



WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN

Robert Kirchner and Helmut Schift :: Paul Scherrer Institut

Origination and replication of 3D surface topographies:
electron beam lithography and nanoimprint

US – Singapore Bilateral Workshop on Nanomanufacturing

Question: 2D or not 2D?



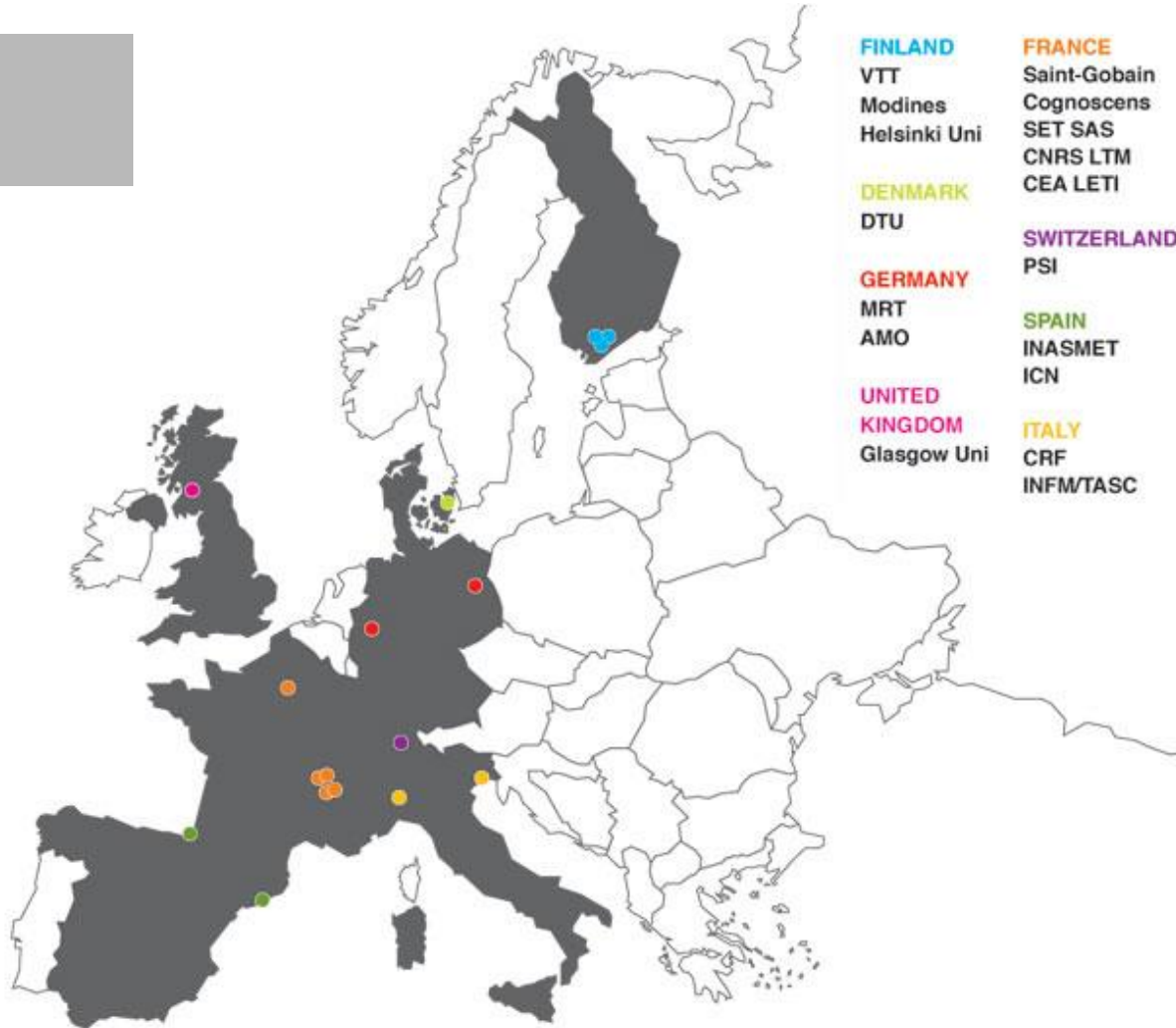
Answer: 3D!



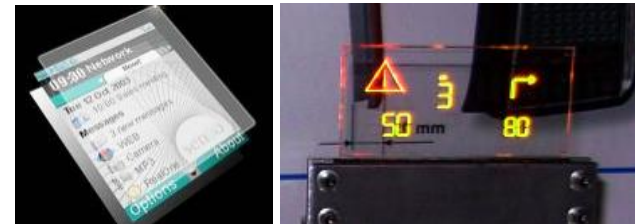
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- *NaPANIL and 3D lithography*
“A collective - a European - approach.”
- 3D lithography and replication
“EBL & NIL for large area precision”

NaPANIL



Planar Diffractive Optical Elem.
Emissive Head-up Displays
Light directional Elements

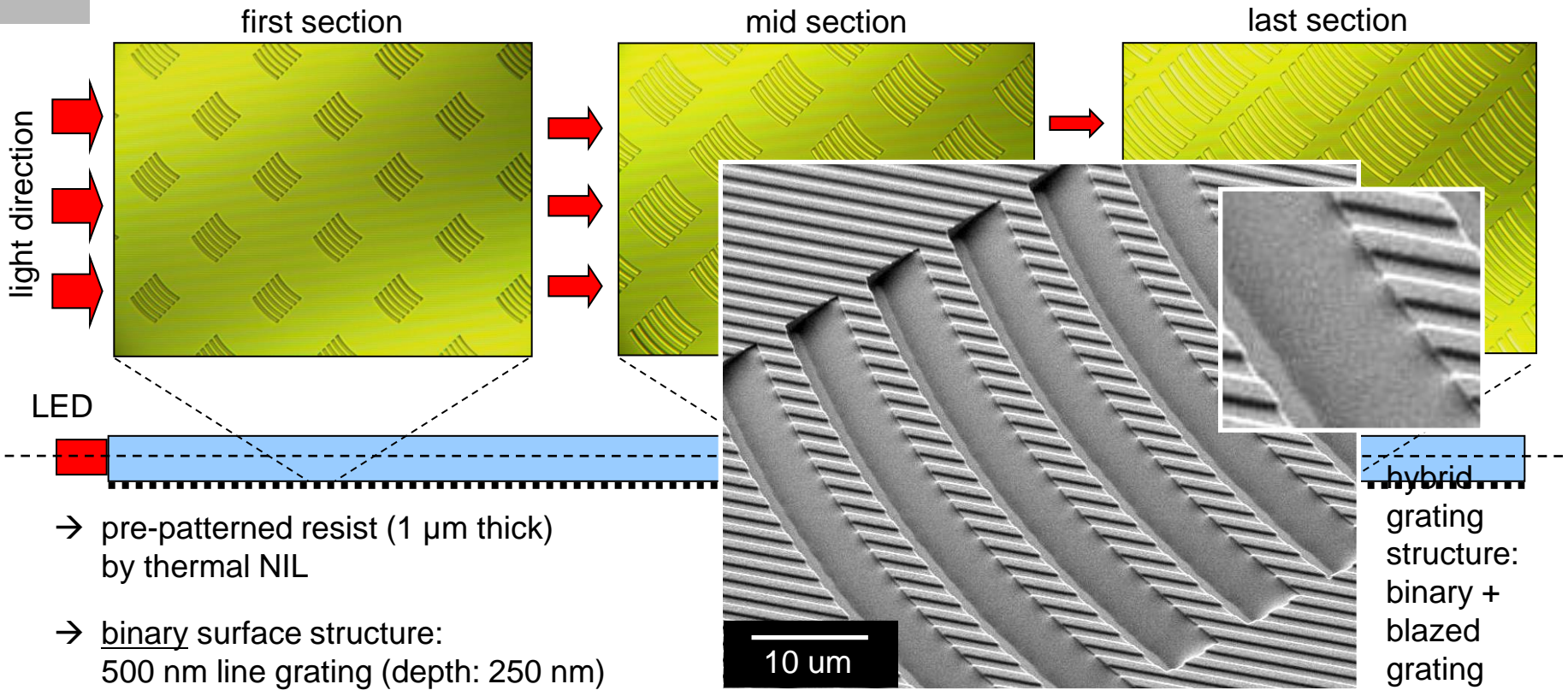


3D at 100 nm level for industrial upscaling

- Trans European
- 16 Mio €
- 17 partners (8 EU)

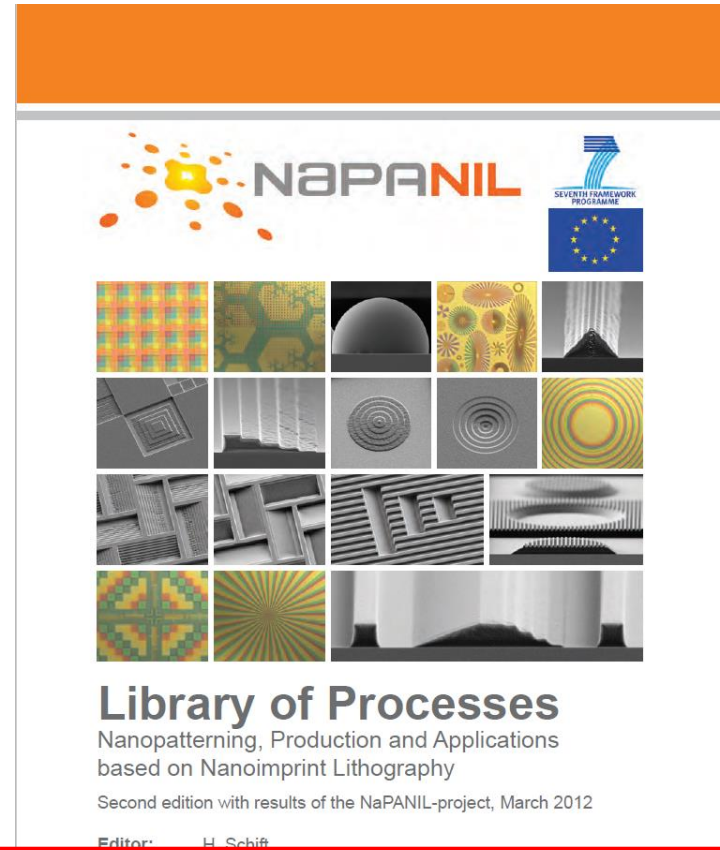
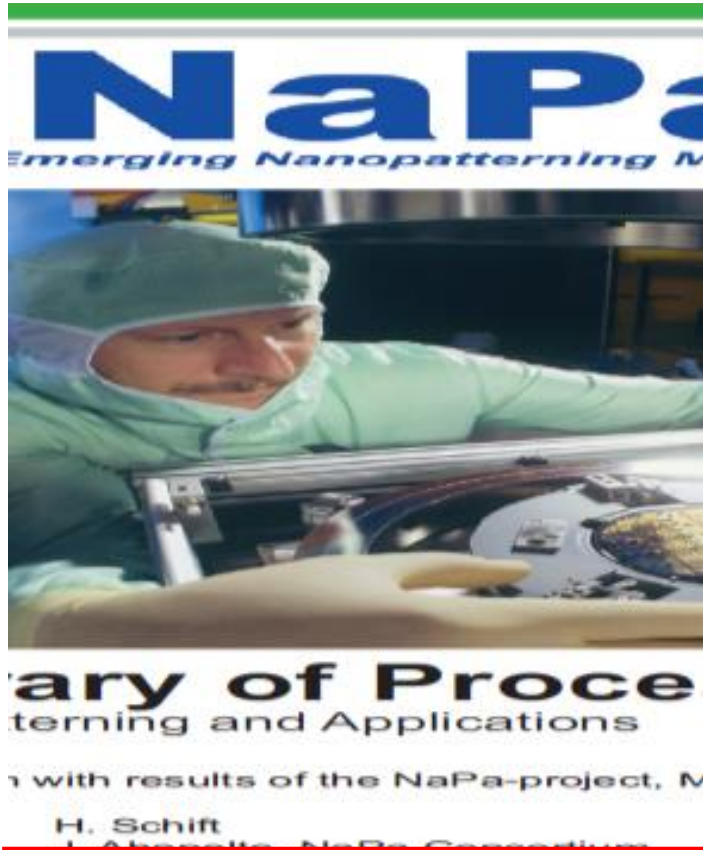
Fabrication of hybrid gratings by selective thermal reflow

Pixelized lightguide surface for backlighting devices: outcoupling elements and anti reflective pattern



- pre-patterned resist (1 µm thick) by thermal NIL
- binary surface structure: 500 nm line grating (depth: 250 nm)
- blazed angle up to 29.7°

Kari Rinko, Light outcoupling structure for a lighting device, Patent application: US 2008/0225393 A1



Book (micro resist technology GmbH)

Download (<http://www.psi.ch/lmn/helmut-schift>)

① Annual industrial workshop



② New European projects



(P4F) 2012-2015: “structural colors”
 (SNM) 2013-2016: “single-digit 2D”

③ Open Large Scale Facilities for Nanoresearch (since 2015)



An “outsiders” perspective

- Collective approach
- Open network & research
- “Melting Pot” for European NIL



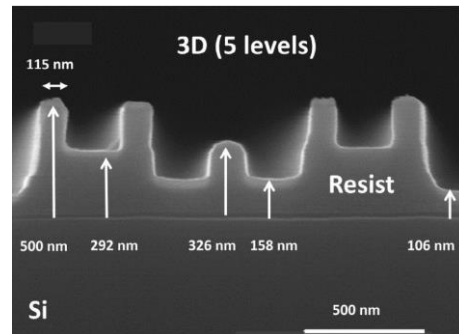
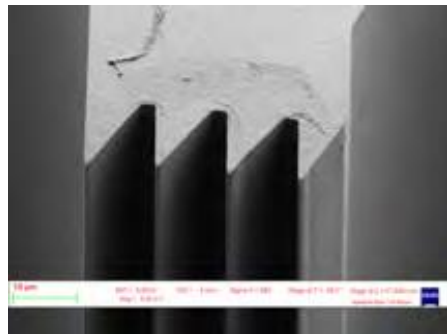
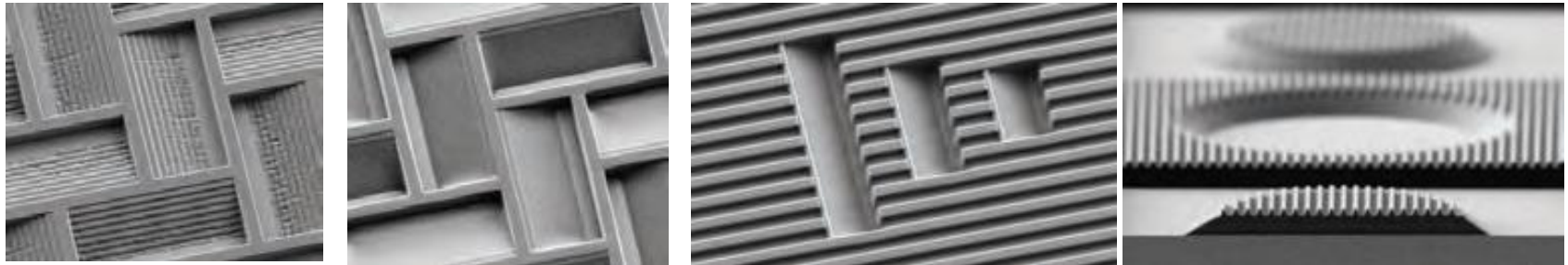
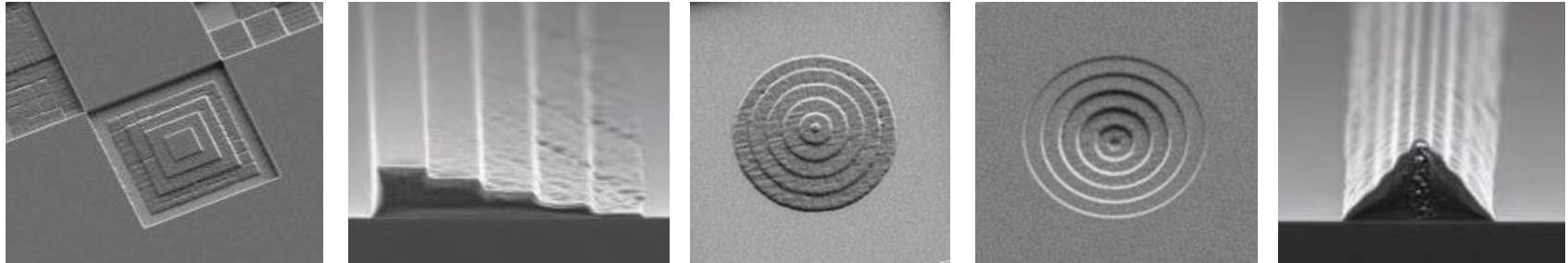
- Technology lift (+2-3 TRLs)
- Driven by industry



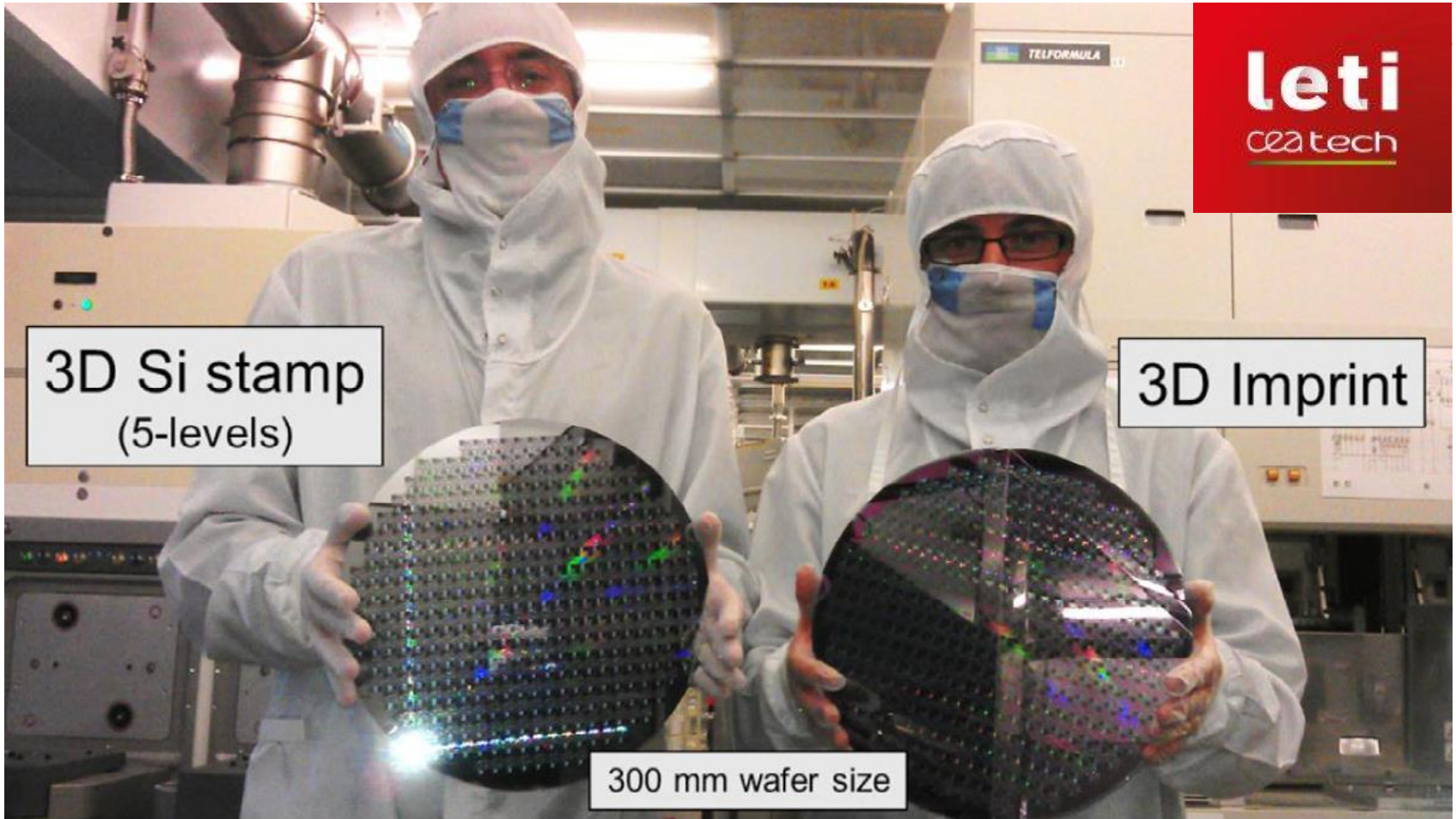
- Established still active network
- Trans-national cooperation



NaPANIL – The origin of 3D-EBL and 3D-NIL



NaPANIL Library of processes: A. Schleunitz et al., M. Tormen et al. | S. Landis et al., Micro-electron Eng. 110 (2013), 198-203



S. Landis et al., Microelectron Eng. 110 (2013), 198-203

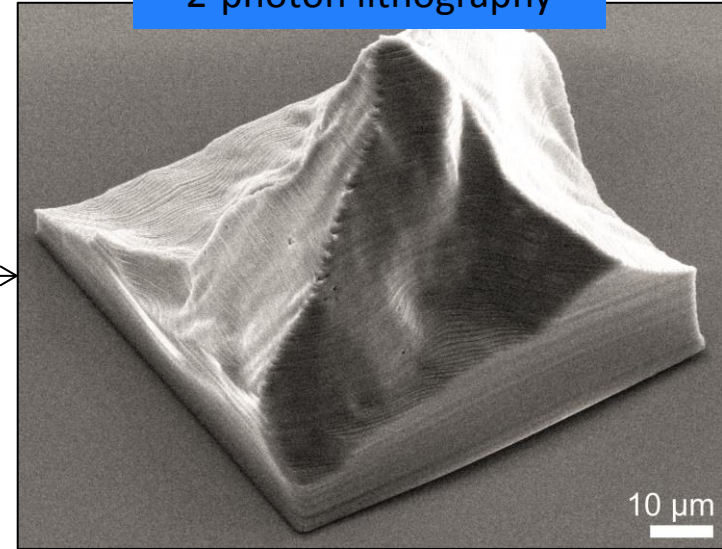
3D Lithography and replication

Scaling 3D technologies

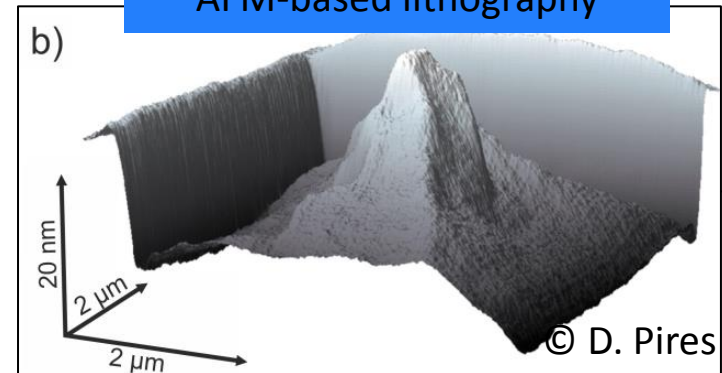
3D printing



2-photon lithography



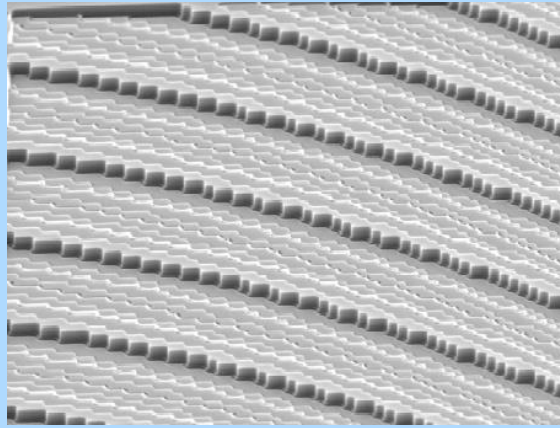
AFM-based lithography



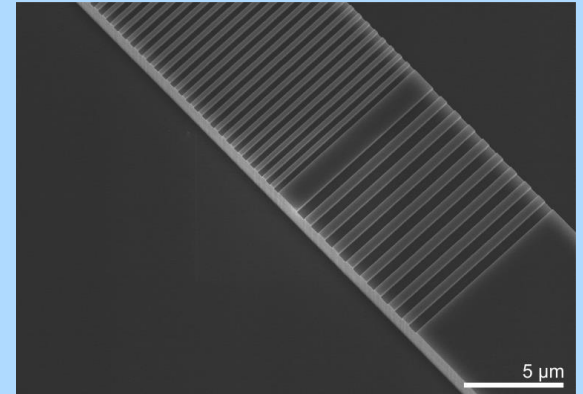
<http://www.thingiverse.com/thing:458775> | R. Kirchner and H. Schift, *Microelectron. Eng.* 141 (2015), 243-244 | D. Pires et al., *Science* 328 (2010), 732-735

3D topographies used in ...

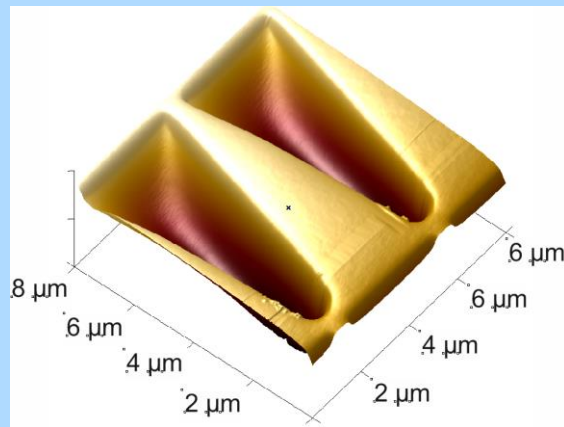
Optics



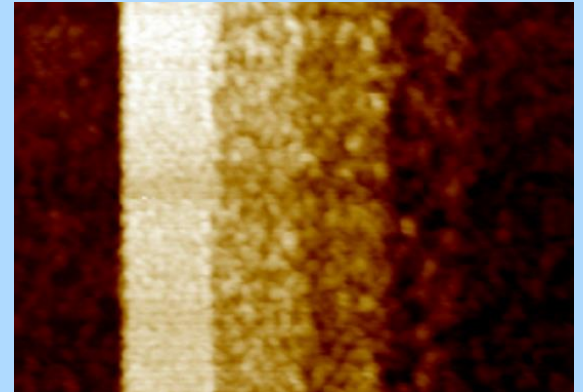
Photonics



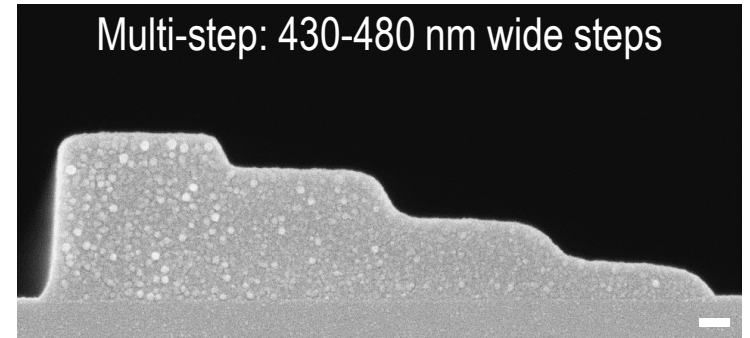
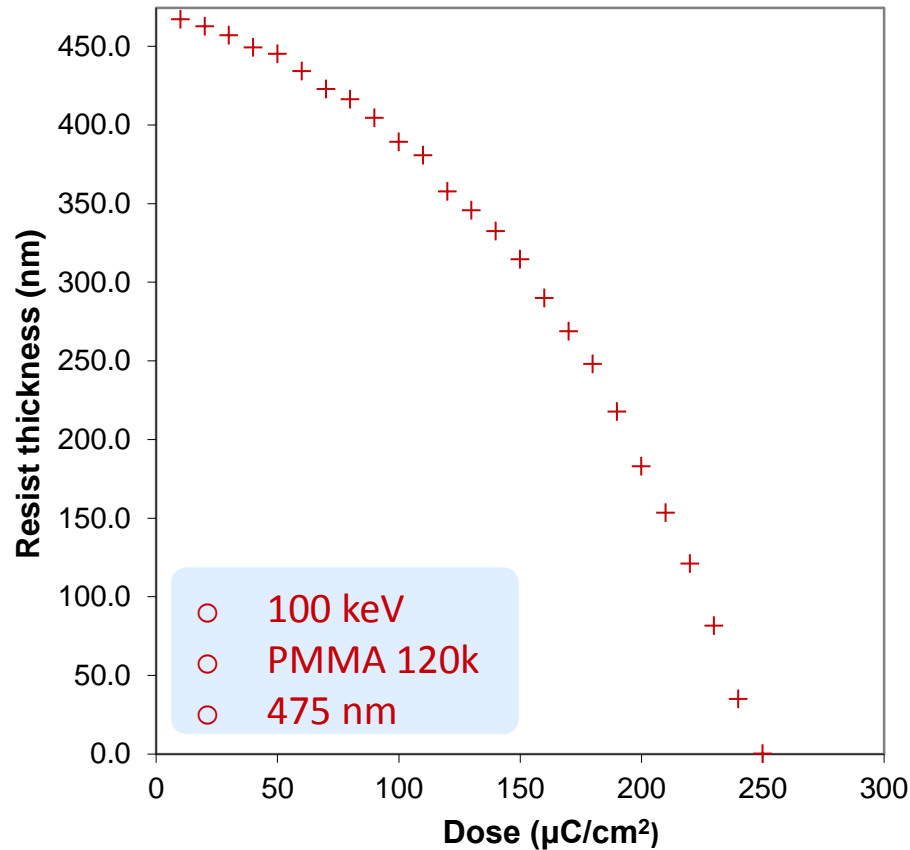
Biomimetics



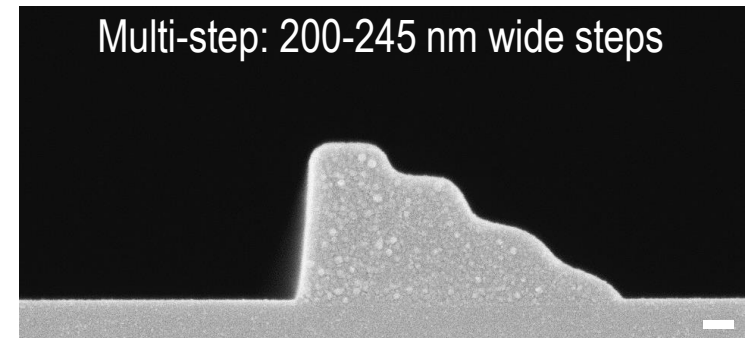
Single-Digit



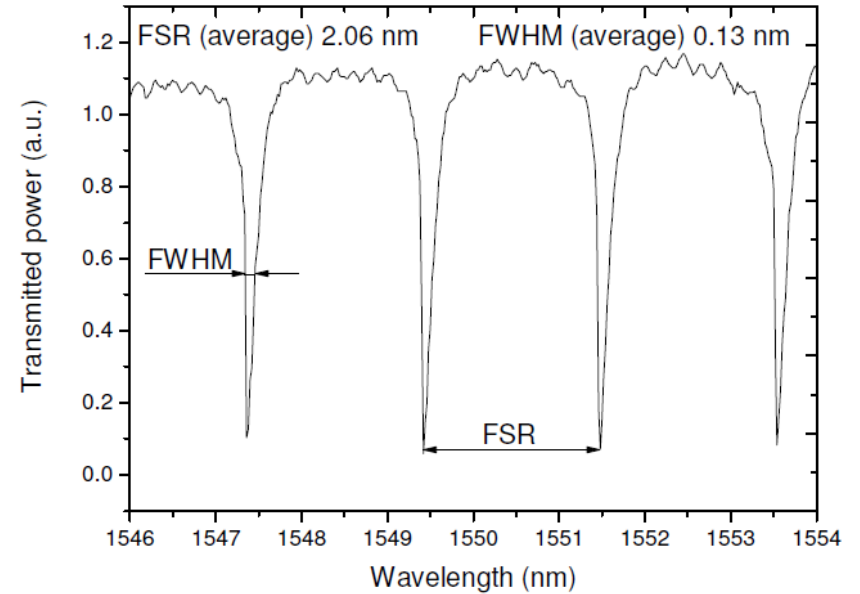
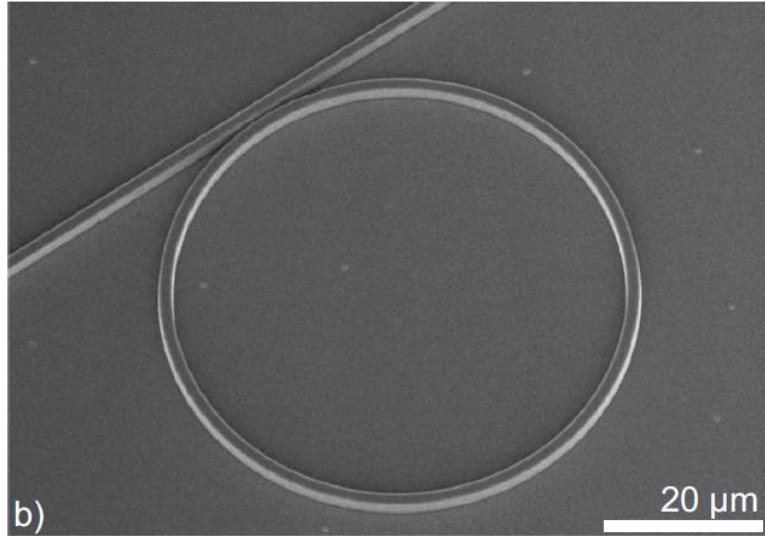
Electron beam grayscale lithography



Scale bar 100 nm



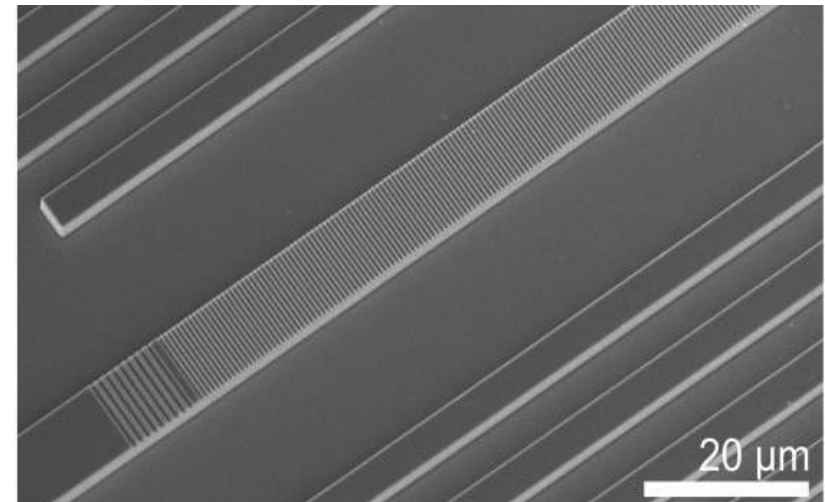
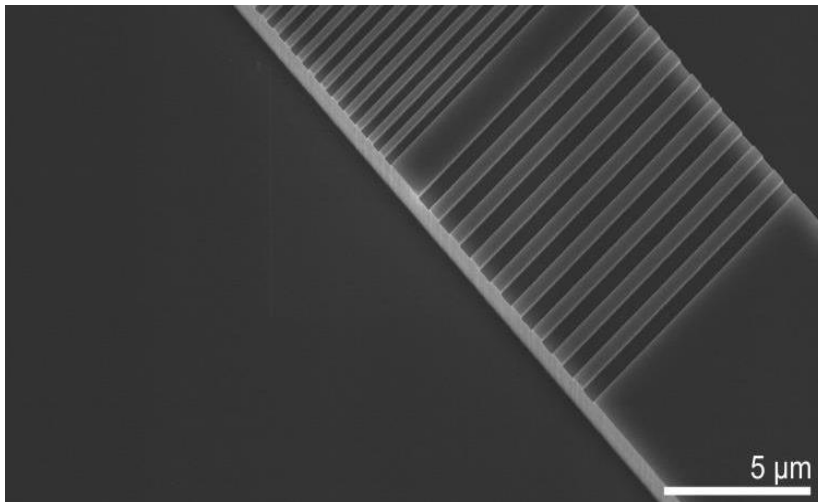
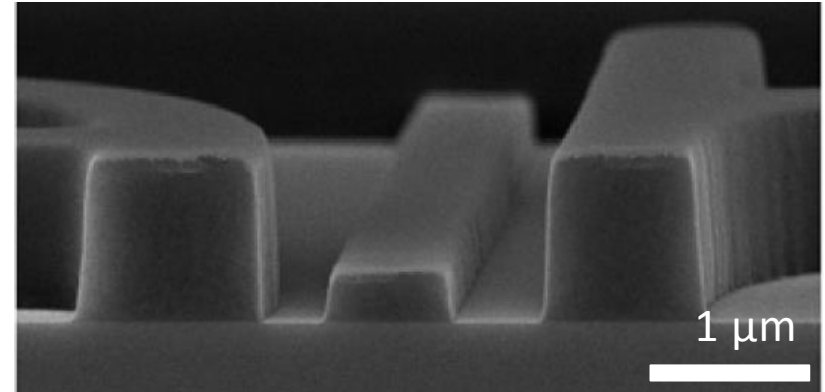
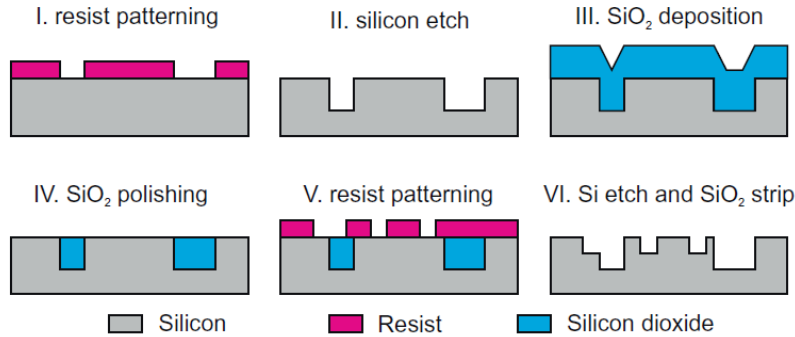
S. Pfirrmann et al., *Proc. SPIE*, **2016**, 9779, 74 (13pp)



- Microring resonators
- Directly UV-imprinted (cross-linked) polymers
- Negligible residual film

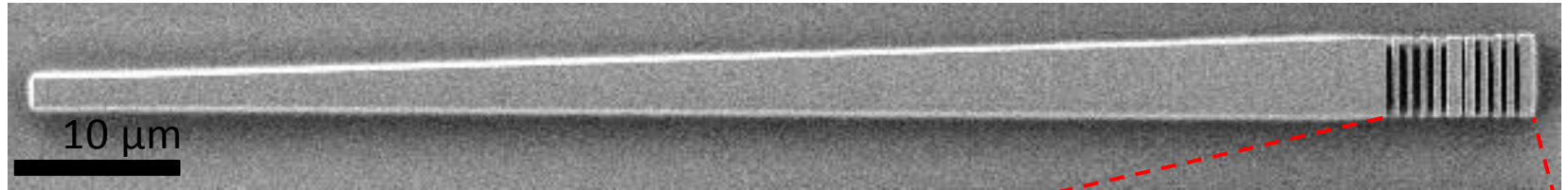
R. Kirchner et al. *J. Lightwave Technol.* 32 (2014), 1674-1681

3D photonics applications



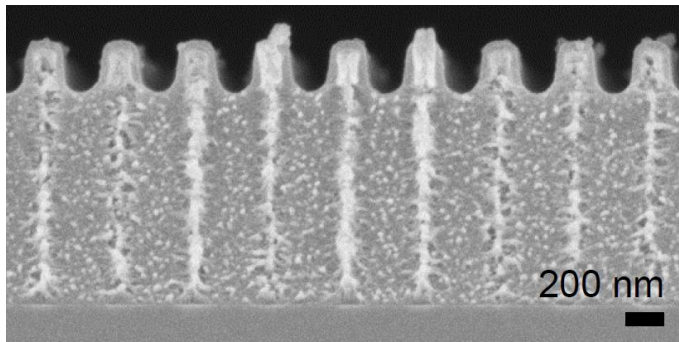
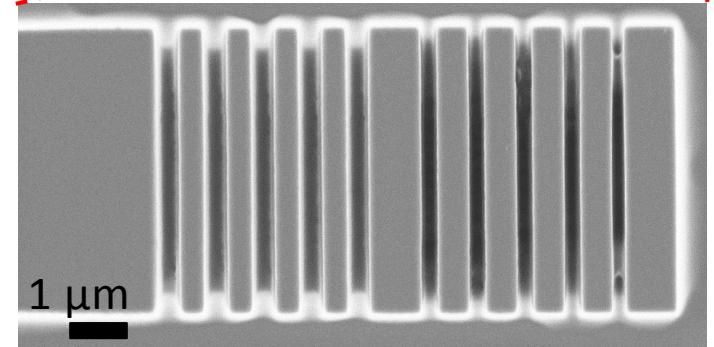
A. Finn et al., *Microelectronic Engineering* 98 (2012) 284–287 | R. Kirchner and A. Finn, *Fabrication of multilevel polymer photonic microsystems by UV-nanoimprint based replication*, *Dresdner Beiträge zur Sensorik* 59 (2015), pp. 129-143. ISBN 978-3-95908-011-8

3D: enabling fully integrated photonics

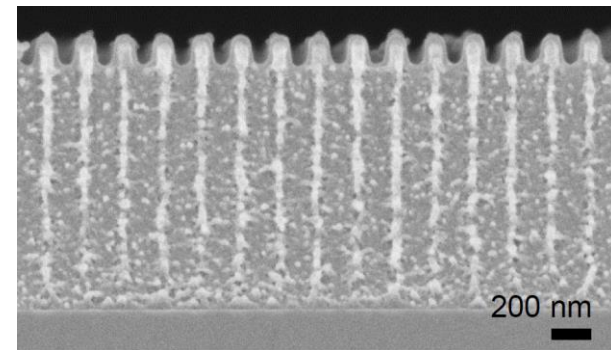


Fully integrated photonics

- Optical cavities (transducer)
- Shallow gratings (coupling)
- Deep gratings (reflectors)



Period 400 nm



Period 200 nm

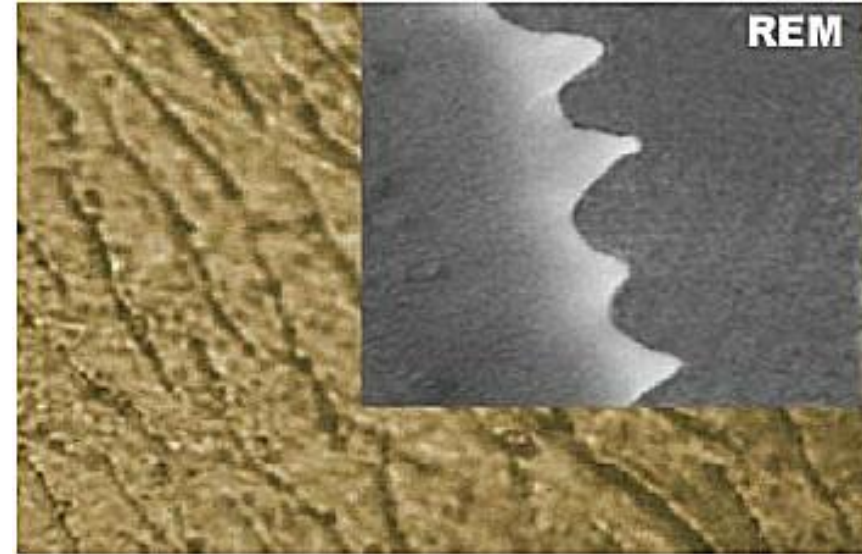
A biological role-model



© Chris Harrison (www.kingsnake.com)

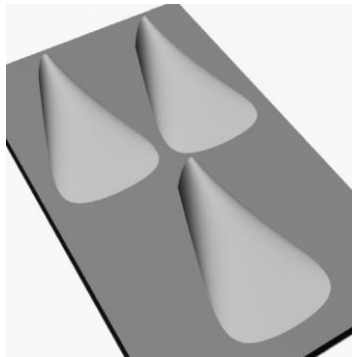
Sandboa

- Low and anisotropic friction
- Wear resistance

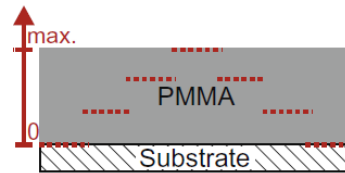


K. Staudt, Comparative surface and molecular investigations of the sandfish's epidermis (Squamata: Scincidae: *Scincus scincus*), Dissertation RWTH Aachen, 2012

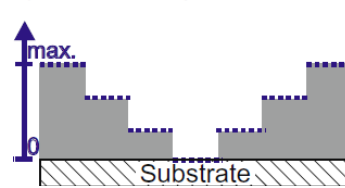
Design



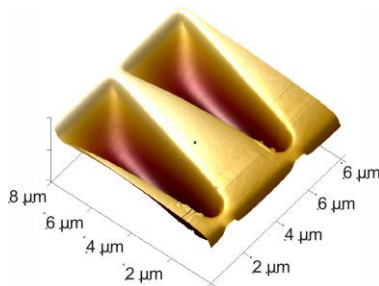
a) dose modulated exposure



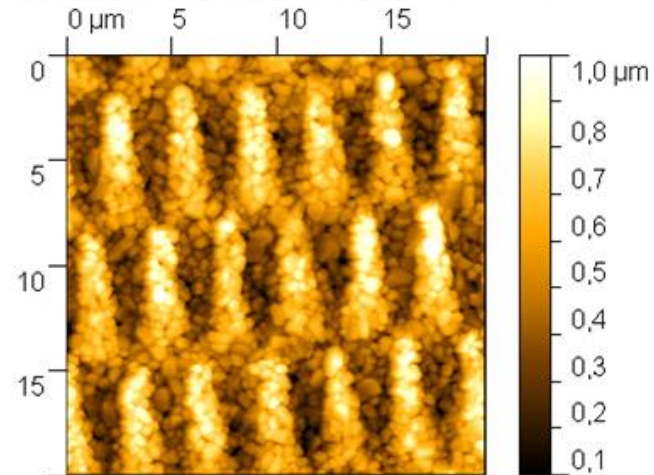
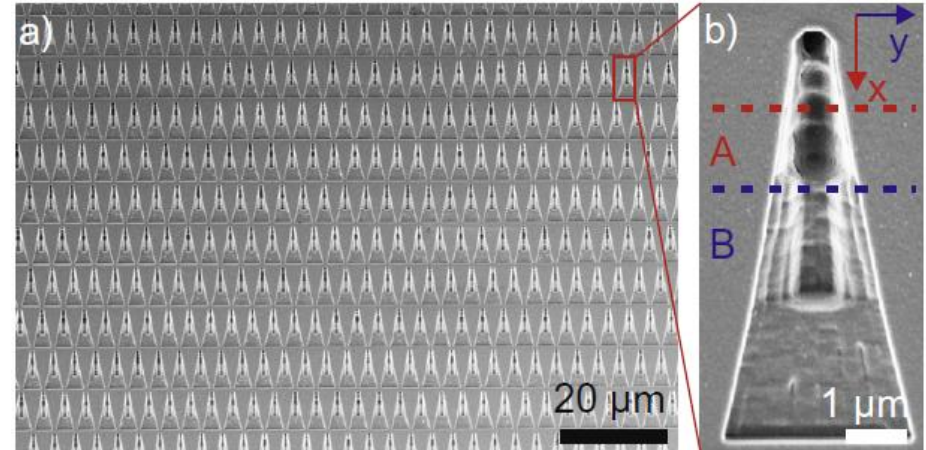
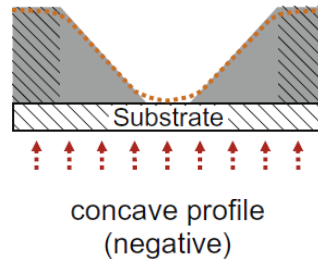
b) wet development



Mold



c) topography equilibration



Ceramic injection molding
16% less solid friction

R. Kirchner et al., Microelectron. Eng. 141 (2015), 107-111 | M. Mühlberger et al. Microelectron. Eng. 141 (2015), 140-144

- 3D lithography technologies are reaching down into the nano-scale regime.
- Typical applications are probably found in photonic and bio-inspired and hierarchical area.
- The biggest challenge is the scaling towards large-areas and a current solution is employing the full process chain: origination – pattern enlargement – large scale replication.



The 15th International Conference on
NNT 2016

Nanoimprint and Nanoprint Technology

Braga, Portugal
Sept 26th – Sept 28th

week after
MNE 2016
(in Vienna)

Chairs: Lars Montelius
Helmut Schift
Gabi Gruetzner

Enjoy the conference and nearby **Porto**, a town of UNESCO World Heritage and good Port wine

NNT 2016



Europe

- International Boundary
- Road
- River
- ★ National Capital
- City or Town

0 250 500 KM
0 250 500 Miles

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Braga, Portugal
Sept 26th – Sept 28th

Matterhorn

A. Schleunitz, P. M. Kristiansen, H.-C. Scheer, V. Guzenko, C. Padeste, K. Vogelsang,

R. Smits, M. Pianigiani

H. Schiff, L. Heyderman, J. Gobrecht

- THANK YOU -

