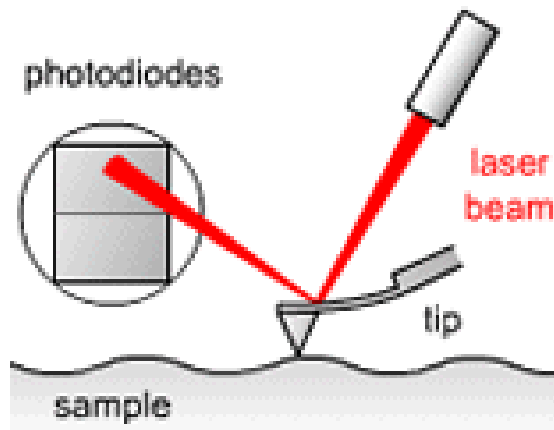


***Elastic fully three-dimensional  
microstructure scaffolds for cell force  
measurements***

**Clemens Franz**

Junior Research Group Nanobiology  
Center for Functional nanostructures  
Karlsruhe Institute of Technology  
19.01.2010

# Atomic force microscopy in cell biology

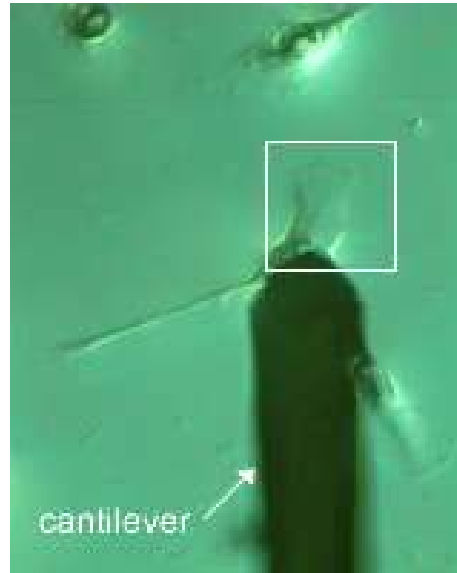


***Easy sample preparation:***

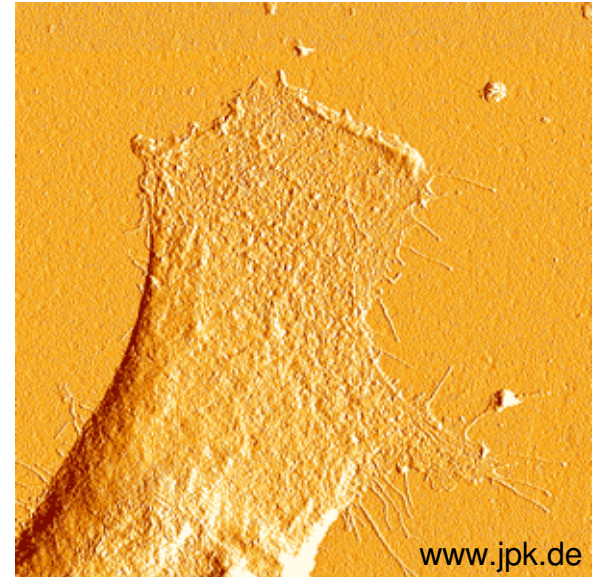
***No staining  
No cutting  
No coating  
No fixation  
No drying***

***Imaging under physiological conditions!***

# ***Combined AFM and optical microscopy***



**Light microscopy**

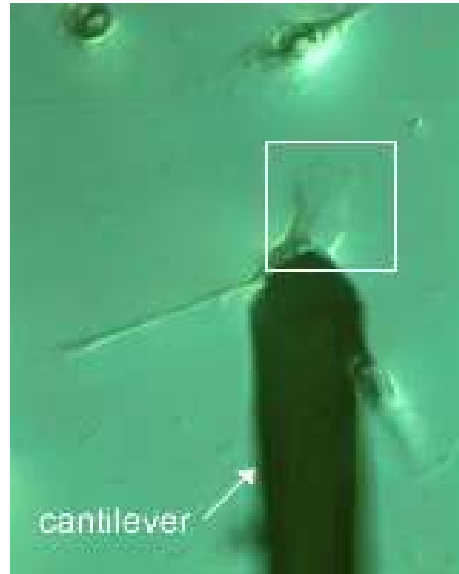


**AFM**

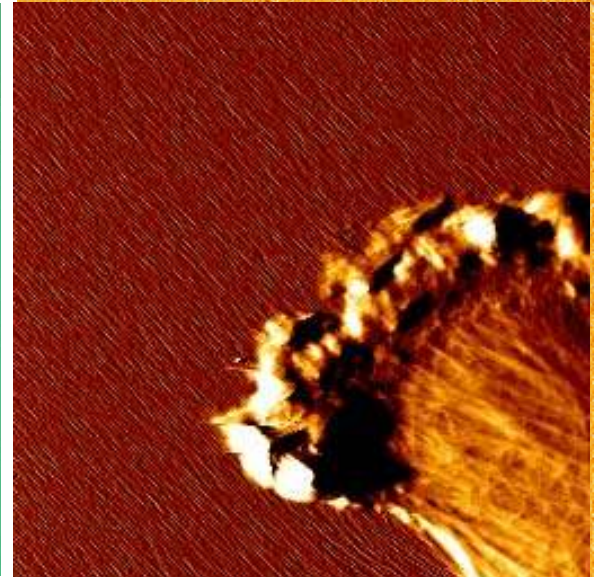


***Temperature control***

# ***Combined AFM and optical microscopy***



**Light microscopy**



**AFM**

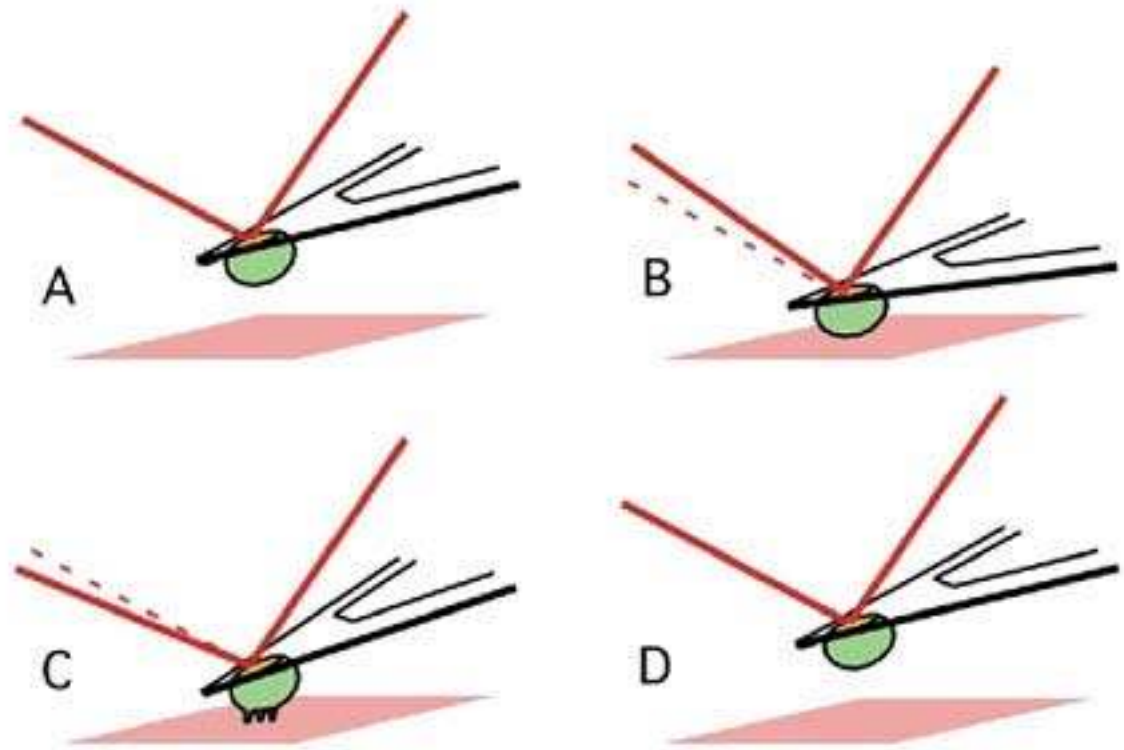
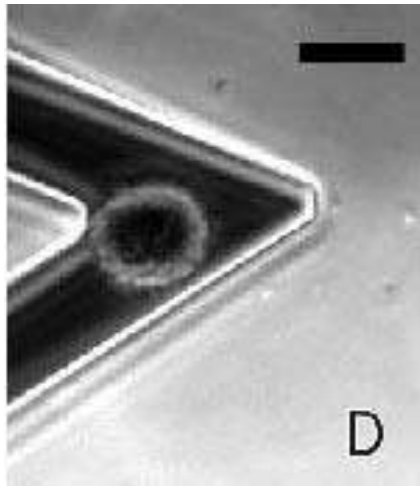


***Temperature control***

# *AFM-based single-cell force spectroscopy*

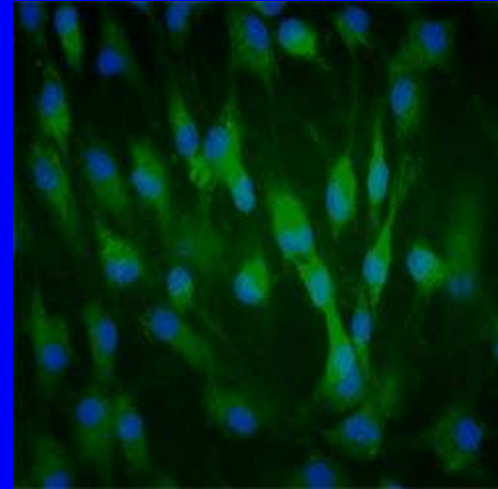


# *Cell attachment to a lectin-functionalized AFM cantilever*



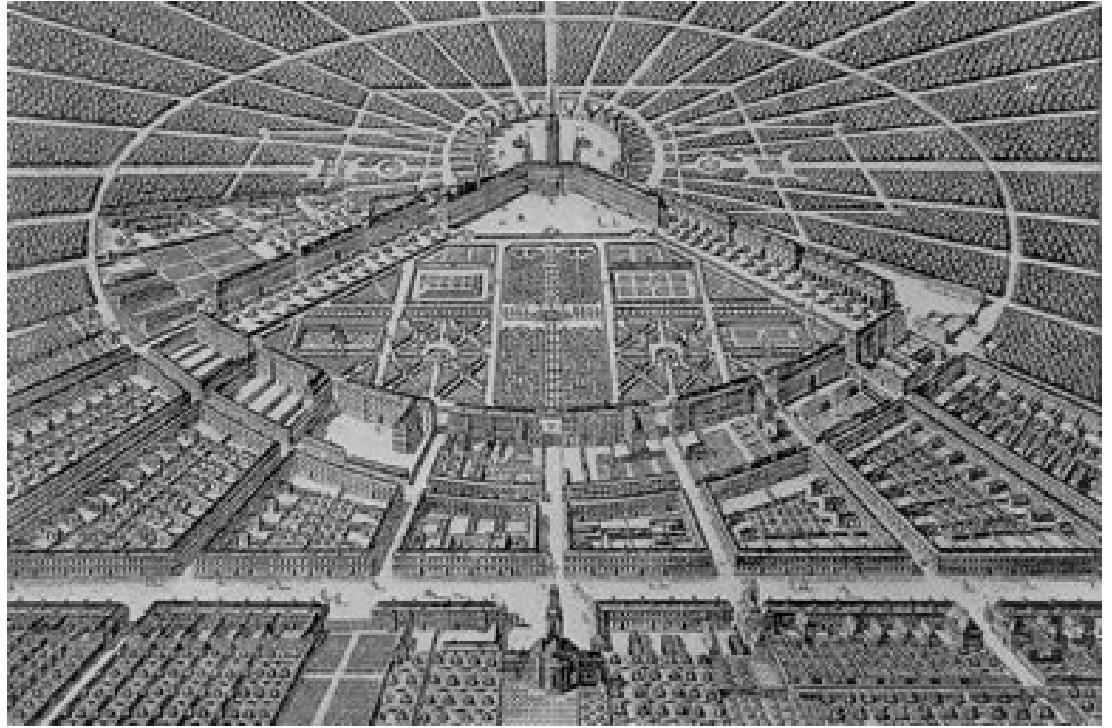
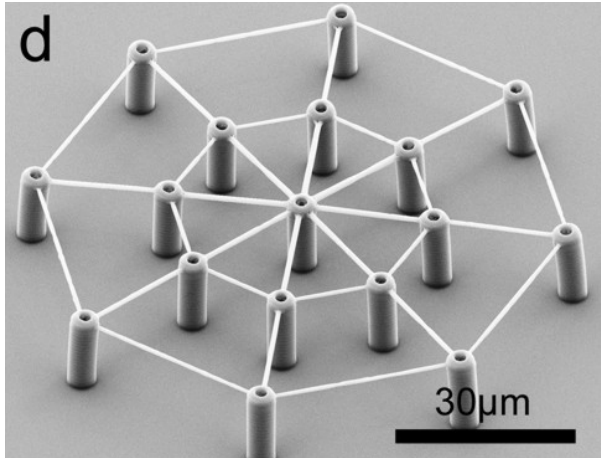
***Quantitating Cellular  
Contraction Forces***

# *Heart beat*



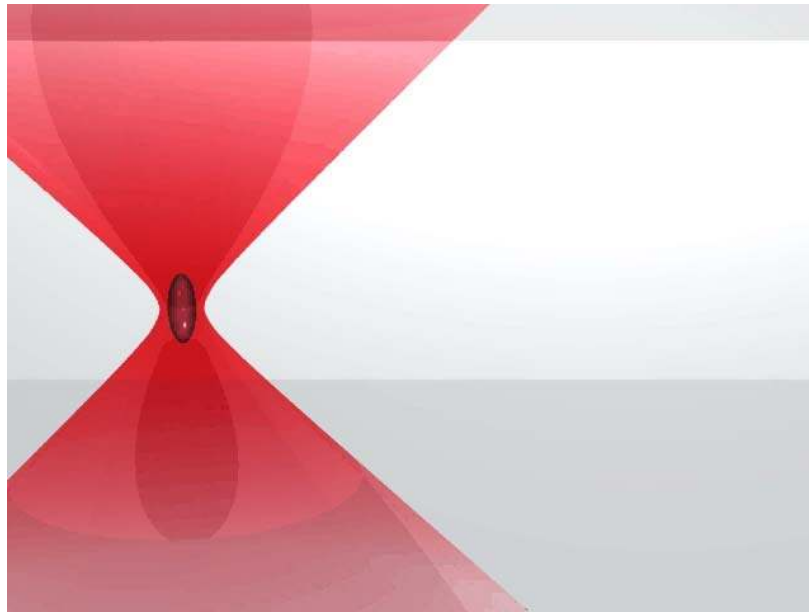


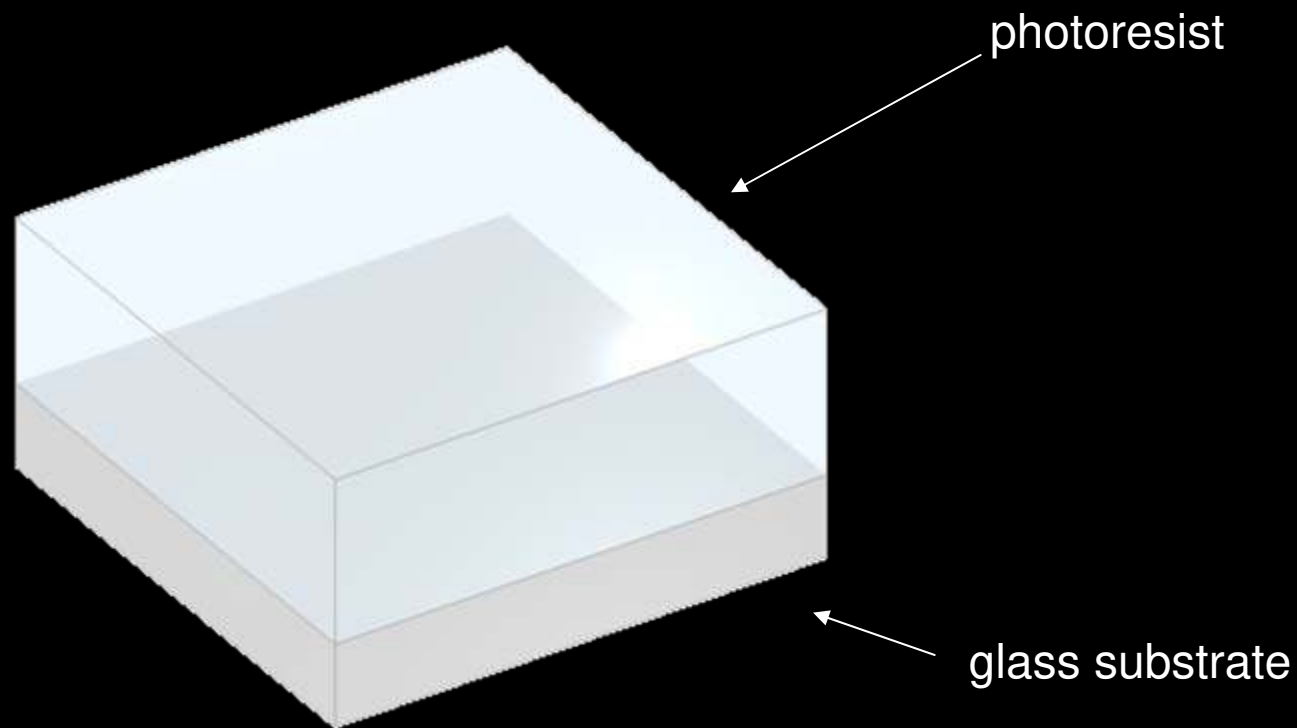
# ***Artificial cell scaffolds – the „Karlsruhe Wheel“***

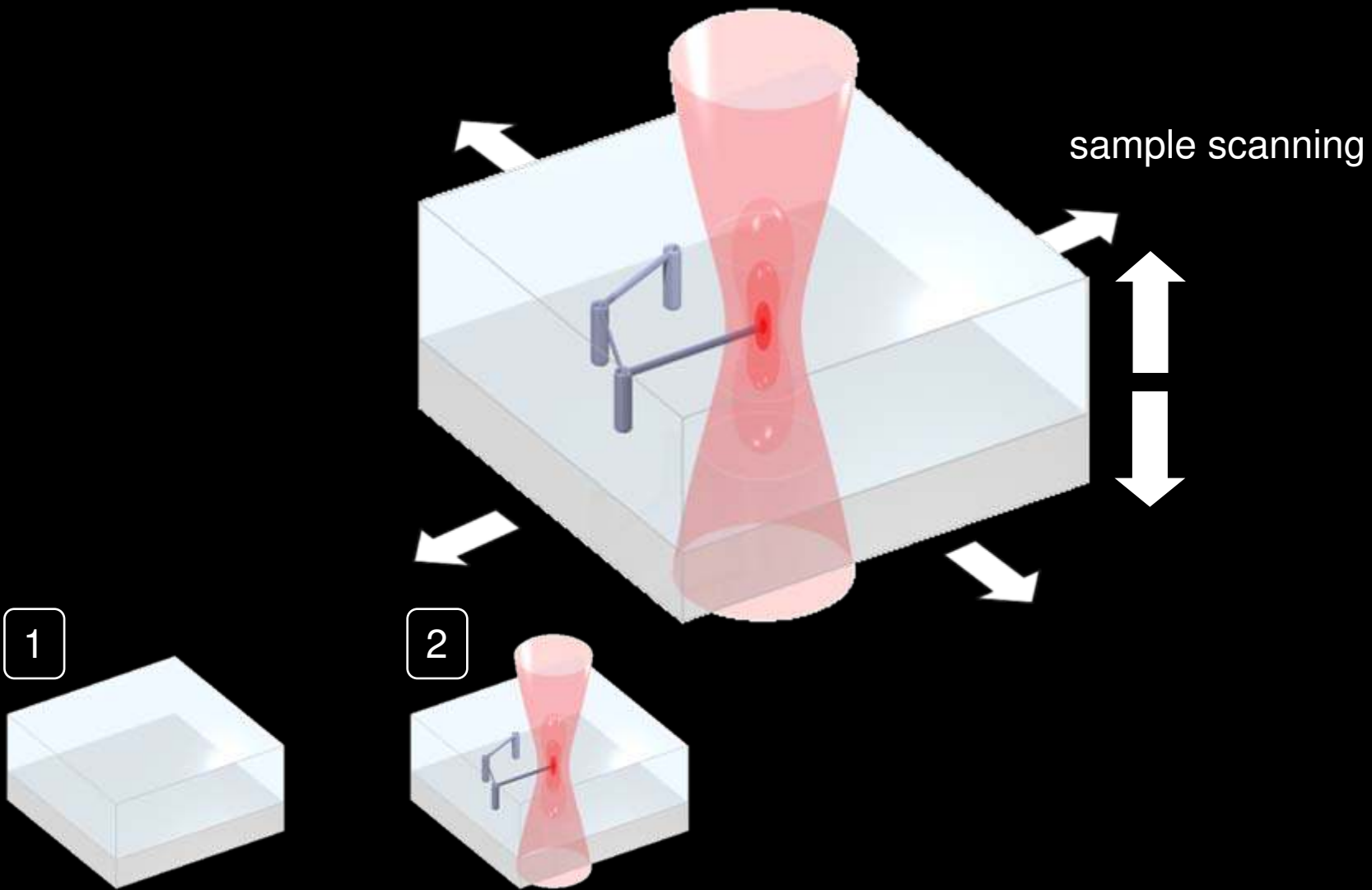


***Schloss und Stadt Karlsruhe***  
*Copper engraving Christian Thran, 1739*

# ***Direct laser writing (DLW)***

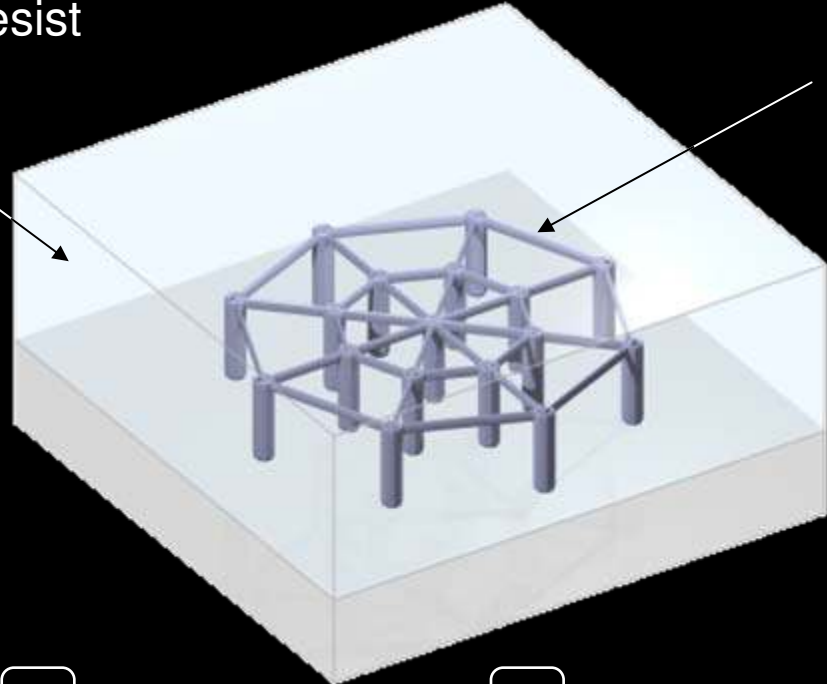






monomeric photoresist

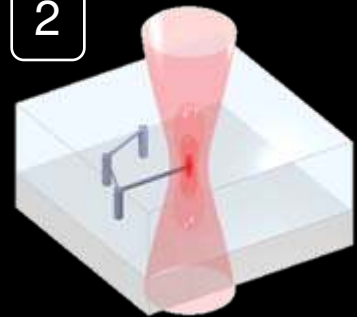
crosslinked polymer structure



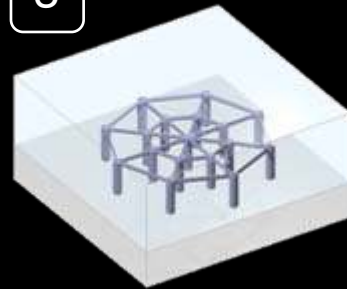
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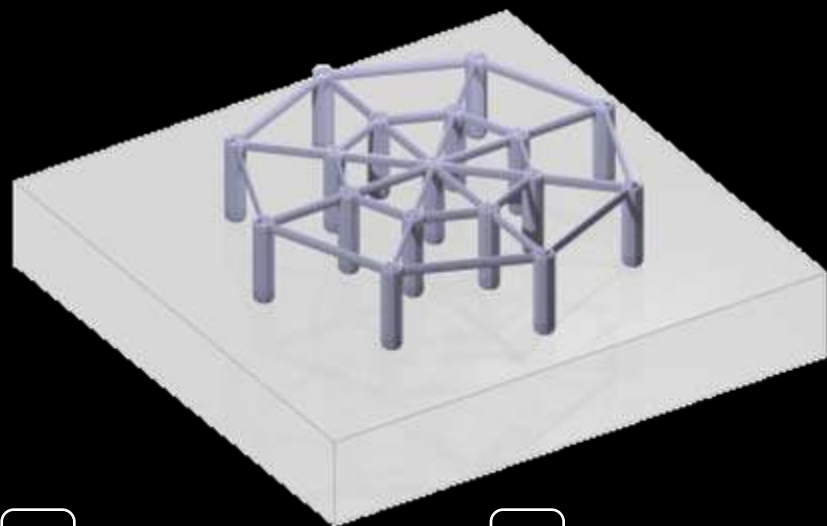


2



3

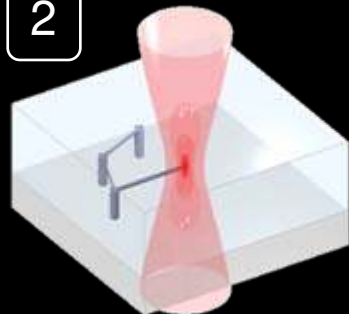




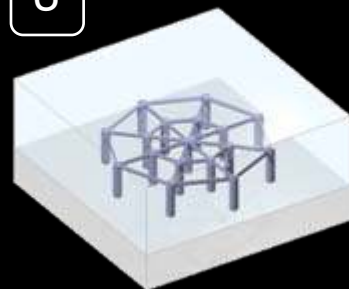
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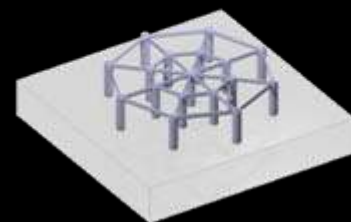
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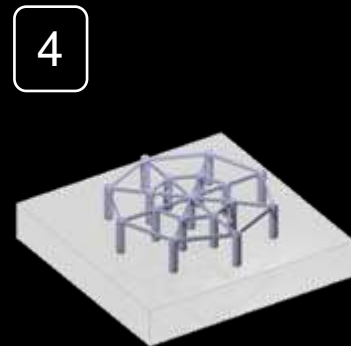
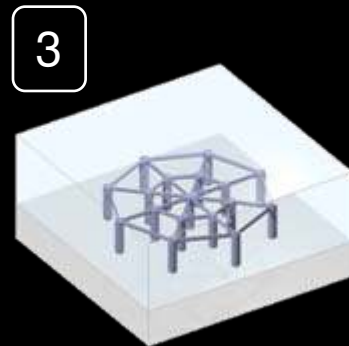
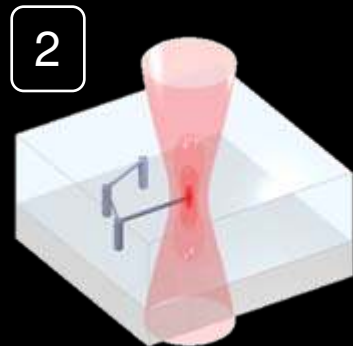
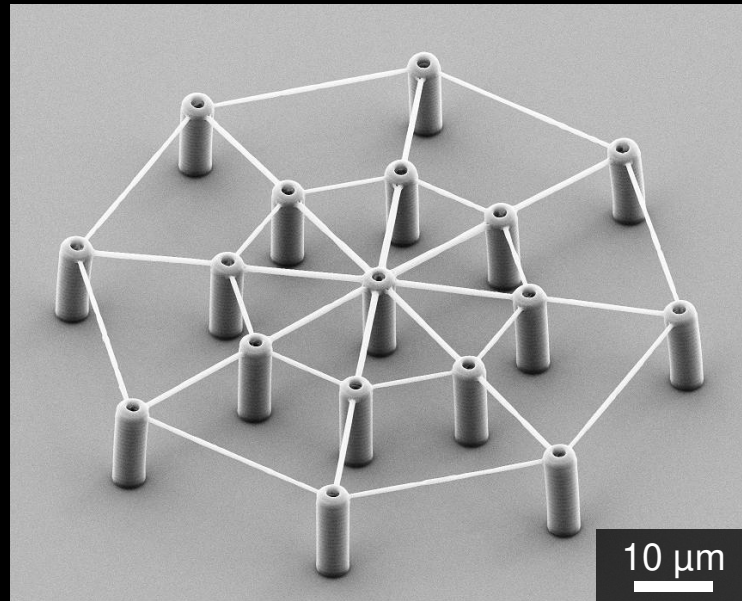


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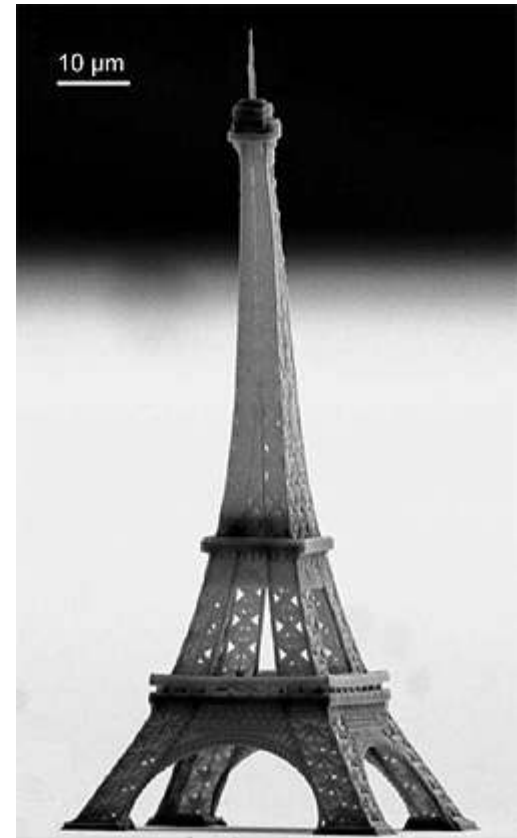
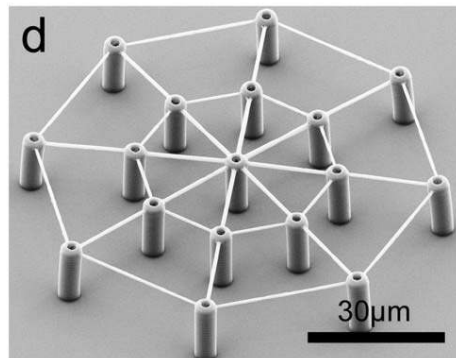
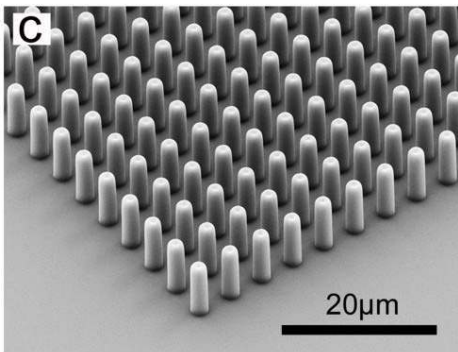
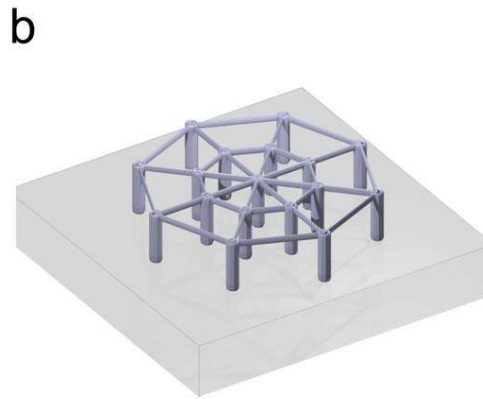
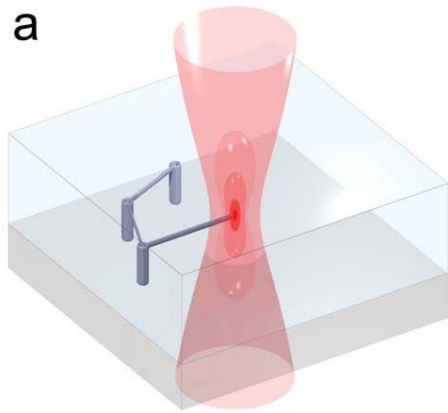


4





# ***Fabricating micro-structured cell culture substrates by direct laser writing (DLW)***



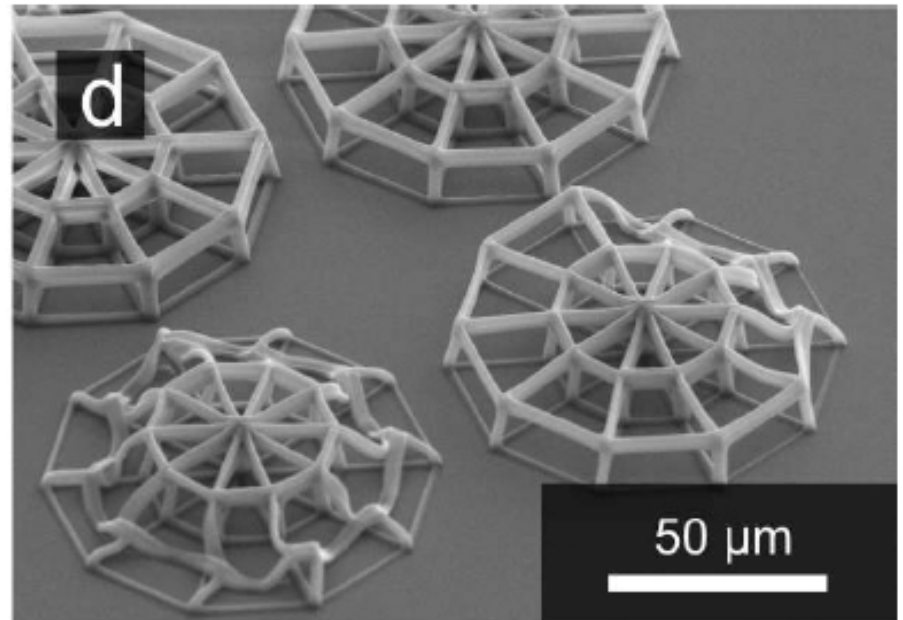
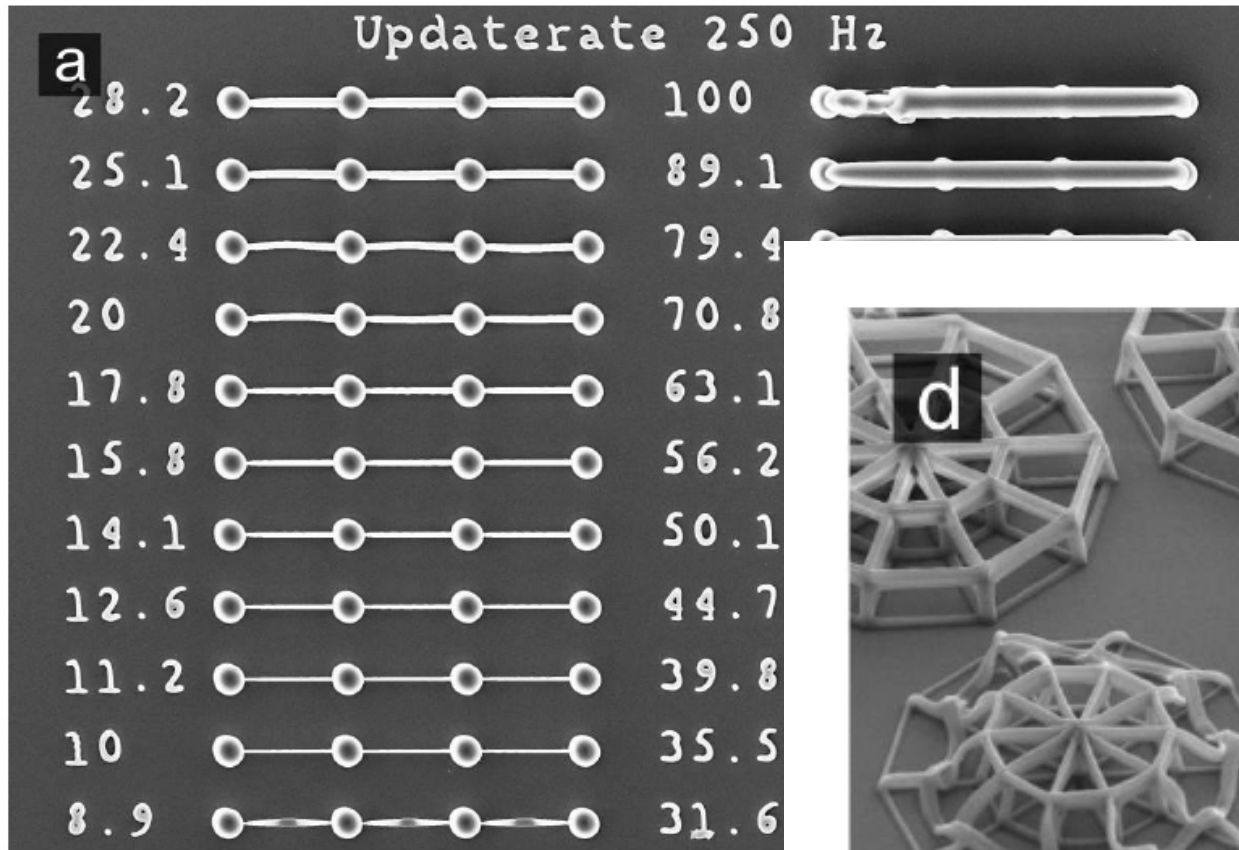
***AG Wegener  
AG von Freymann  
AG Bastmeyer***



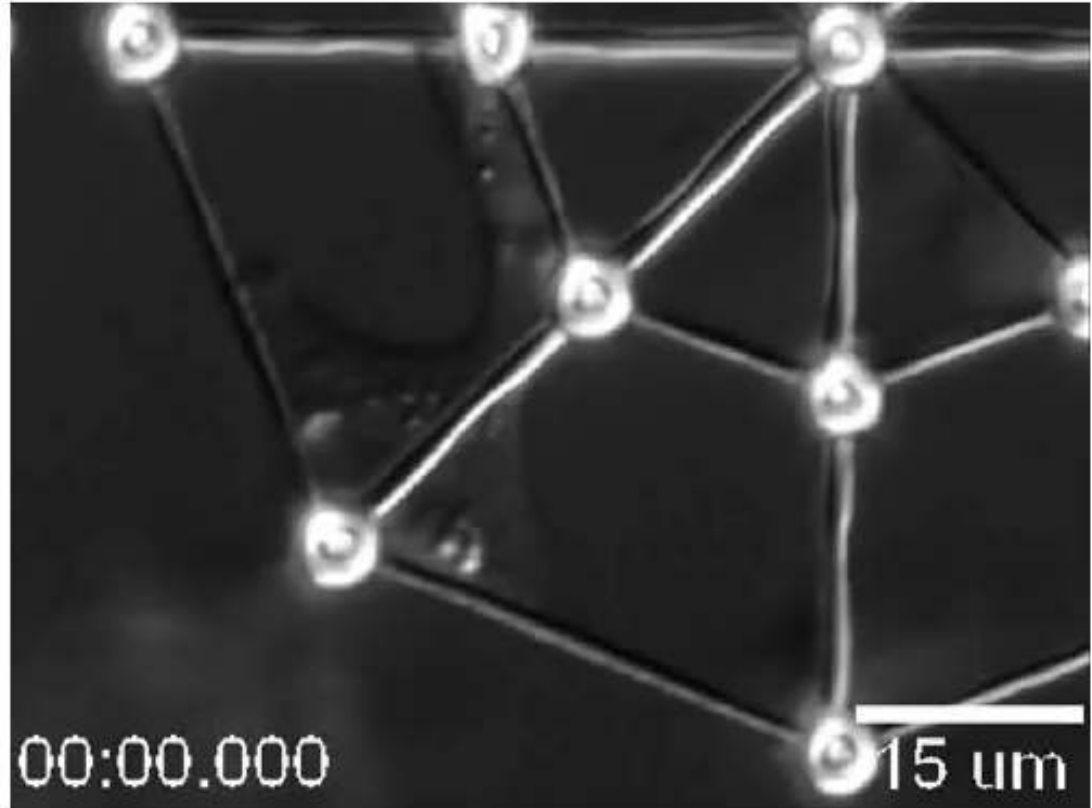
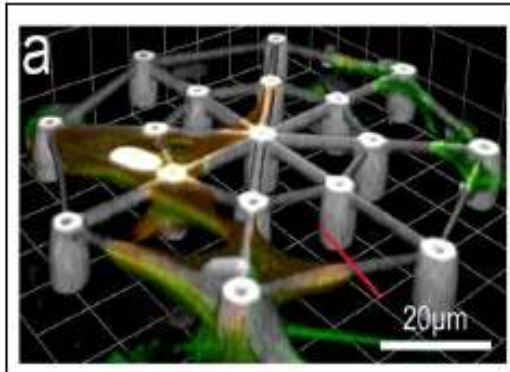
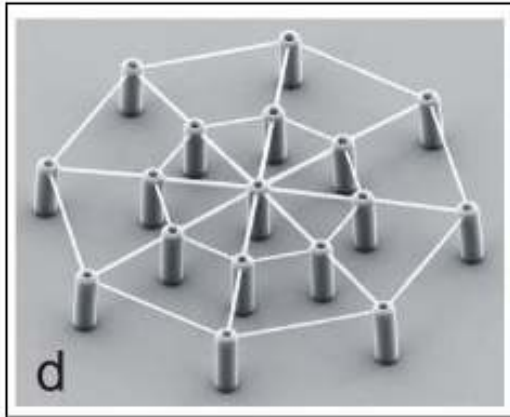
# *Nanoscribe™*



# *Changing the feature size by varying write speed and intensity*

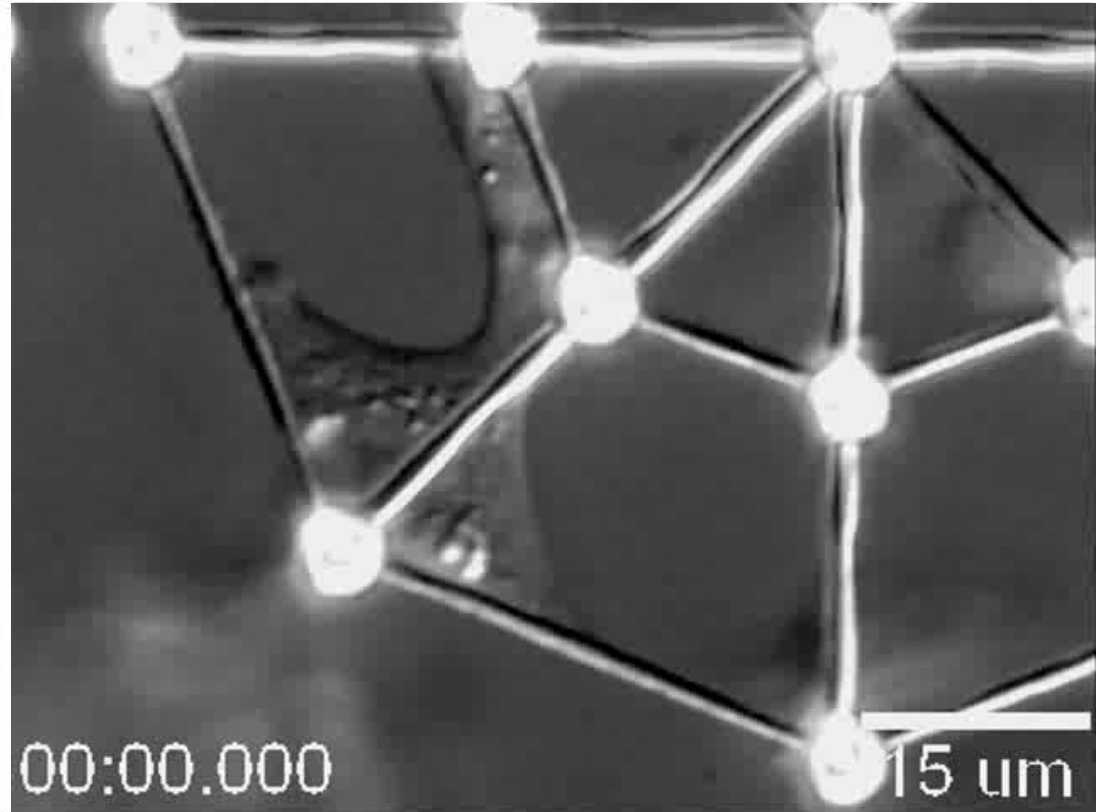
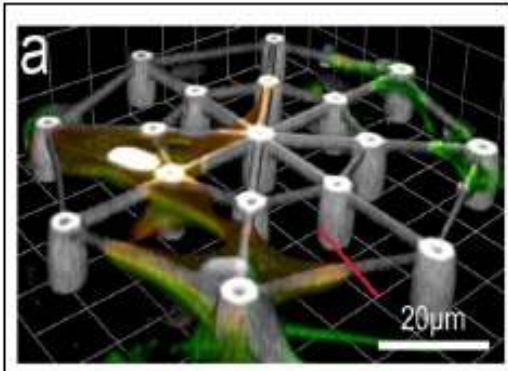
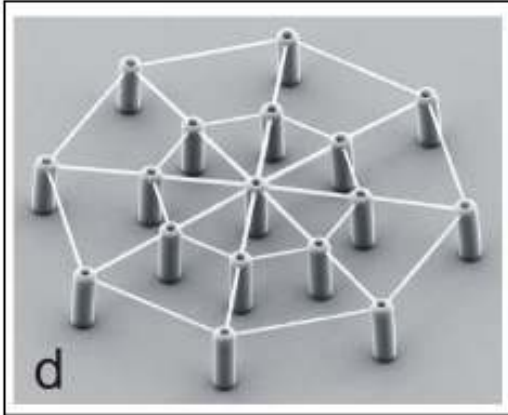


## ***Flexible 3D-substrates produced by direct laser writing***

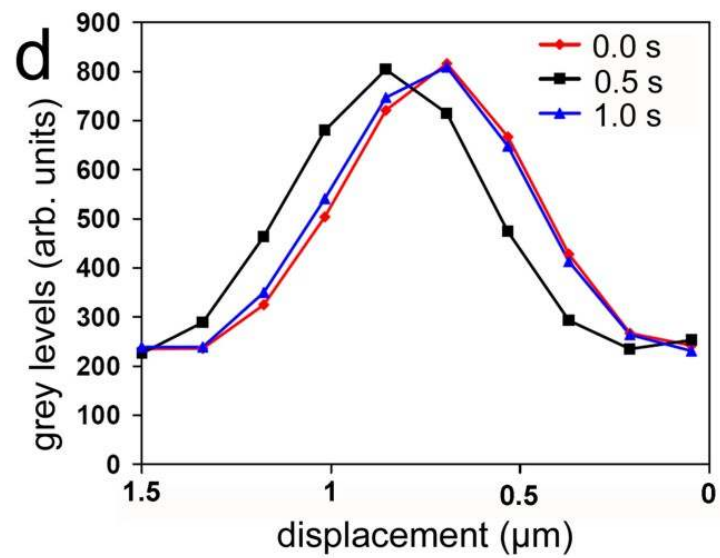
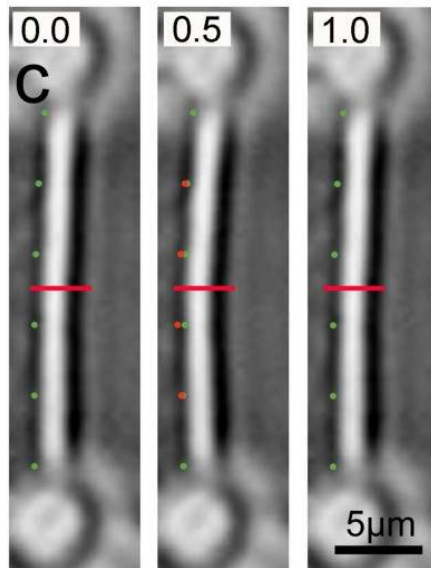
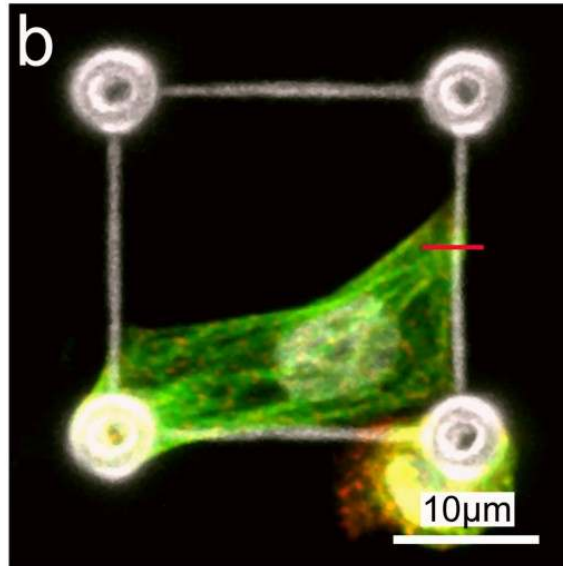
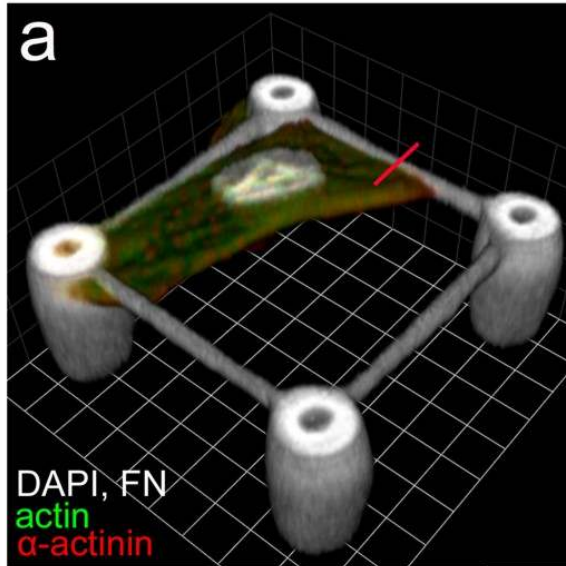


**ORMOCER®: Inorganic-organic Hybrid Polymer**

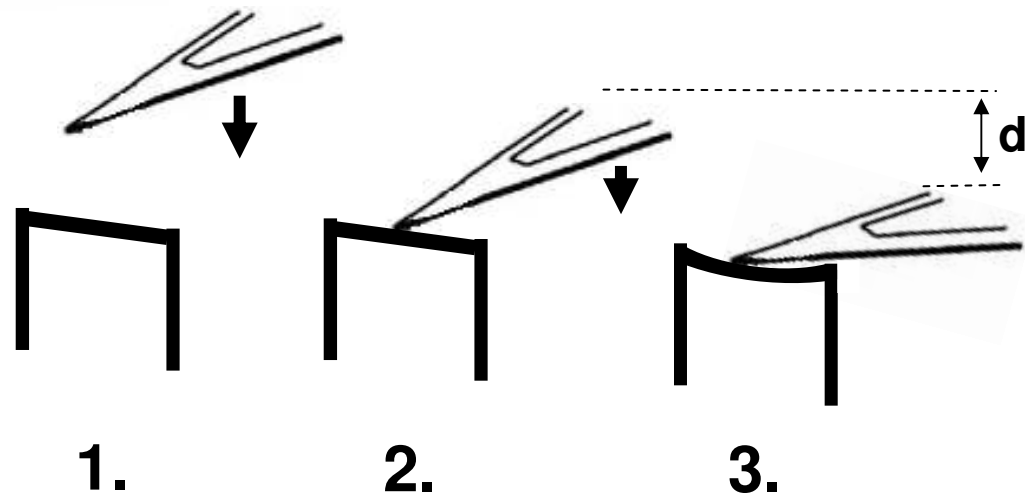
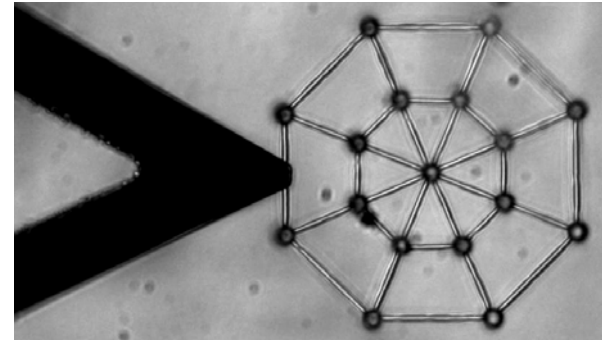
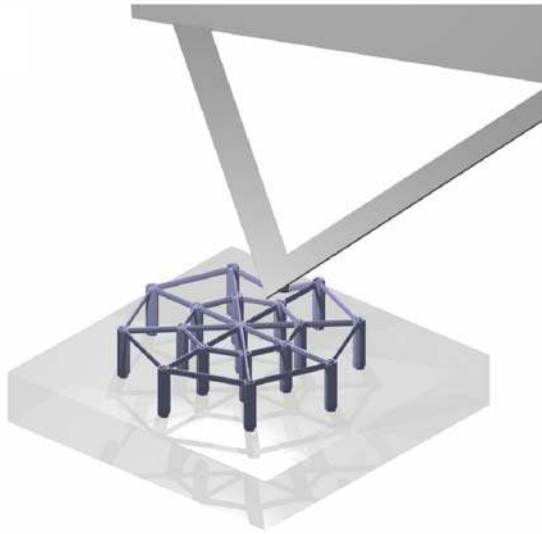
## ***Flexible 3D-substrates produced by Direct Laser writing***

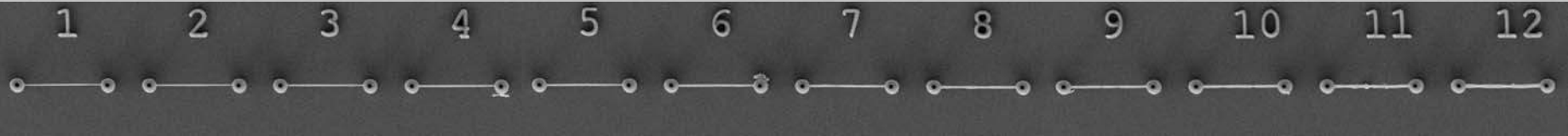


**ORMOCER®: Inorganic-organic Hybrid Polymer**



# *Testing the stiffness of flexible cell culture substrates Using AFM indentation measurements*

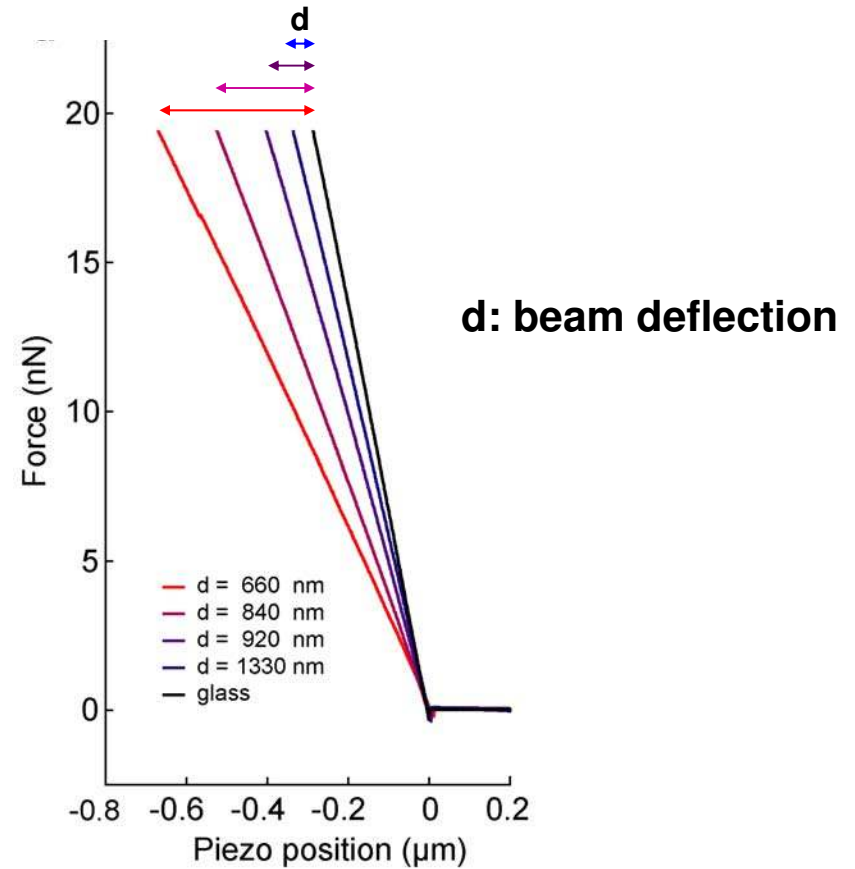
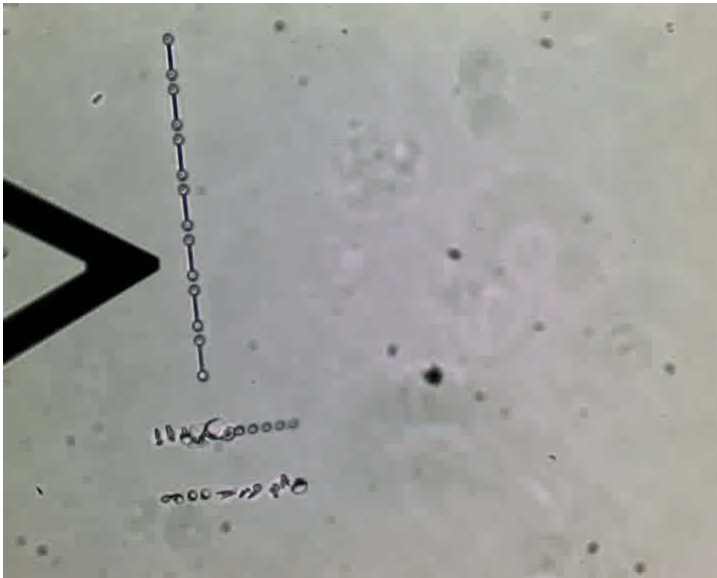




Beam diameter

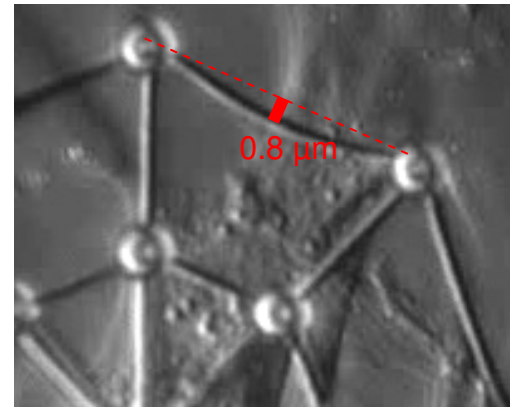
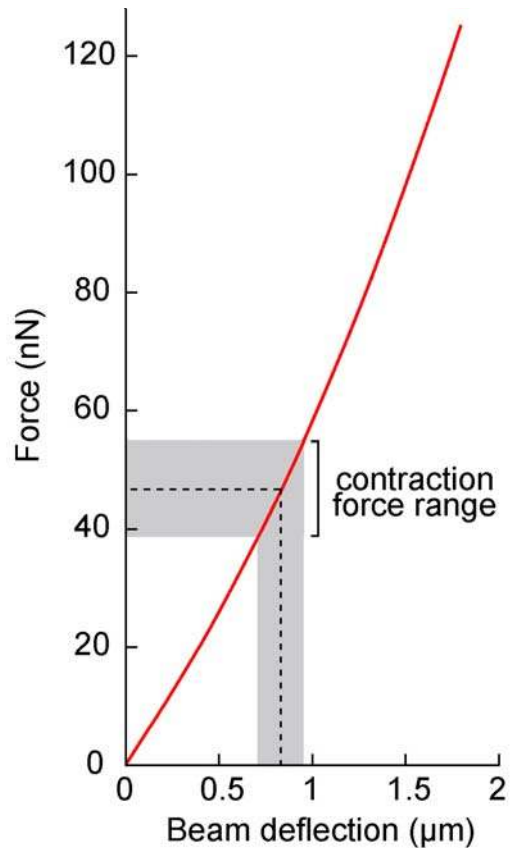
*Thomas Striebel  
Joachim Fischer*

# Testing the stiffness of flexible cell culture substrates to estimate cellular contraction forces





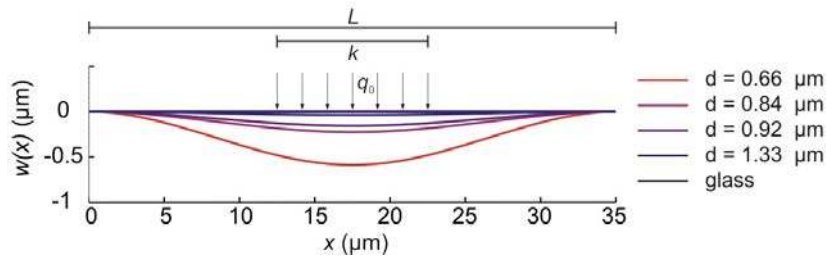
# ***Testing the stiffness of flexible cell culture substrates to estimate cellular contraction forces***



**➔ Cellular contraction forces: ~ 40 to 60 nN**

# Modelling beam bending lines

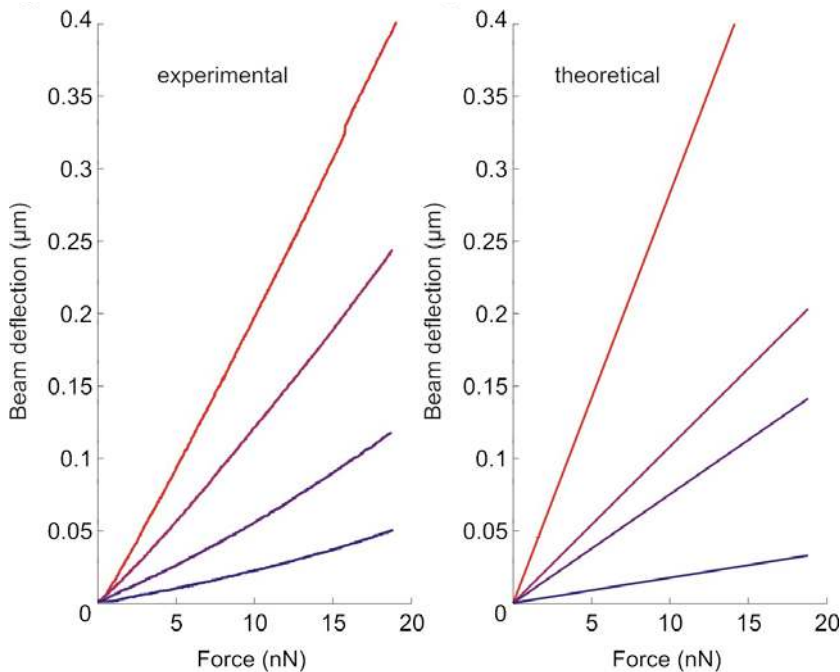
Theoretical beam bending lines at an area load of 20 nN



$$E \cdot I \cdot \frac{d^4}{dx^4} w(x) = q$$

$$E \cdot I \cdot \frac{d^4}{dx^4} w(x) = q_0 \cdot \left( \Theta\left(x - \frac{L}{2} + \frac{k}{2}\right) - \Theta\left(x - \frac{L}{2} - \frac{k}{2}\right) \right)$$

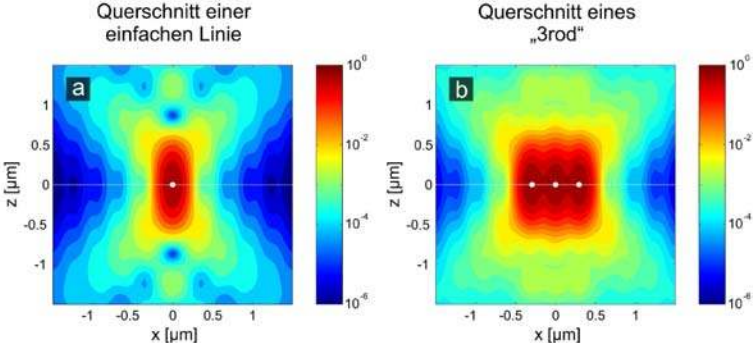
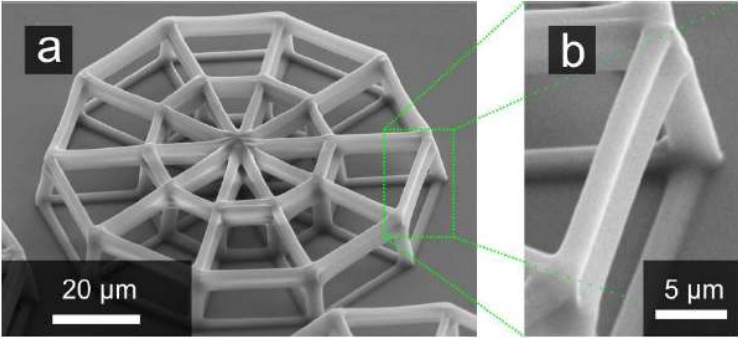
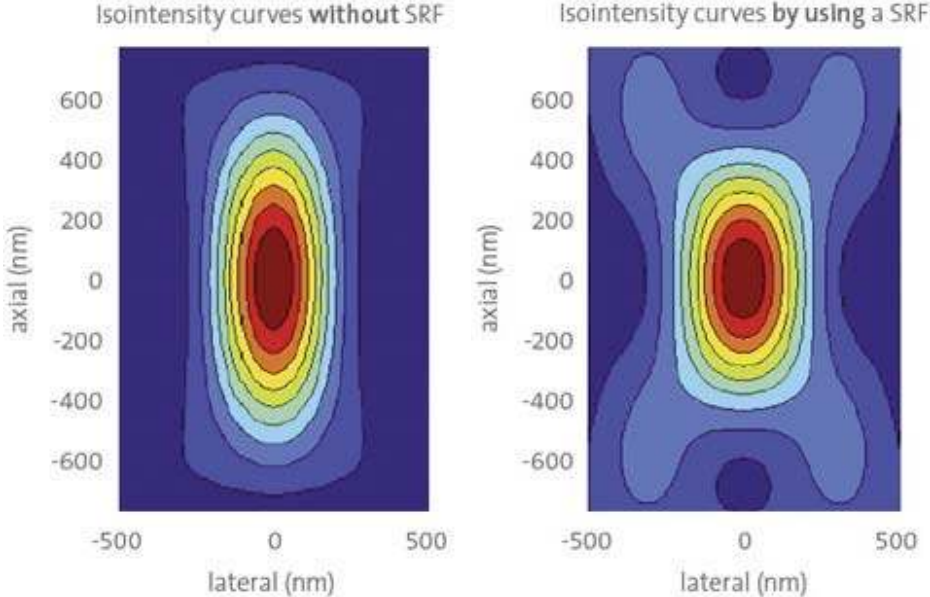
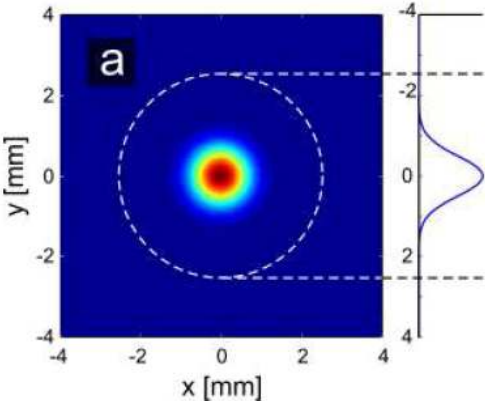
$$w(x=0) = 0 \quad w(x=L) = 0 \quad \frac{d}{dx} w(x=0) = 0 \quad \frac{d}{dx} w(x=L) = 0$$

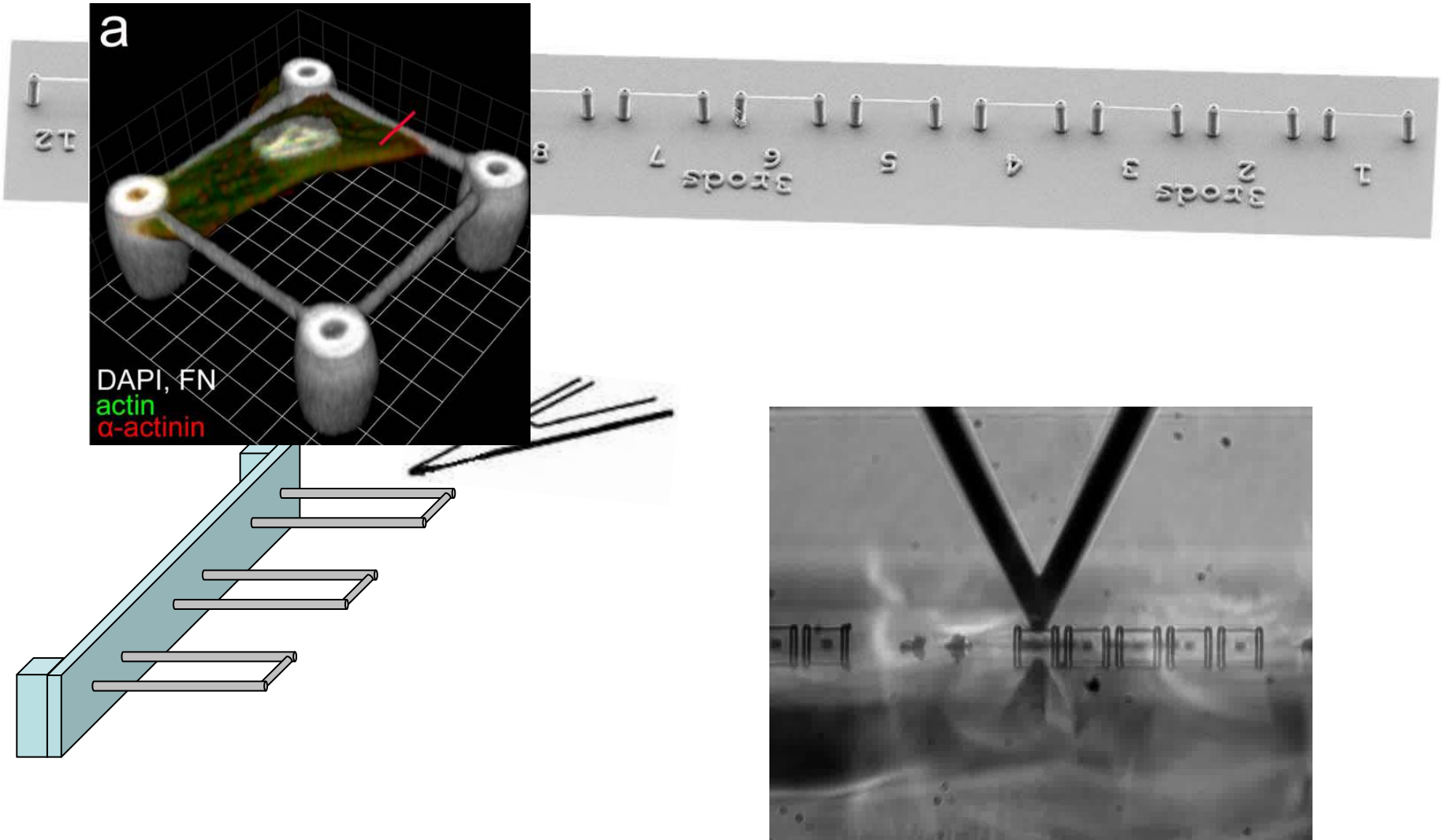


→ PDMS: ~0.02 to 0.3 MPa  
 Polyacrylamid: ~0.002 to 0.04 MPa  
 Ormocer: ~800 MPa  
 Glass: ~70 000 MPa

**$E \sim 800 \text{ MPa}$**

# Optimizing the beam profile





**Thomas Striebel**  
**Joachim Fischer**

Thanks to

Martin Bastmeyer

Martin Wegener

Georg von Freymann

Franziska Klein

Joachim Fischer

Thomas Striebel

Zhongxiang Jiang