



Wir schaffen Wissen – heute für morgen

Partielle Reflow-Technik für optische 3-D Mikrostrukturen

R. Kirchner and H. Schiff

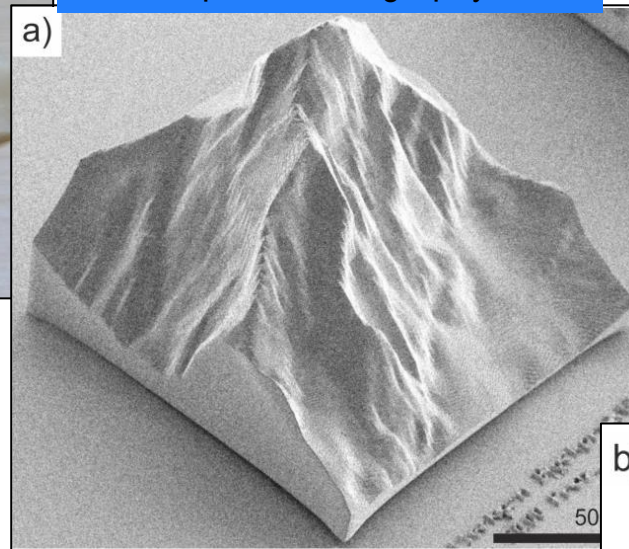
*Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut,
5232 Villigen PSI, Switzerland*

robert.kirchner@psi.ch

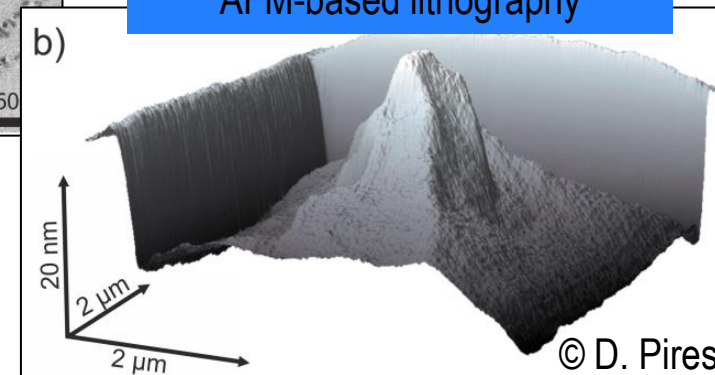
3D printing



2-photon lithography



AFM-based lithography

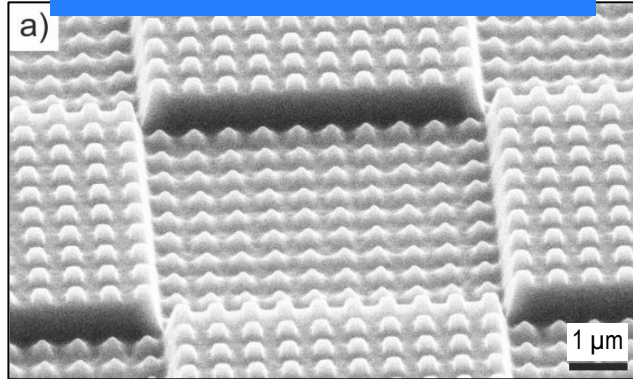


<http://www.thingiverse.com/thing:458775>

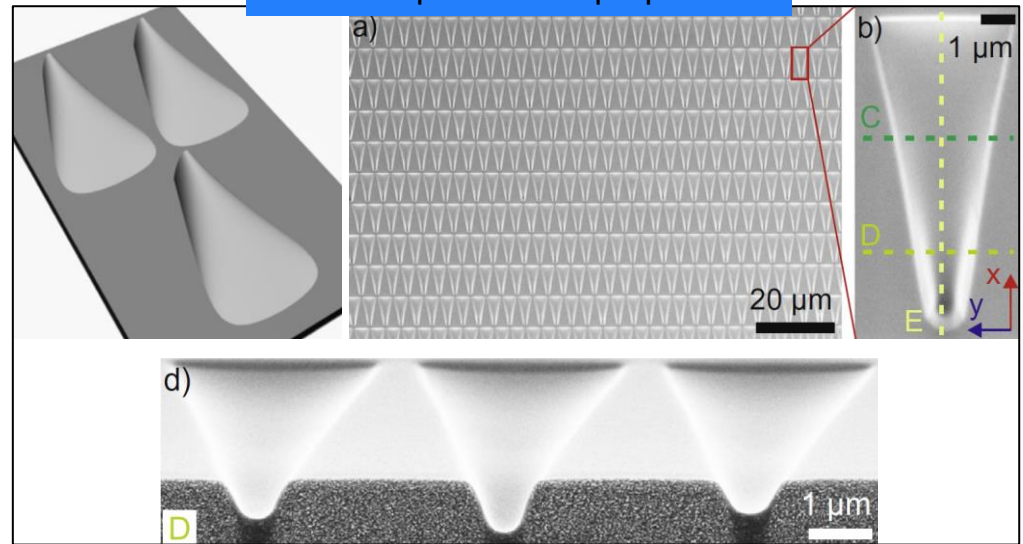
R. Kirchner and H. Schiff, Microelectron. Eng. (2015) [to be published]

D. Pires et al., Science 328 (2010), 732-735

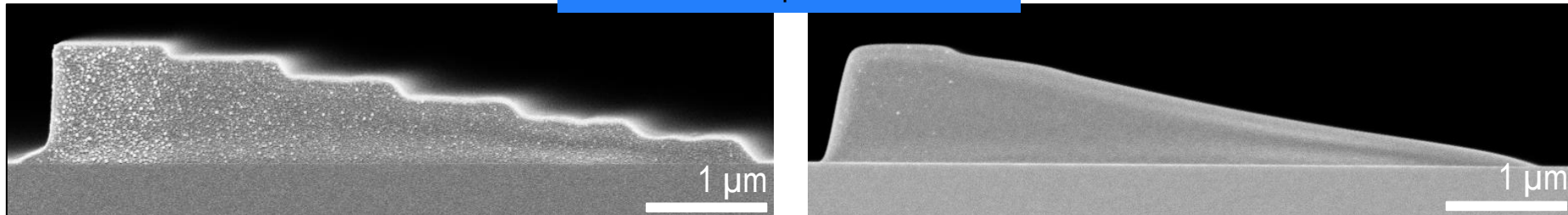
Hierarchical surfaces



Anisotropic surface properties



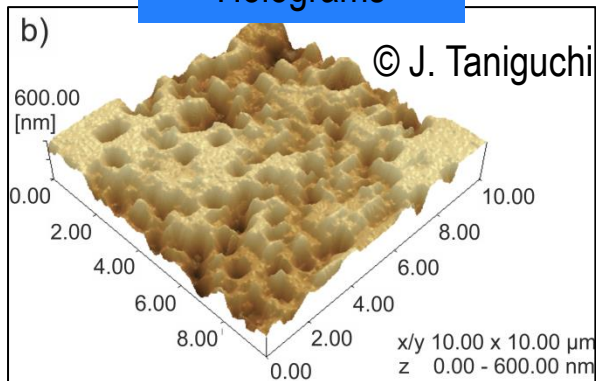
Microprisms



R. Kirchner and H. Schiff, Microelectron. Eng. (2015) [to be published]

R. Kirchner et al., Microelectron. Eng. 141 (2015), 107-111

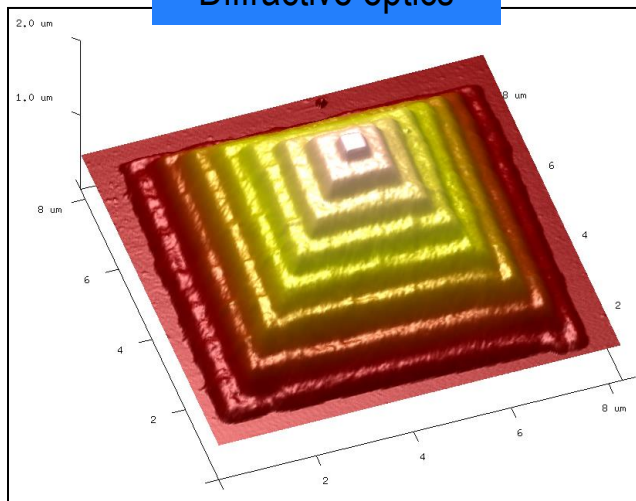
Holograms



Combined Optics



Diffractive optics

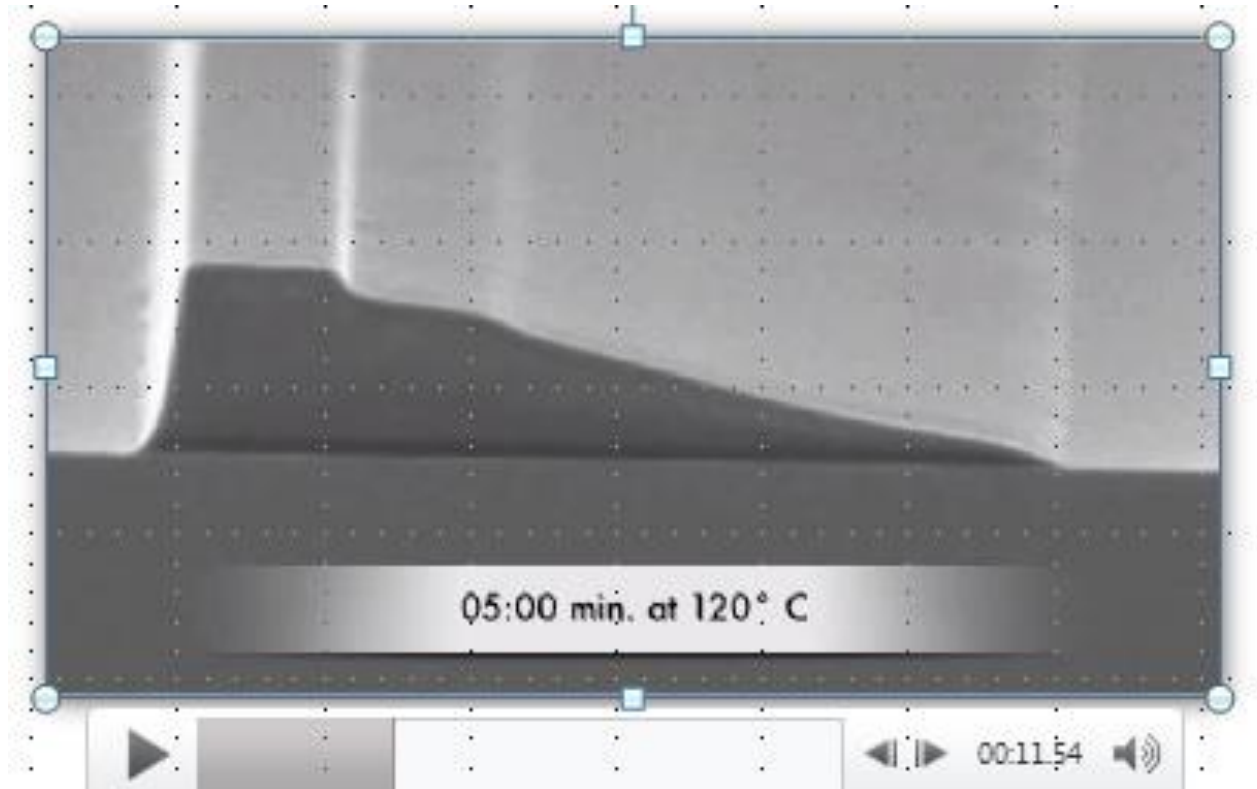


Stereoscopic imaging



R. Kirchner and H. Schiff, Microelectron. Eng. (2015) [to be published] | Y. Shinonaga et al., Microelectron. Eng. 141 (2015), 102-106 | P. Dannberg et al., Micromachines 2014, 5(2), 325-340 | R. Kirchner et al., Microelectron. Eng. 141 (2015), 107-111 | Web: <http://www.eyefly3d.com/>

3D patterns by electron beam lithography and selective thermal reflow



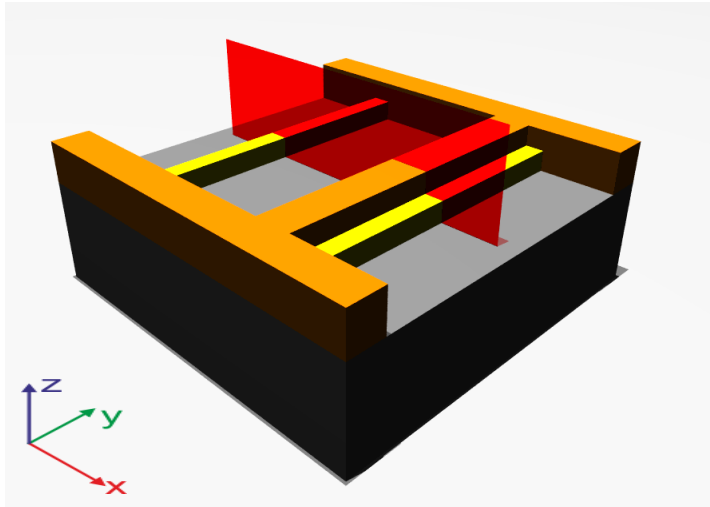
Video: H. Schiff & A. Schleunitz

A. Schleunitz and H. Schiff, J. Micromech. Microeng. 20 (2010), 095022

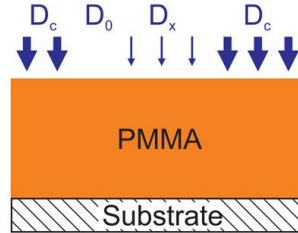
A. Schleunitz et al., J. Vac. Sci. Technol. B. 29/6 (2011), 06F302

A. Schleunitz et al., NanoConvergence 1/1 (2014), 7pp

Electron beam grayscale patterning



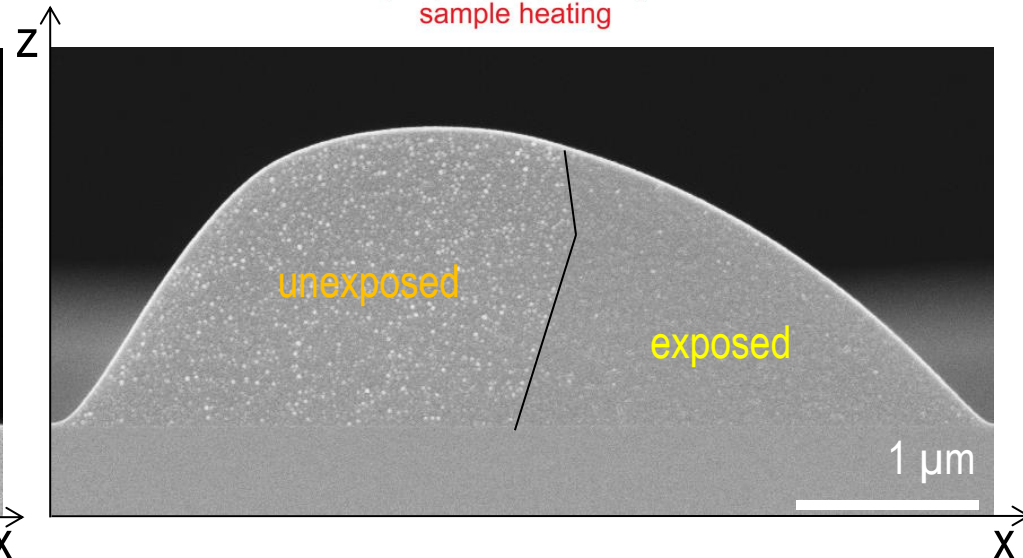
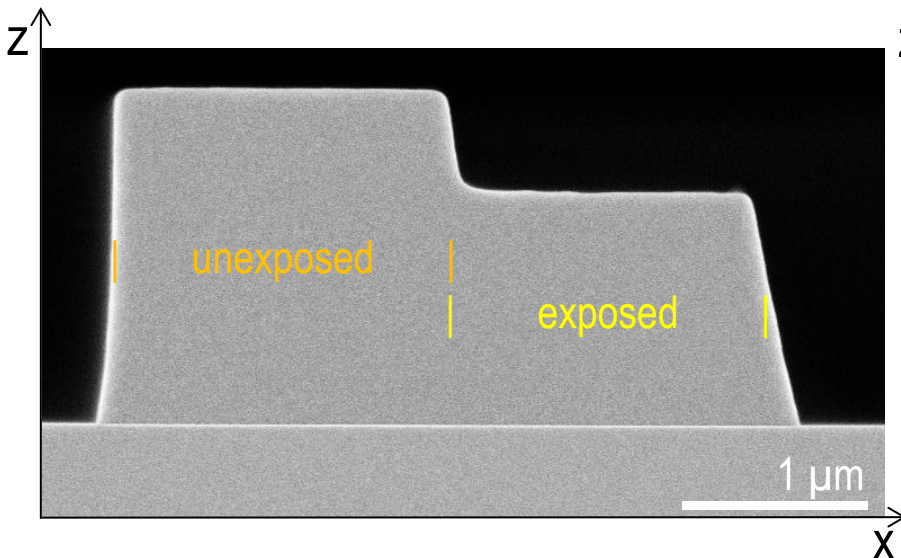
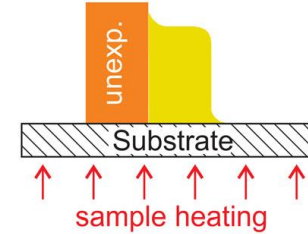
a) dose-modulated exposure



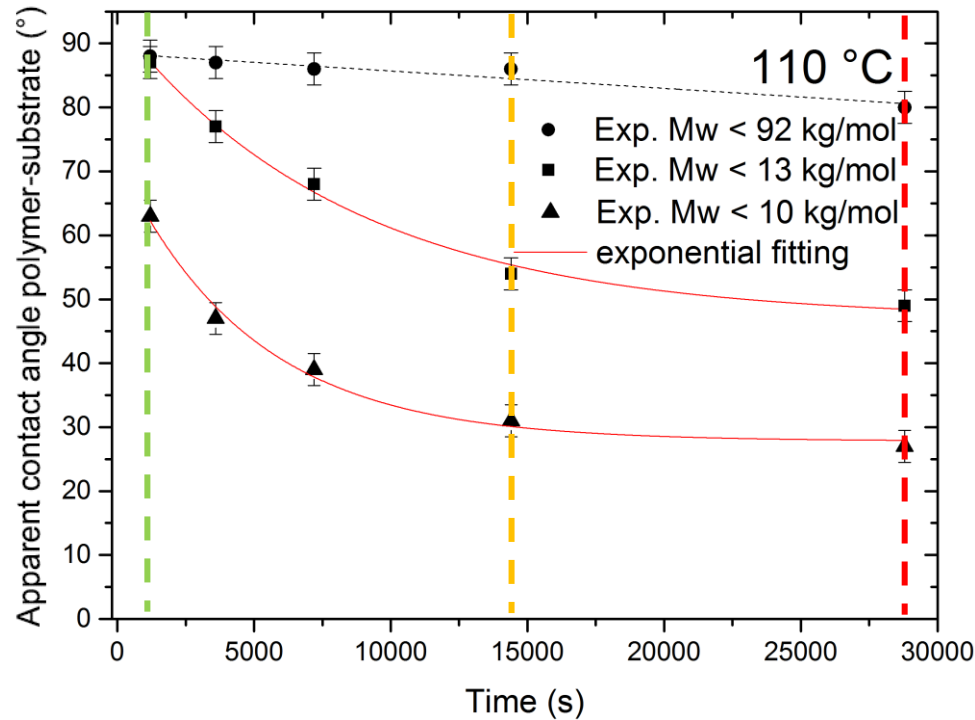
b) wet development



$D_0=0$ $D_c > D_x > D_0$ e-beam Dose D
 $M_{w,0}$ $M_{w,x} < M_{w,0}$ Molecular weight M_w
 $T_{g,0}$ $T_{g,x} < T_{g,0}$ Glass trans. temp. T_g
 c) selective equilibration by reflow



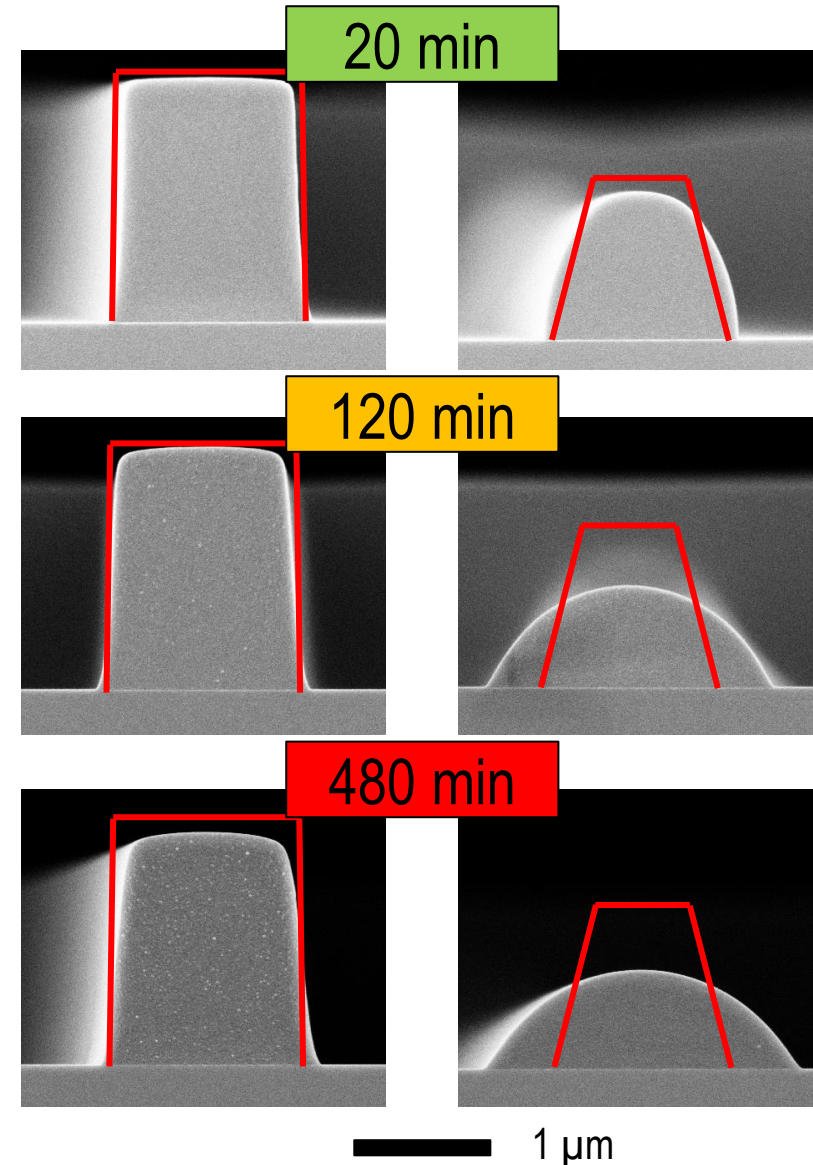
Contact angle optimization



- Model calibration from experiment

$$\alpha(t) = \alpha_t = \alpha_{\infty} + \Delta\alpha \cdot \exp(-t/\tau_{\alpha})$$

R. Kirchner et al., J. Micromech. Microeng. 24 (2014), 055010 (7pp)

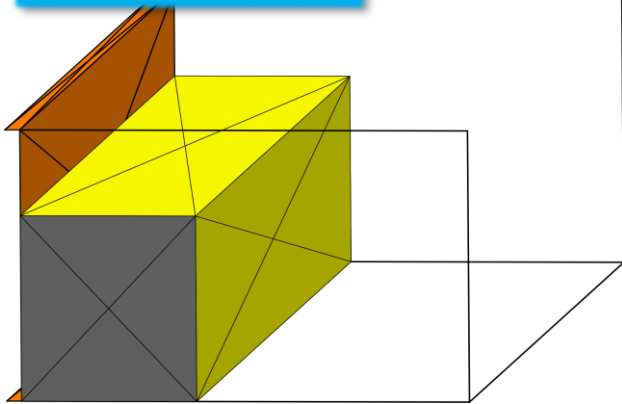


Surface Evolver (SE)*

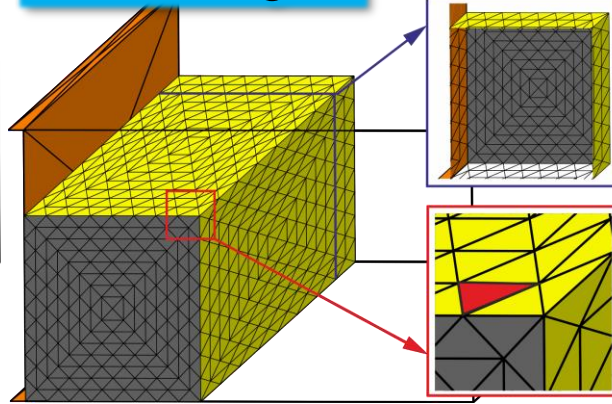
- Finite element
- Energy based (minimal energy surface)
- Shape evolution
- Soapfilm model (“3D with 2D”)

G-B-P

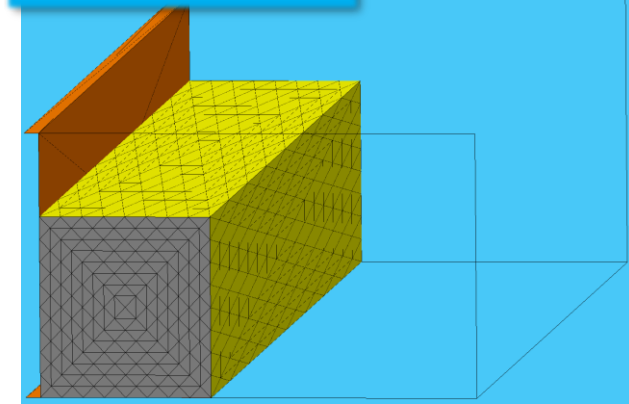
Initialization



Meshing



Evolution



Data-Export

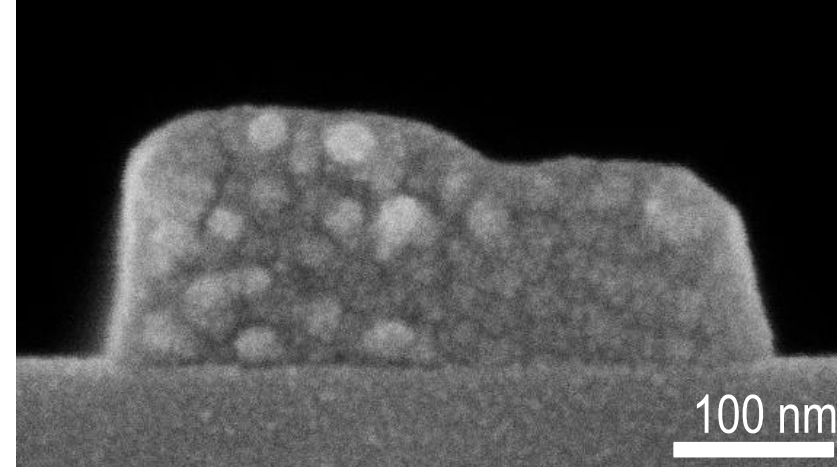
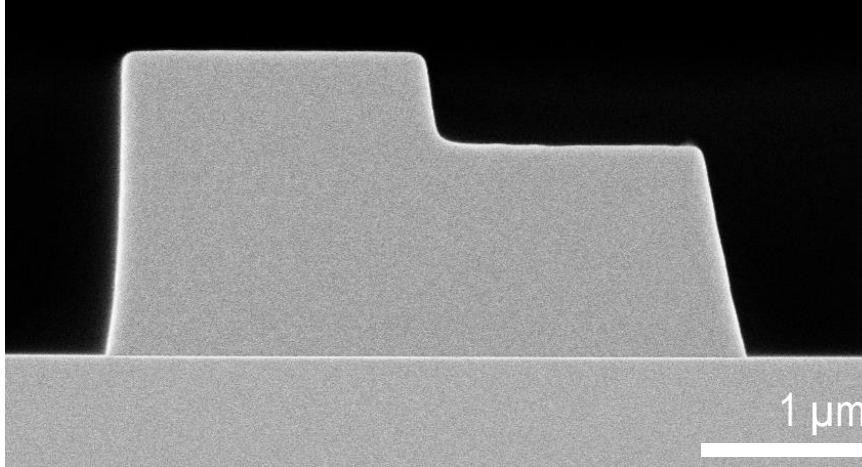
*K. Brakke, Experimental Mathematics, vol. 1, no. 2 (1992), 141–165

Scaling reflow: double step

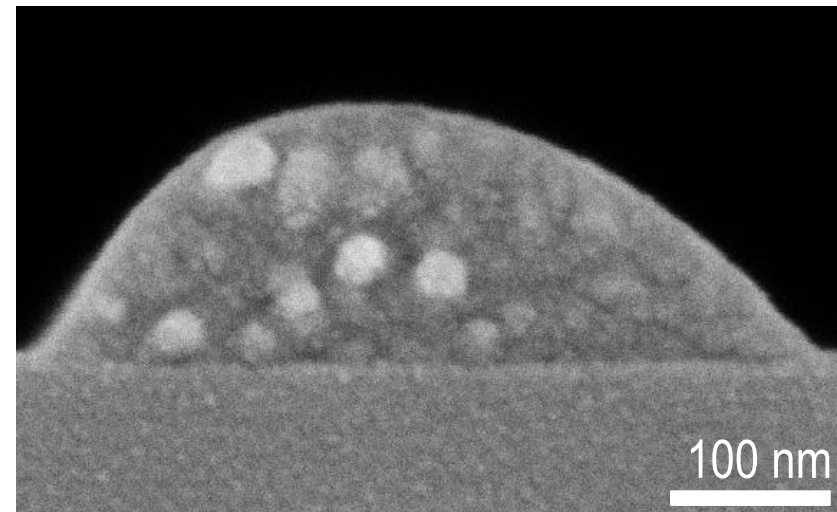
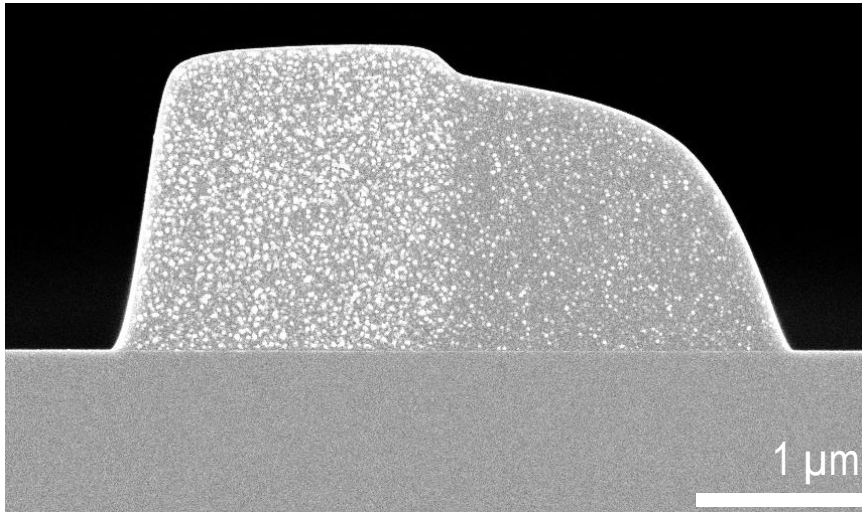
2000 nm film

200 nm film

initial



120 min @ 120°C



- (1) 3D techniques are enabler for future devices.
- (2) Promising fields are microoptics, microfluidics and biomimetics.
- (3) 3D lithography and 3D replication are complementary methods and are required for pattern origination and (high) volume manufacturing.



- THANK YOU -