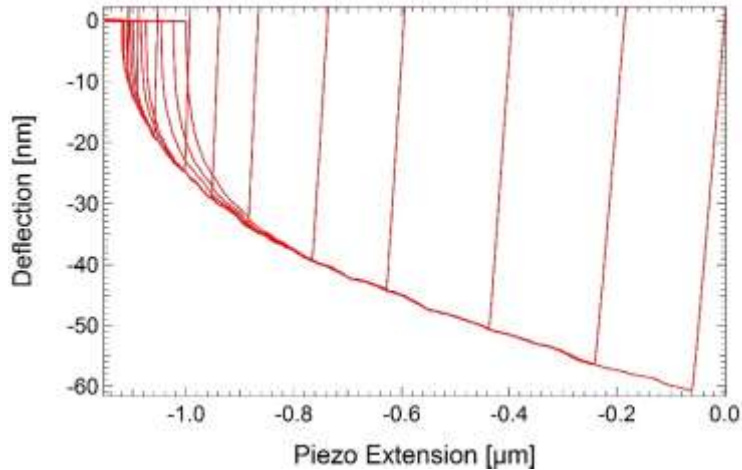


thick



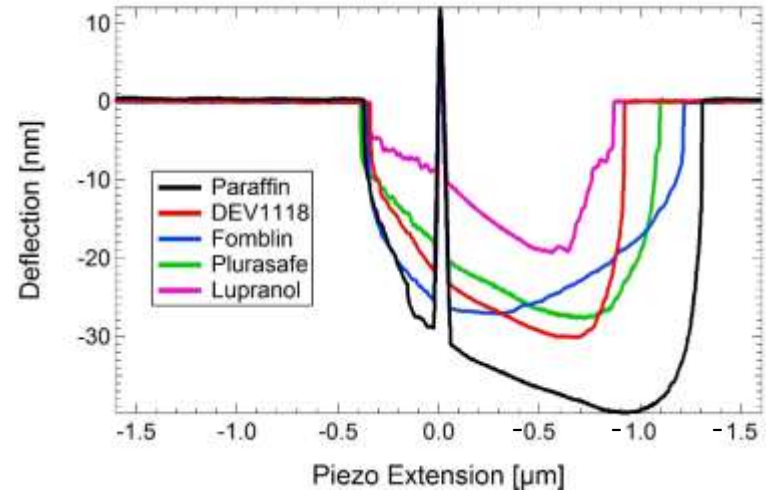
thin

Squalane films of varying thickness



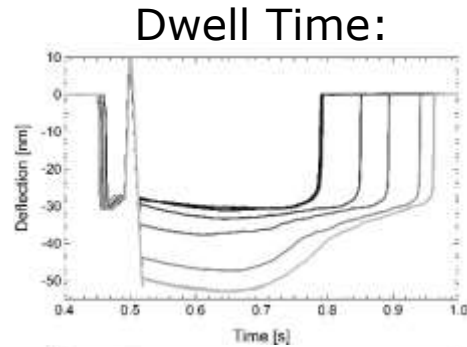
Overlapping curves
→ Shape determined by tip perimeter

Different lubricants



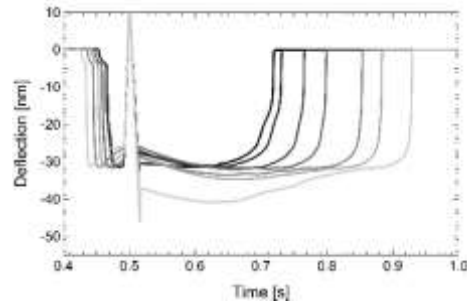
Shape determined by viscosity,
surface tension, binding energy
(adhesion)...

Low viscosity:



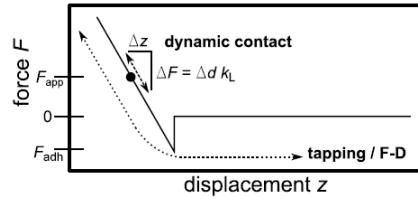
The lubricant climbs
up the tip

High viscosity:



Experiments for
distinguishing
properties

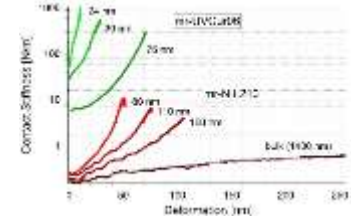
Conclusion



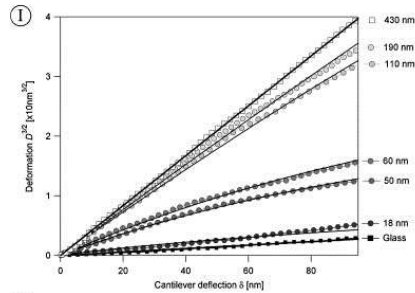
Comparison of FDC and CR on identical polymer samples

FDC:
more precise
better understood

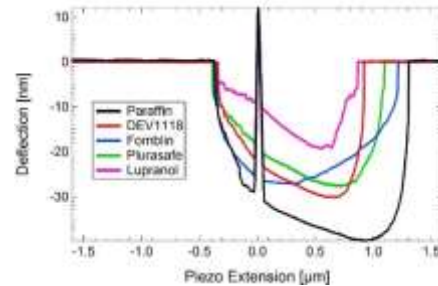
CR:
faster
higher lateral resolution



Applications:



coatings



lubricants