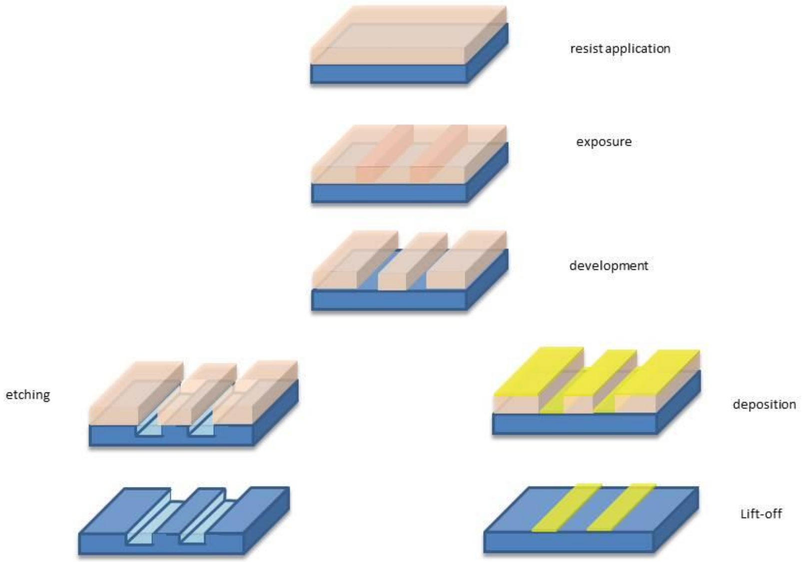
Direct laser lithography

Direct laser lithography is one of the patterning techniques that enables us to create structures on the surfaces of substrates using lithography process.

- thin film of photoresist
- not laser ablation, scribing or similar
- resist exposure without using a photomask
- not two-photon process
- Direct laser writing, Laser direct imaging, maskless lithography...

Damjan Svetin

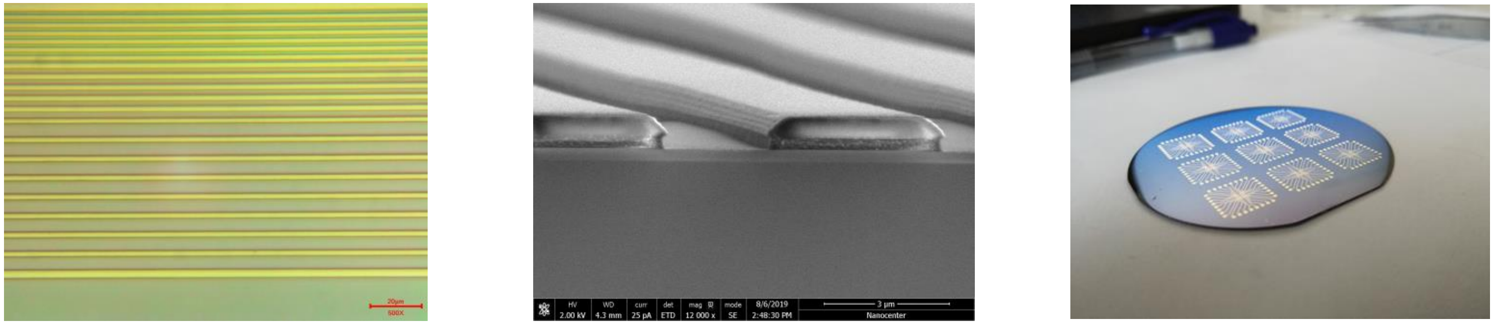
Lithography process



- substrate (Si, glass ,ceramic... cleaning, priming)
- pattern design (dxf, GDSII)

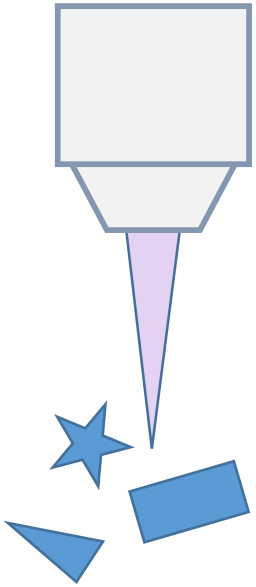
- photoresist spin-coating
- exposure - UV laser
  - positive
  - negative
- development

- pattern transfer lift-off/etching



Advantages of direct laser lithography

- Allows frequent, quick and inexpensive pattern design changes.
- Suitable for testing; pattern layout, device geometry, fabrication of custom circuits, custom devices, prototypes...
- Drawing of arbitrary shapes, (not limited to basic objects) laser write directly from CAD design
- No mask
- Not limiting for substrate material
- No vacuum required
- Application: microelectronics, surface microstructuring 2D (3D prisms), grayscale litho., microfluidics, lab-on-chip



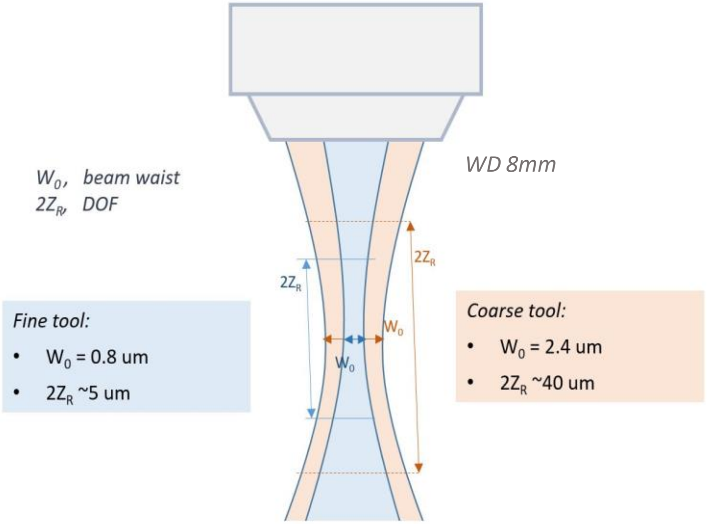
Limitations

- low writing speed (<1 mm^2/s), small scale fabrication, not suitable for series replication
- Linewidth resolution limit ~1um

Direct laser lithography at CENN Nanocenter

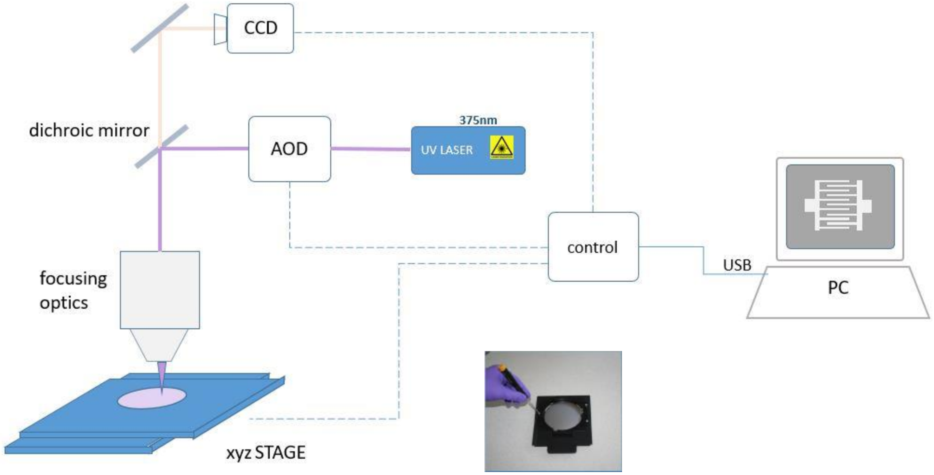
- Desktop system
- closed box, entirely software control and operation

- UV laser 375nm, 20mW
- AOD 100kHz, control beam scanning, blanking, power
- CCD camera, sample observation, alignment
- xyz stage, 100 mm x 100 mm, 4mm, 3-point support, sample tilt correction



Fine tool:
- W_0 = 0.8 um
- $2Z_R$ ~5 um

Coarse tool:
- W_0 = 2.4 um
- $2Z_R$ ~40 um



sample tray

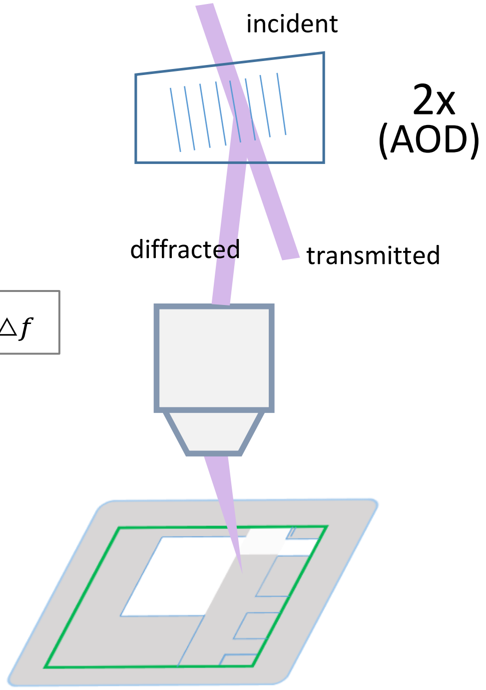
DaLI system (originaly Protolaser LDI, LPKF)

Writing strategy

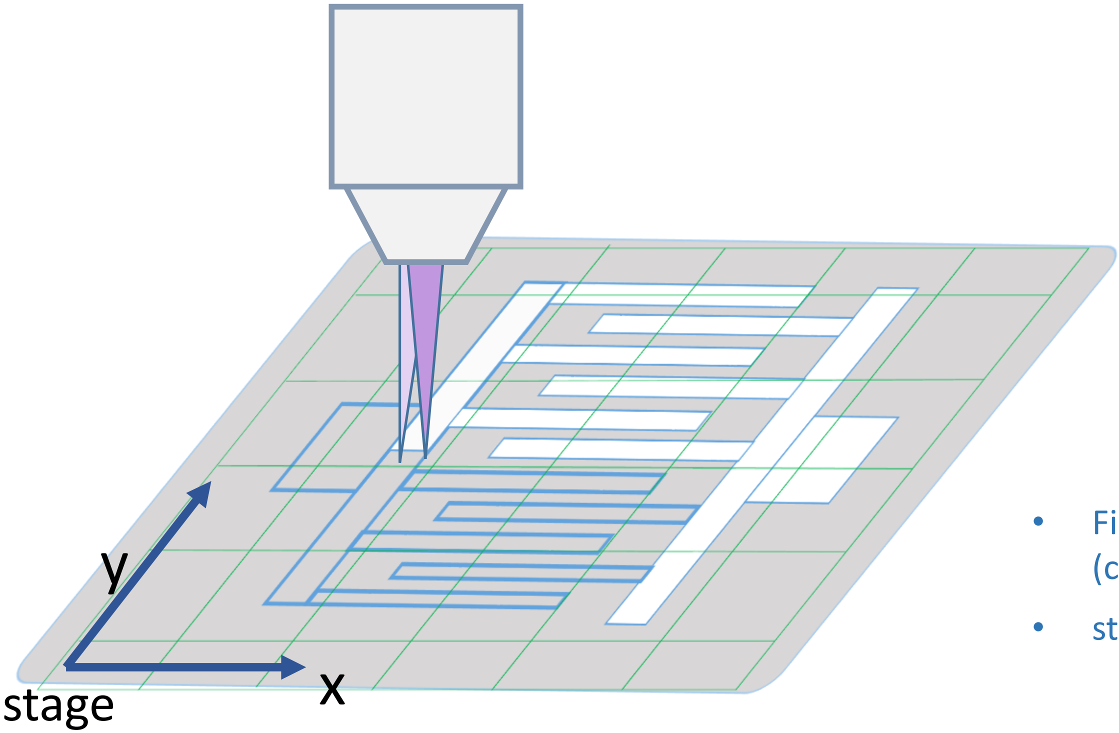
writing field
(beam deflections)

+

filed stitching
(stage translations)



$$\triangle\theta = \frac{\lambda}{v}\triangle f$$



- Field size: Up to 300 um (fine tool), 900um (coarse tool)
- stitching accuracy <250 nm/100 um field

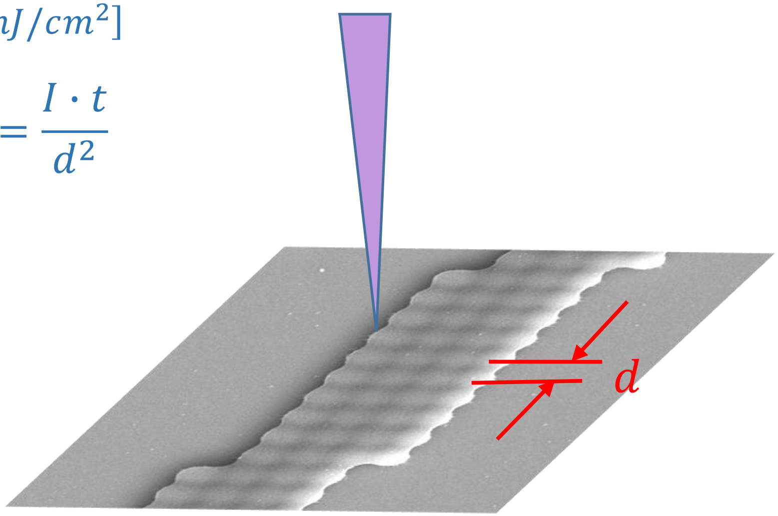
Writing parameters

- *Spot spacing*:
  - 50 nm – 400 nm (fine tool)
  - 600 nm – 1200 nm (coarse tool)
- *Pixel exposure time*, min. 10us

Dose

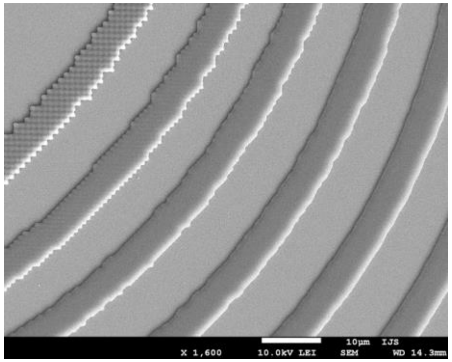
$[mJ/cm^2]$

$$D = \frac{I \cdot t}{d^2}$$



Total writing time:

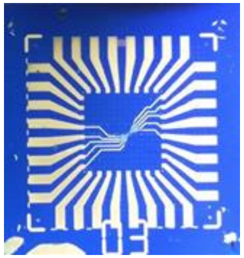
- scanning speed, (AOD max frequency 100kHz)
- spot space
- Resist sensitivity
- Stage steps (number of fields)

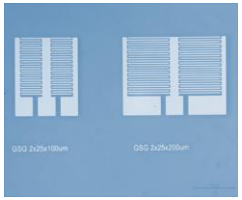


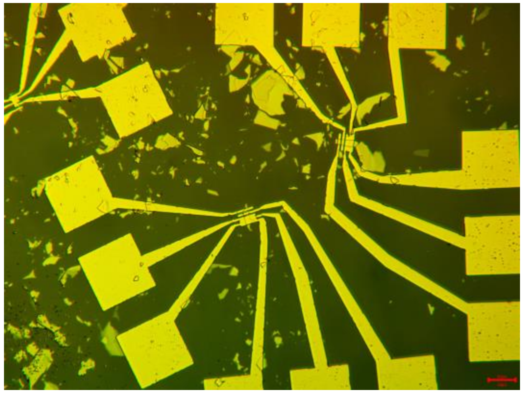
B. Kavčič

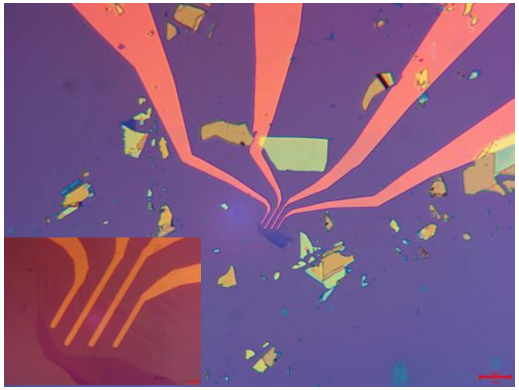
Application

- most of applications Lift-off type, double layer resist, deposited materials: Au, Au/Pd, Cr.
- complementary to EBL; fabrication of pads, coarse parts, waveguides
- testing of circuit layouts, varying geometry parameters
- microelectronic applications, for fabrication of custom electronic circuits, electrodes and contacts to the samples of exfoliated materials (TaS2, TaSe, TiS2, Tb2Te3, graphene... , thicknesses 1nm-200nm)









graphene, Wadym Tkachuk UNG

Electronic circuits

- measuring transport properties of materials (1T-TaS$_2$)
- Electrical switching

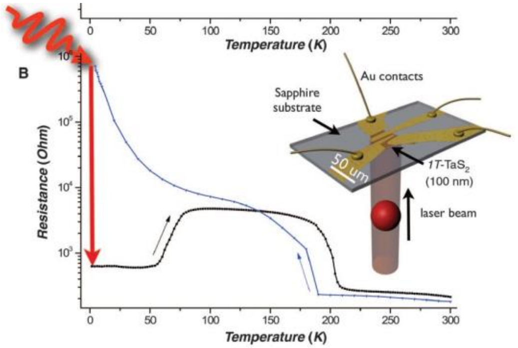
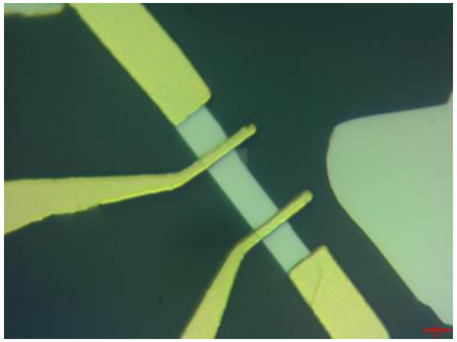
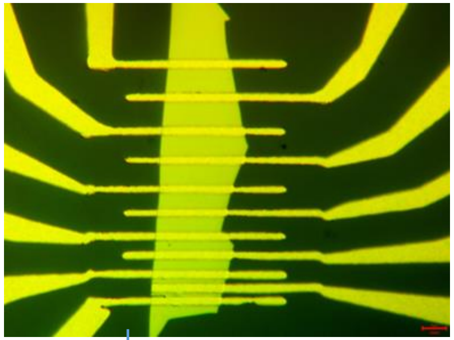


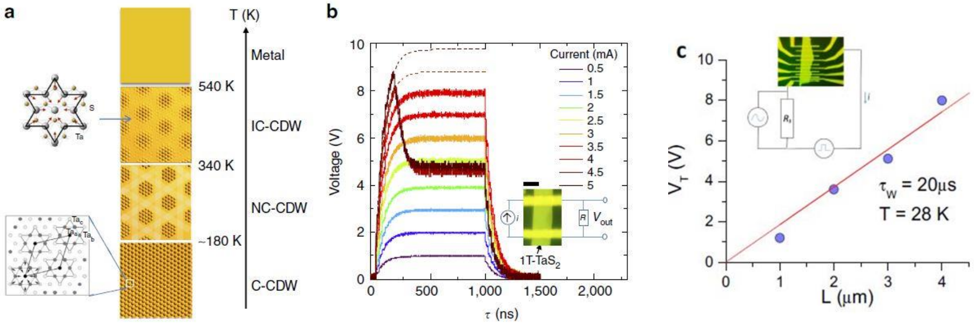
Fig. 1. Resistivity switching of 1T-TaS$_2$ by a 35-fs laser pulse at 800 nm. (A) Temperature

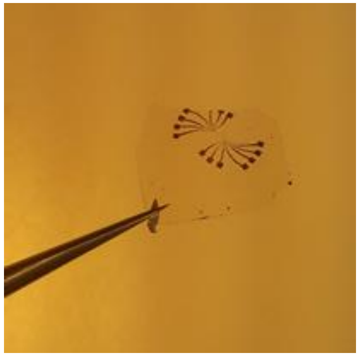




L. Stojchevska, I. Vaskivskyi, T. Mertelj, P. Kusar, D. Svetin, S. Brazovskii, D. Mihailovic, Ultrafast switching to a stable hidden quantum state in an electronic crystal. *Science* 344, 177–180 (2014).

scaling effect → ‘‘CDW memory‘‘

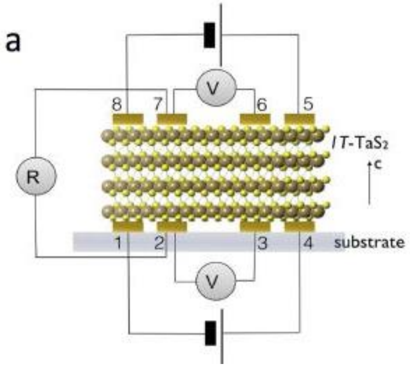


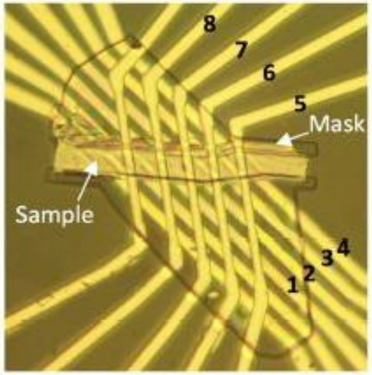


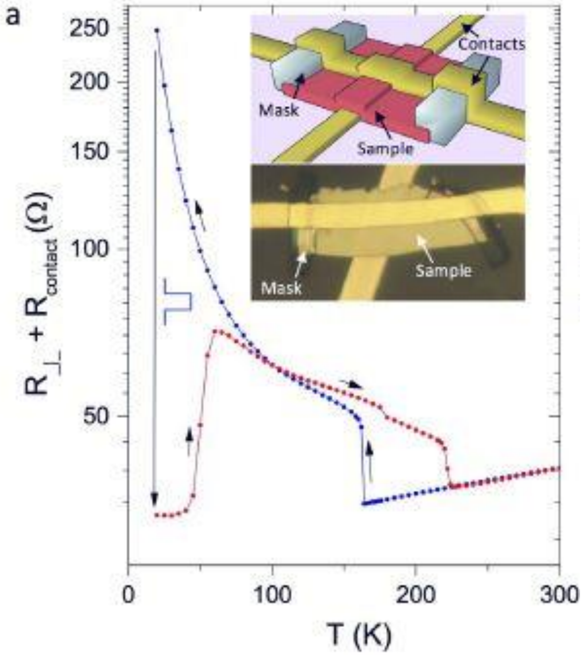
Vaskivskyi, I. *et al.* Fast electronic resistance switching involving hidden charge density wave states. *Nat Comms* **7,** 11442 (2016).

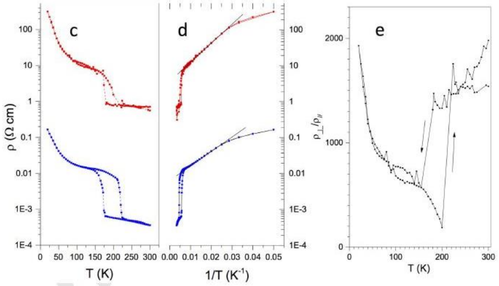
sapphire, quartz, Si/SiO2, MgO, CaF2, GaAs,..
PMMA

- c-axis transport properties in 1T-TaS2 crystal (in-plane/out-of-plane conductivity)
- stacking applications







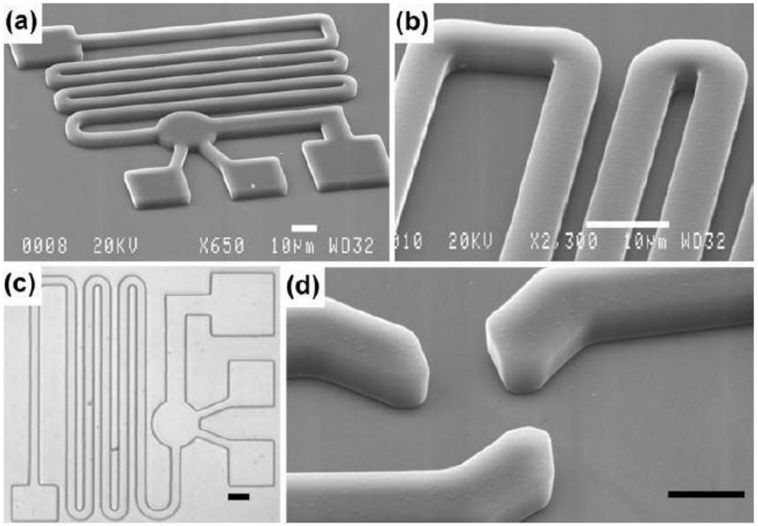


Svetin, D. *et al.* Transitions between photoinduced macroscopic quantum states in 1T TaS2 controlled by substrate strain. *Appl. Phys. Express* **7,** 103201 (2014).

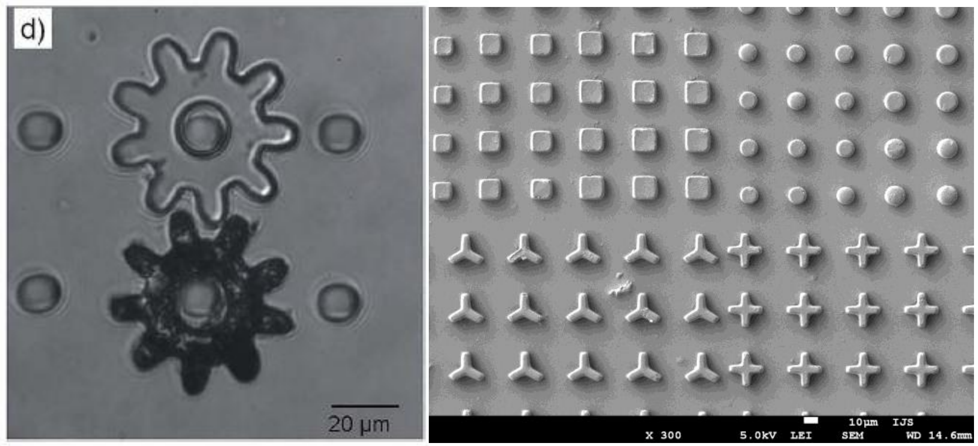
Microfludic applications

SU-8 structuring, thickness up to 100 um

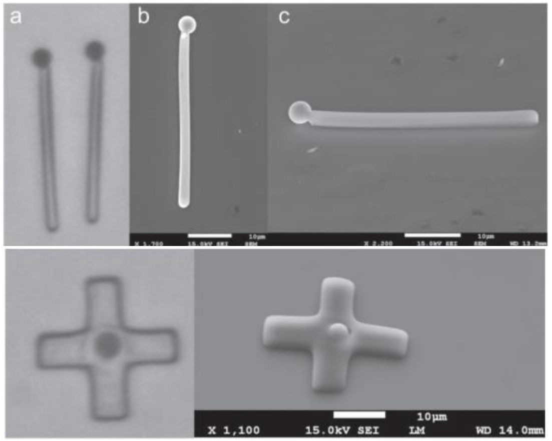
- molds for microfluidic channels in PDMS
- fabrication of prism-like 3D micro-objects



B. Kavčič, D. Babić, N. Osterman, B. Podobnik, and I. Poberaj, Rapid prototyping system with sub-micrometer resolution for microfluidic applications, *Microsyst. Technol.* 18, 191 (2012).



I. Kavre, G. Kostevc, S. Kralj, A. Vilfan, and D. Babič, Fabrication of magneto-responsive microgears based on magnetic nanoparticle embedded PDMS, *RSC Adv.* 4, 38316 (2014).



Blaž Kavčič *et al* One-pass manufacturing of multimaterial colloidal particles using optical recognition-enhanced laser direct imaging lithography 2016 *Appl. Phys. Express* **9** 026501