Microstructuring of diamonds with laserlithography

presentation of the lithography area in the cleanroom of the detector laboratory at GSI

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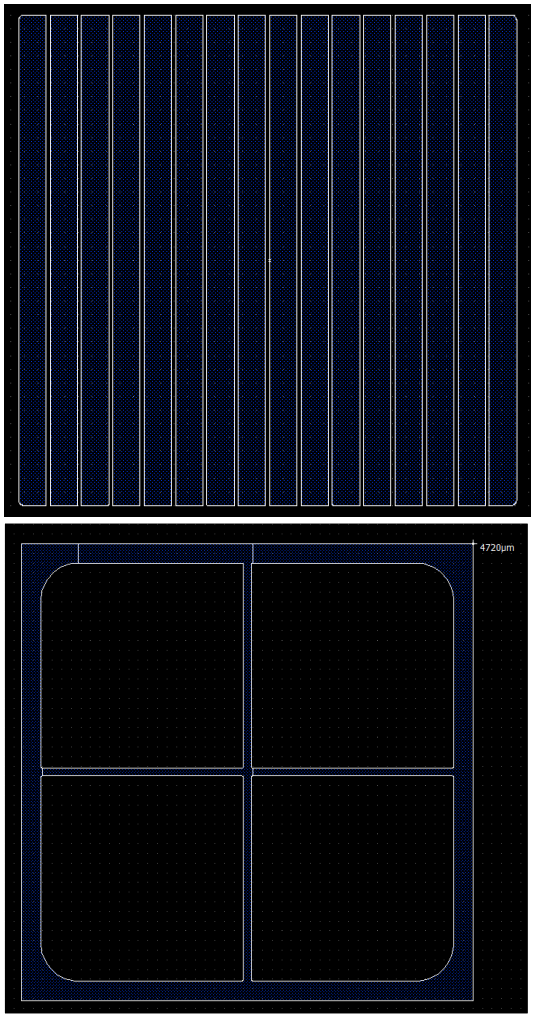
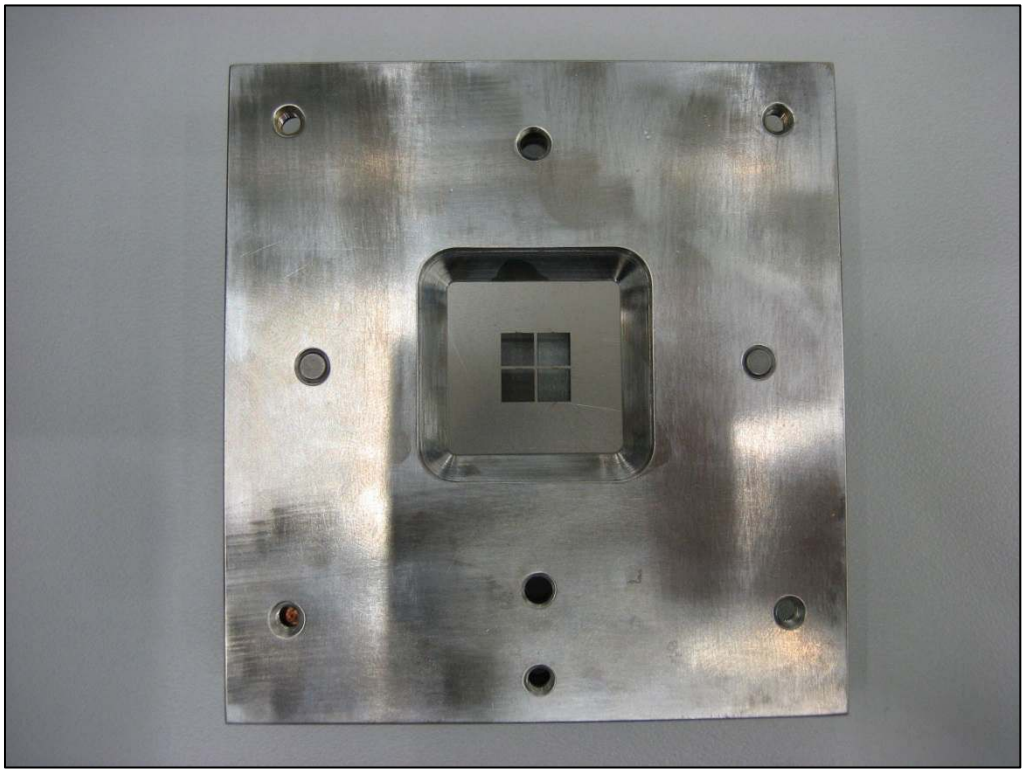
contents

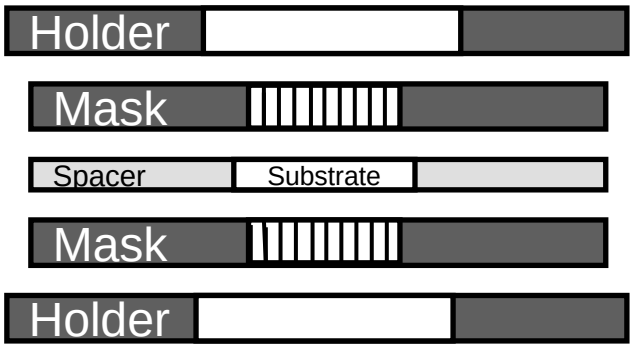
1. previous procedure
2. equipment
3. processes
4. problems & possible solutions
5. future prospects



1. previous procedure

-> mounting of the substrate in a fixture that consists of spacers and masks of thin metal foil

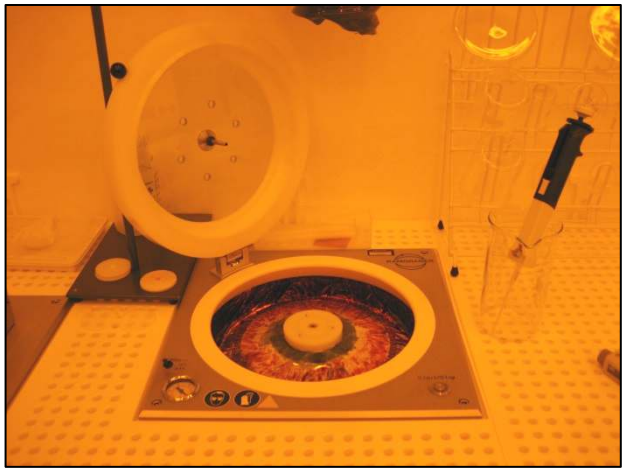




2. equipment

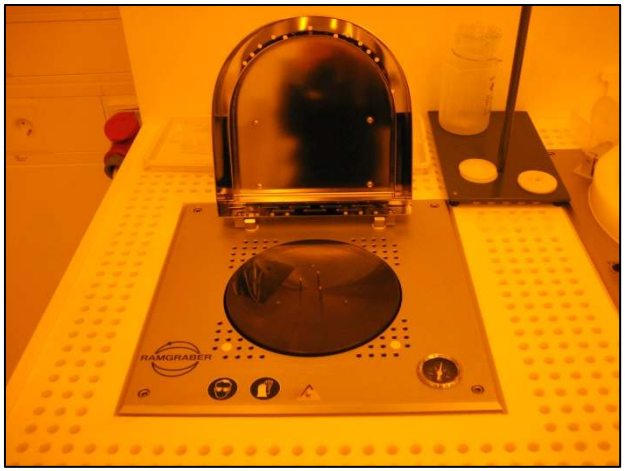
cleanroom ISO 3

2.1 spincoater & hotplate



Ramgraber Spin Coater M150:

- suitable for wafers up to 6“
- speed up to 6000 rpm
- acceleration ramp up to 1500 rpm
- process time up to 999 sec
- programmable for up to 20 recipes
- equipped with a chuck for small substrates



Ramgraber Hotplate M-HP150

* suitable for wafers up to 6“
* temperature between 20 and 200°
* process time can be set between
* 1 and 999 sec
* equipped with lift pins to allow exact process times and easy handling

2.2 laserlithography

Laser lithography system µPG101 by Heidelberg Instruments:

- diode laser with 405 nm wavelength/ 100 mW
- max. writing area 90 x 90 mm²
- min. structure size of 1 µm
- write speed of 3 mm²/ min
- multiple data input formats (dxf, cif, bmp)
- manual or automatical alignment
- 3D exposure mode

2.3 metallization

Sputtering machine Senvac L560:

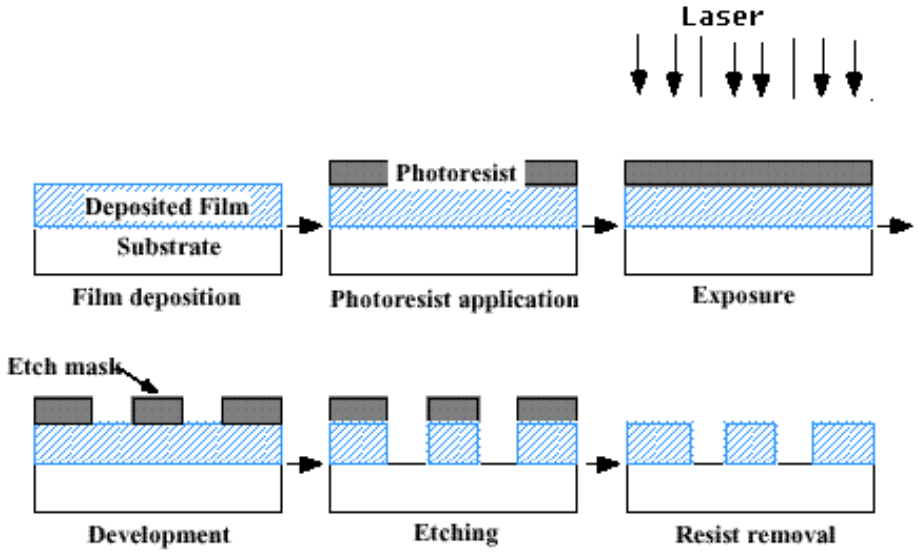
- 3 high performance 3“-cathodes for 600W HF-sputtering (sputter up)
- rotating substrate holder on top with 10 positions
- possibility for 180°-turn of the substrates

⇒ up to 3-layer-systems on both substrate sides in situ are possible

start-up not completed

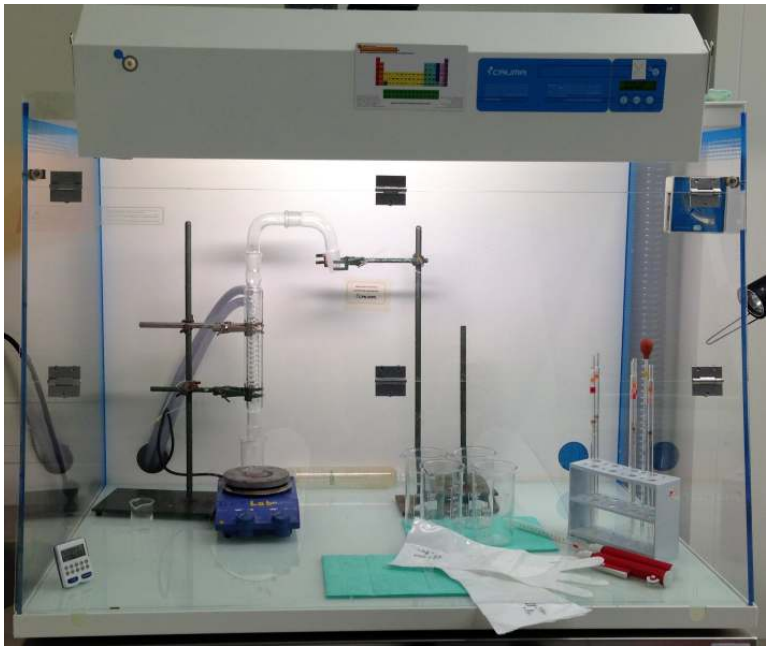
3. process for positive resist

- cleaning
- metallization
- photoresist application
- exposure and developing
- etching
- photoresist removal



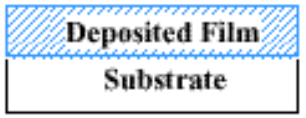
3.1 cleaning

After a microscope inspection the diamond substrate is cleaned directly before the metallization in a H2SO4/ HNO3 acid mixture, followed by an O2-plasma cleaning.



3.2 metallization

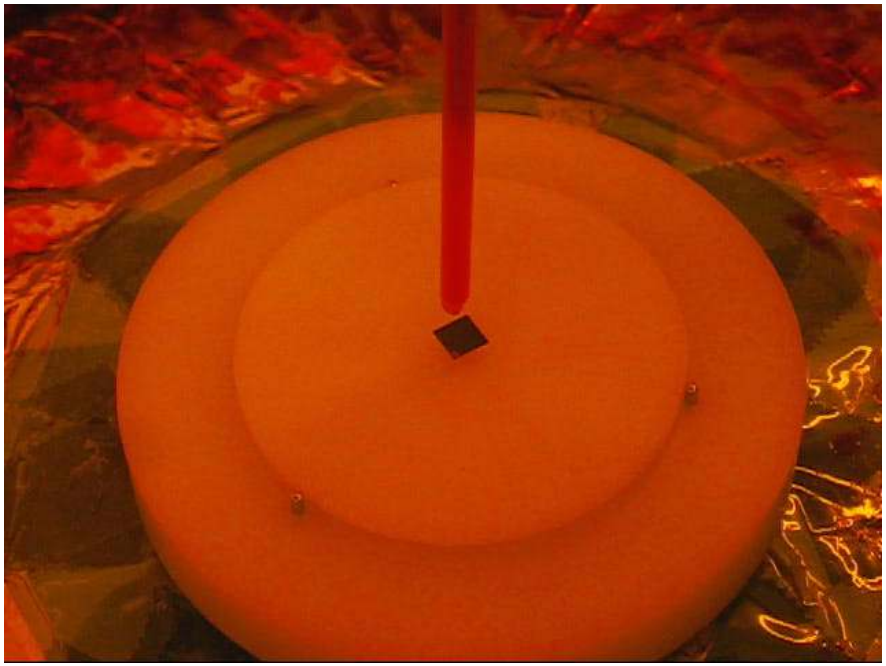
50 nm chrome and 150 nm gold are deposited by an Edwards Auto 500 sputtering machine in the GSI target-laboratory.

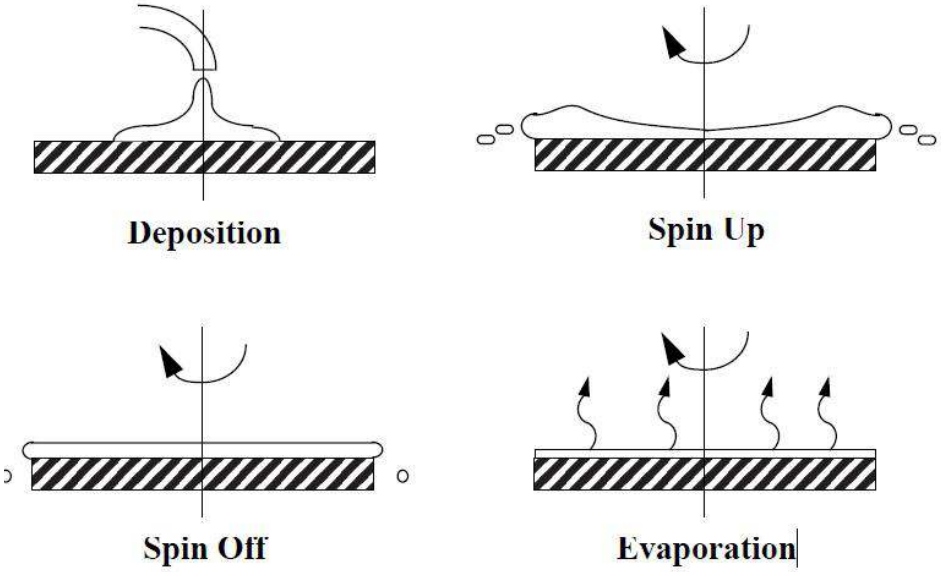


Film deposition

3.3 photoresist application

- cleaning in acetone, isopropanol and DI-water with ultrasonic energy
- dispensing of the liquid resist in the center of the substrate, spinning has to be started immediately
- prebaking of the substrate for 30 sec at 100℃ to driv e off excess solvent

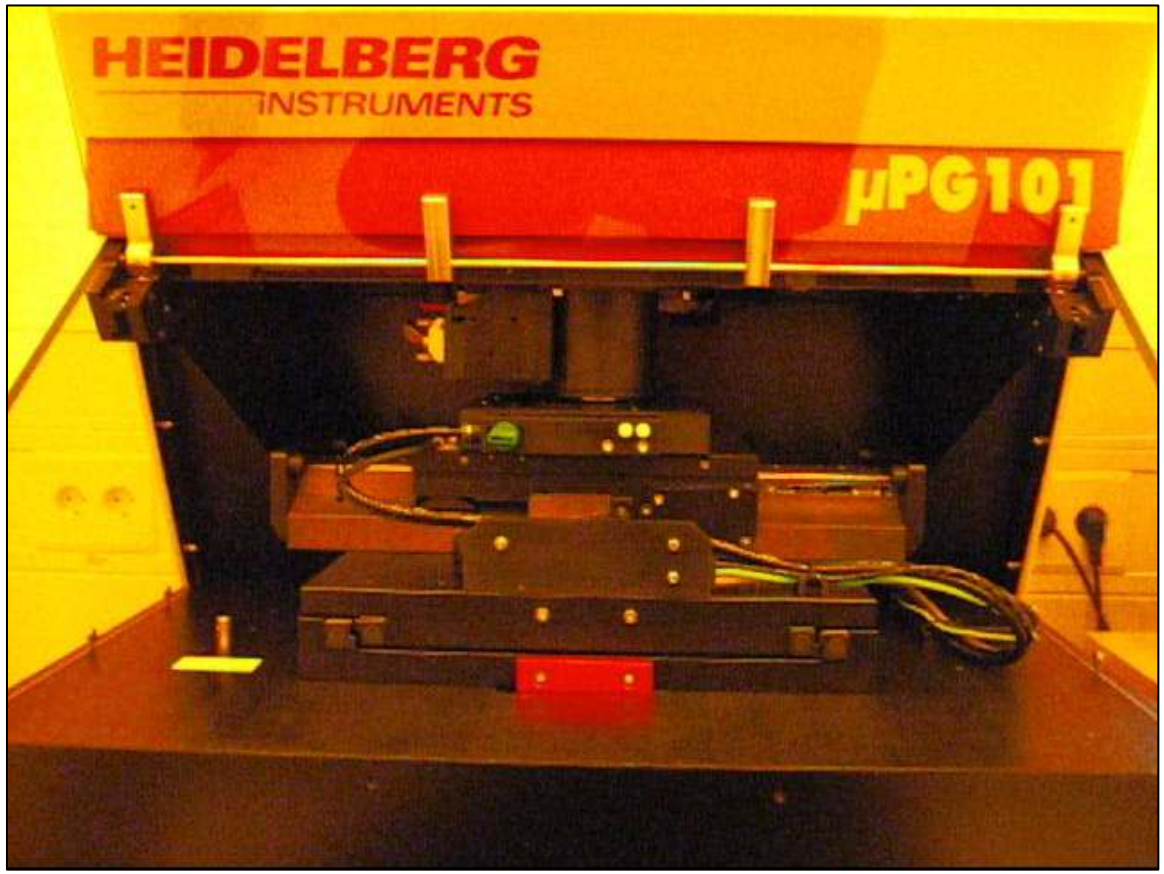


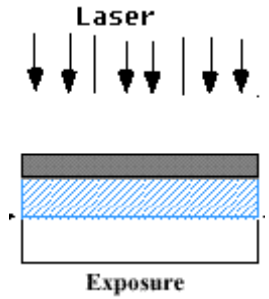


[1]

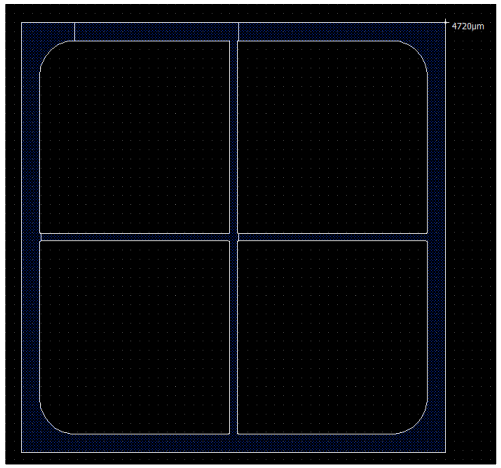
3.4 exposure and developing

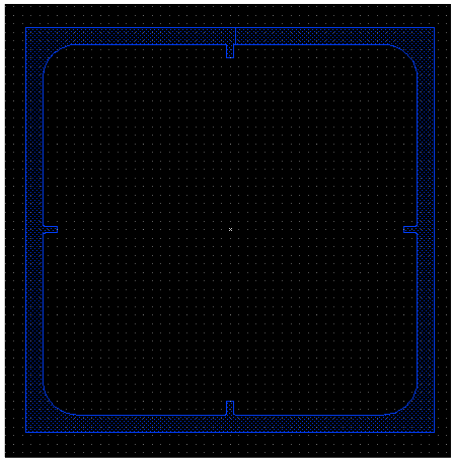
- The laser diode is then scanning the substrate with suitable parameters for the resist and the film thickness.

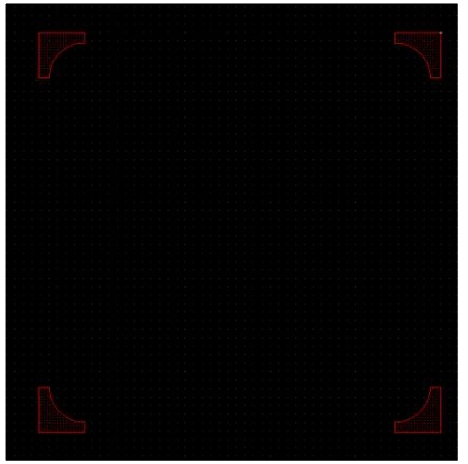




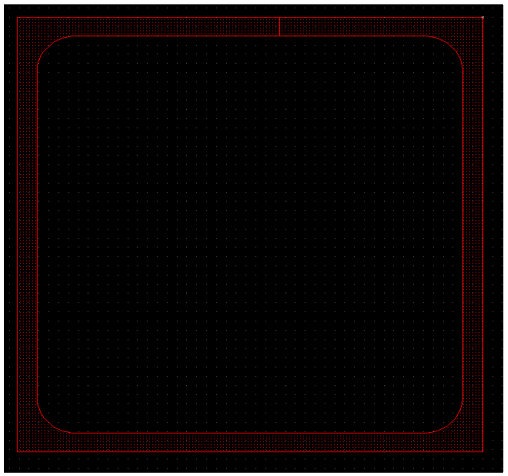
Substrate Side 1

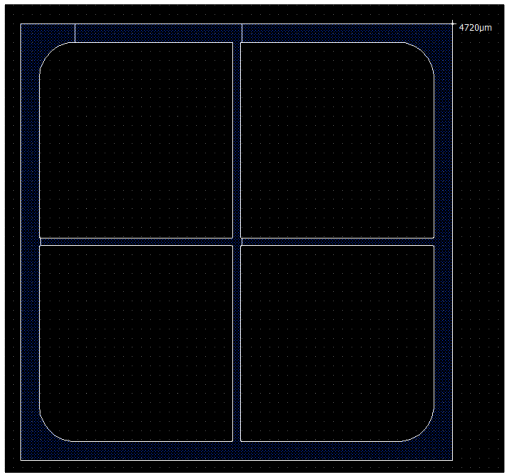


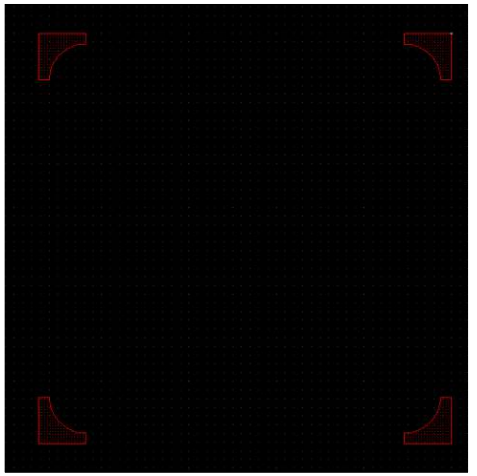




Substrate Side 2

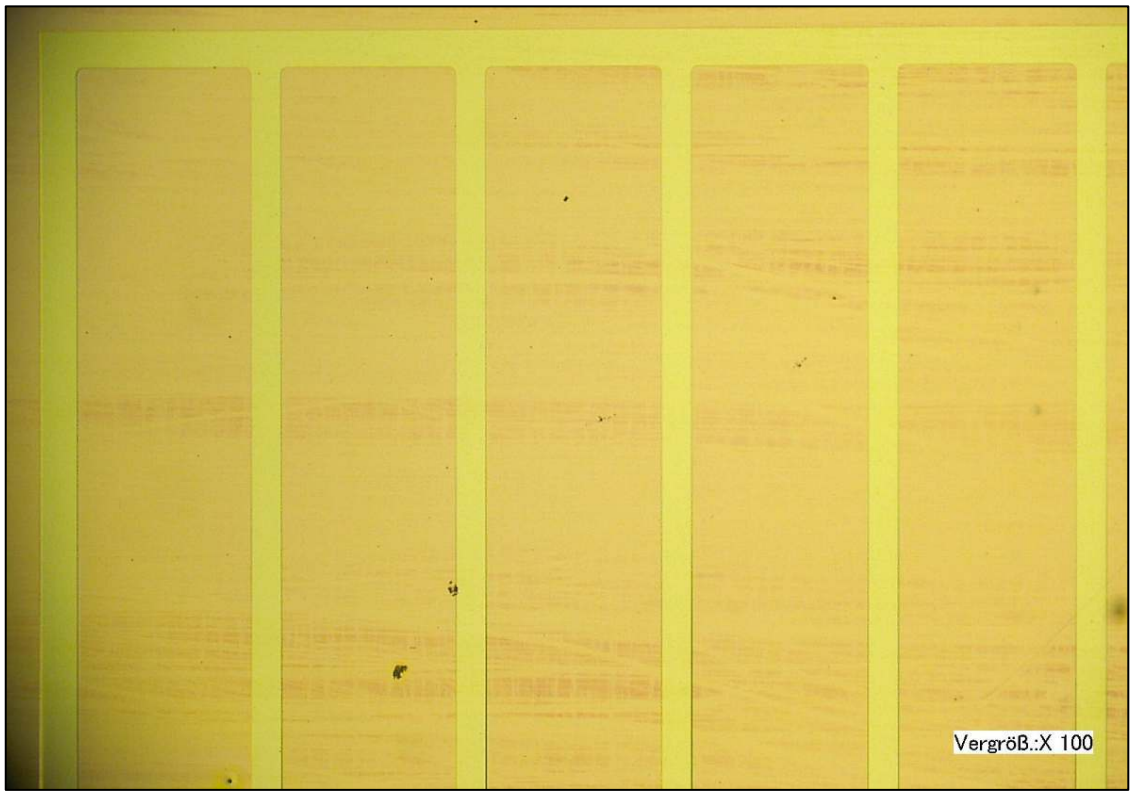


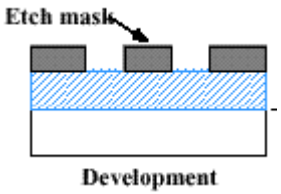




- The exposure to radiation causes a chemical change of the resist:

  -> positive resist becomes soluble in the developer by exposure

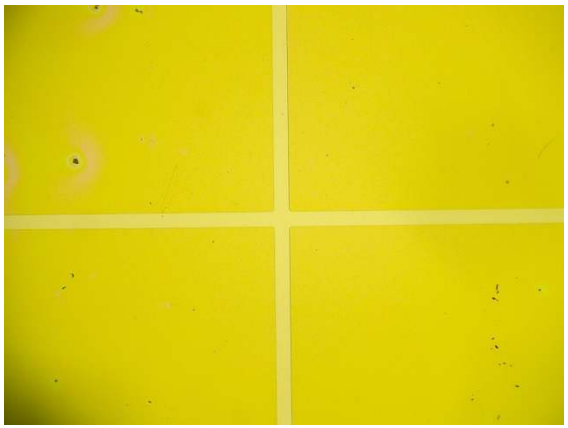


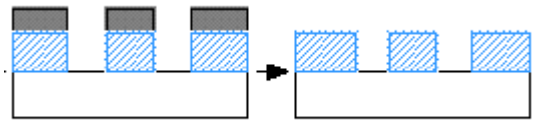


3.5 wet etching & photoresist removal

- wet etching with a suitable etching fluid (aqua regia, chrome etch,..)

1. after lithography

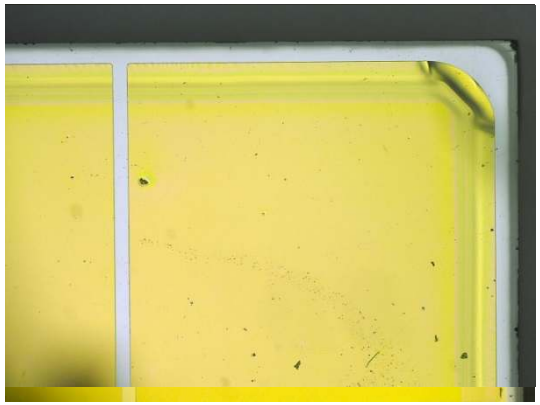


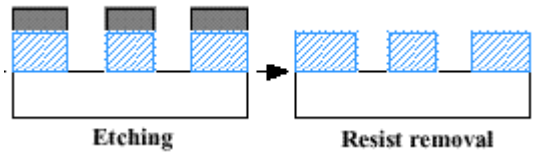


3.5 wet etching & photoresist removal

- wet etching with a suitable etching fluid (aqua regia, chrome etch,..)

1. after lithography
2. after 60 sec. aqua regia

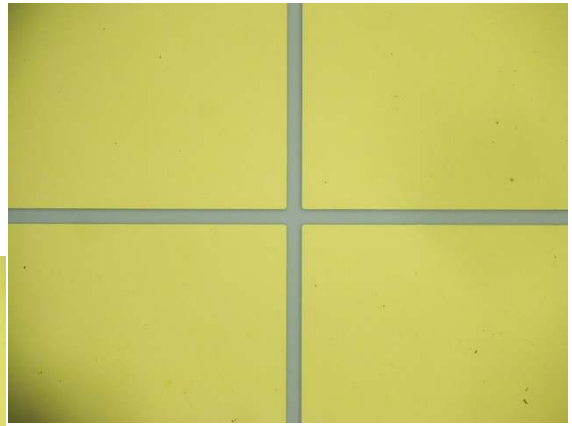


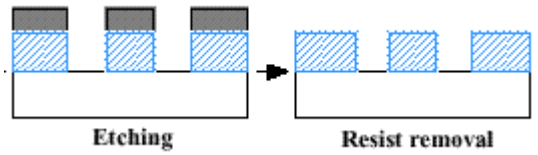


3.5 wet etching & photoresist removal

- wet etching with a suitable etching fluid (aqua regia, chrome etch,..)

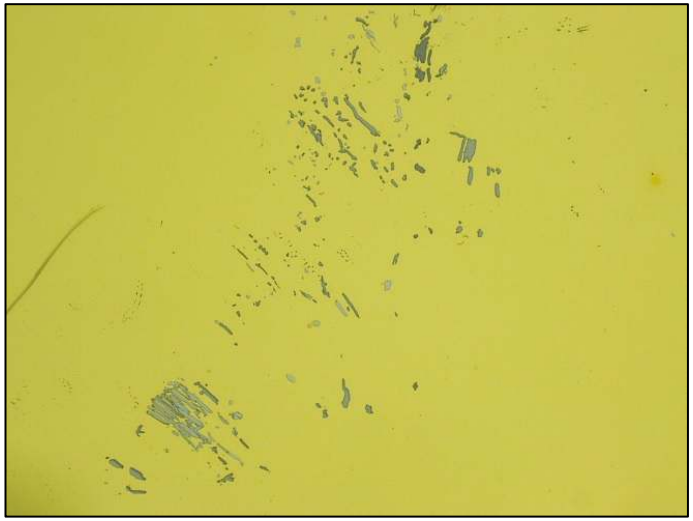
1. after lithography
2. after 60 sec. aqua regia
3. after 40 sec. chrome etch





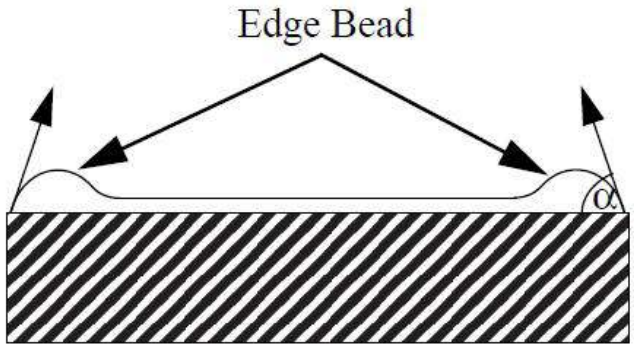
4. problems and possible solutions

4.1 damages caused by ultrasonic cleaning

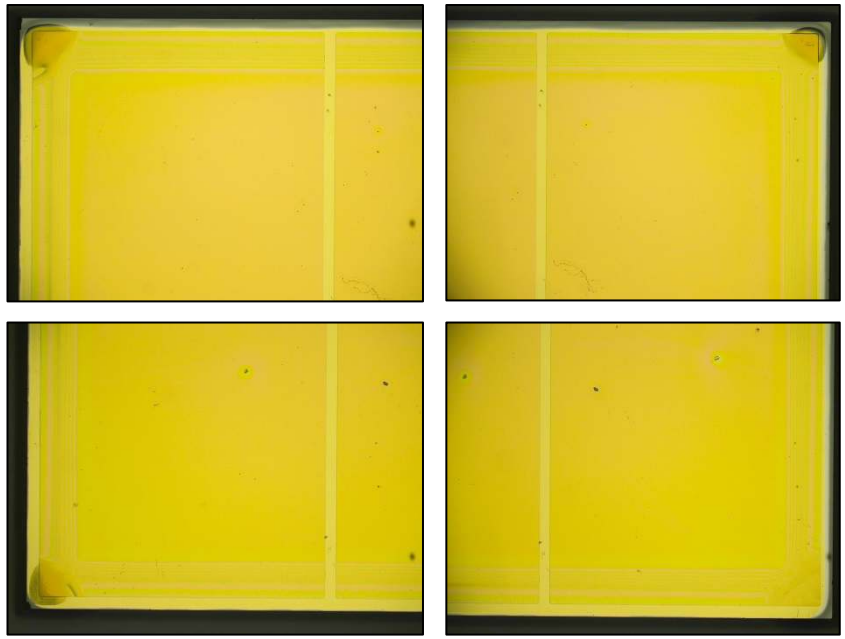


-> using an ultrasonic bath with adjustable intensity could solve the problem

4.2 build-up of edge beads caused by the rectangular shape of the substrate:



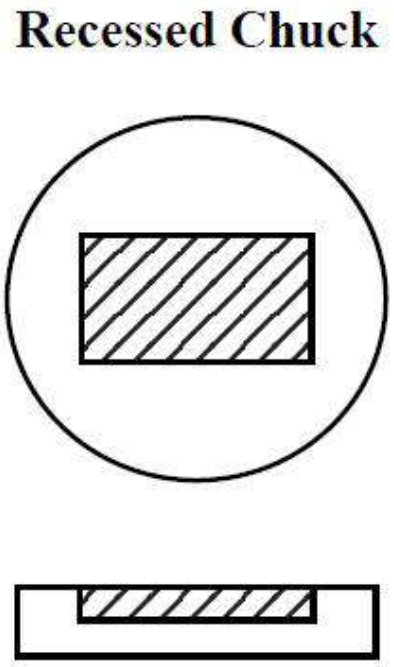
[2]



The solvent evaporates during rotation, the resist becomes more viscous.

-> coating with other resists of different viscosities

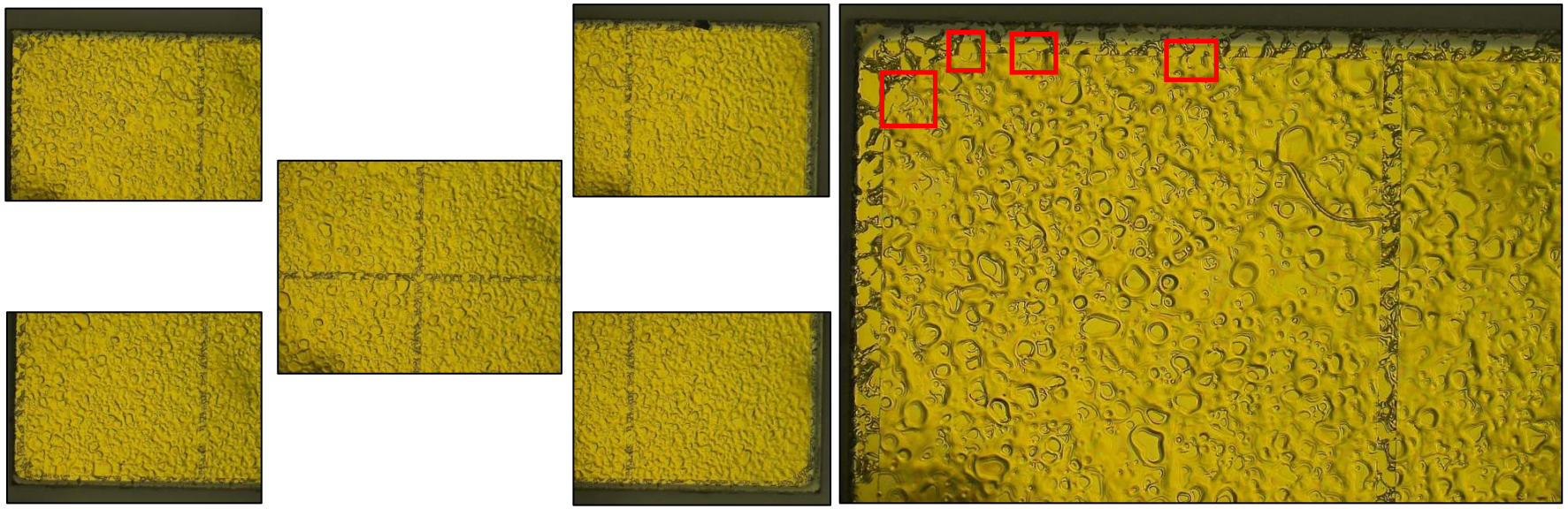
-> use of a recessed chuck to avoid the rectangle shape



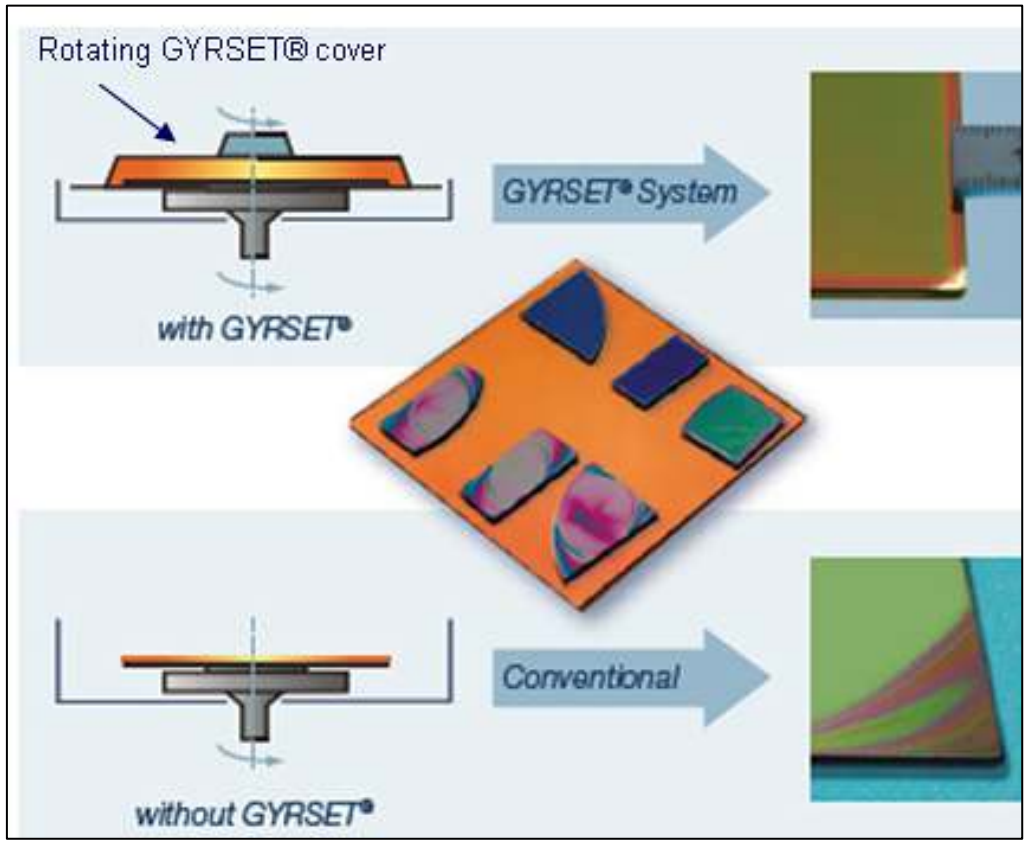
[2]

-> spraycoating:

the resist is applied by a spray head that is scanning across the substrate

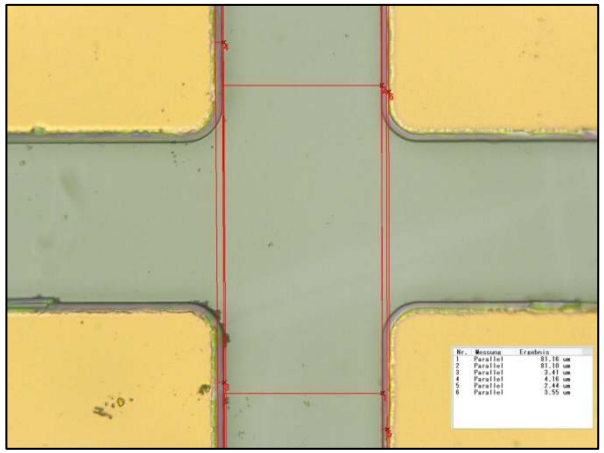


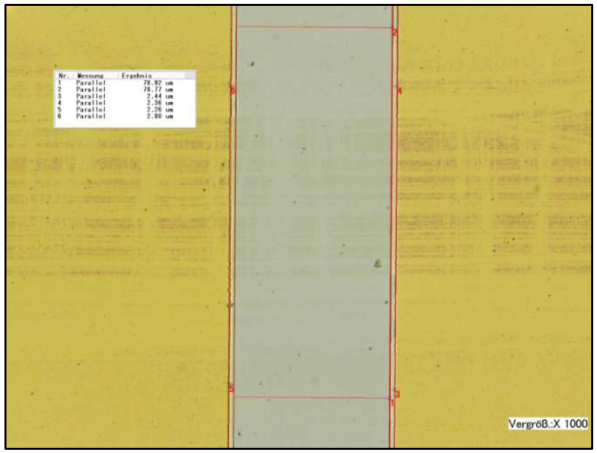
-> Karl Süss Gyrset:



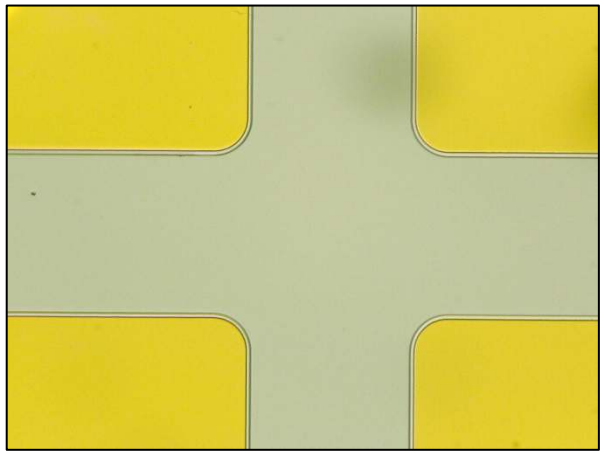
A cover is lying above the substrate and spin coating is done in a solvent atmosphere.

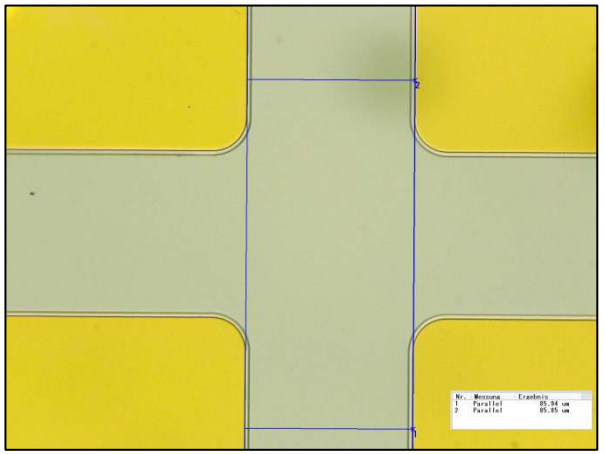
4.3 undercut of the resist during wet etching:





-> etching experiments with other etching fluids





5. future prospects

5.1 metallization in the detector laboratory with up to 3 layers, both sides

5.2 lift-off-process

-> another laser diode is required

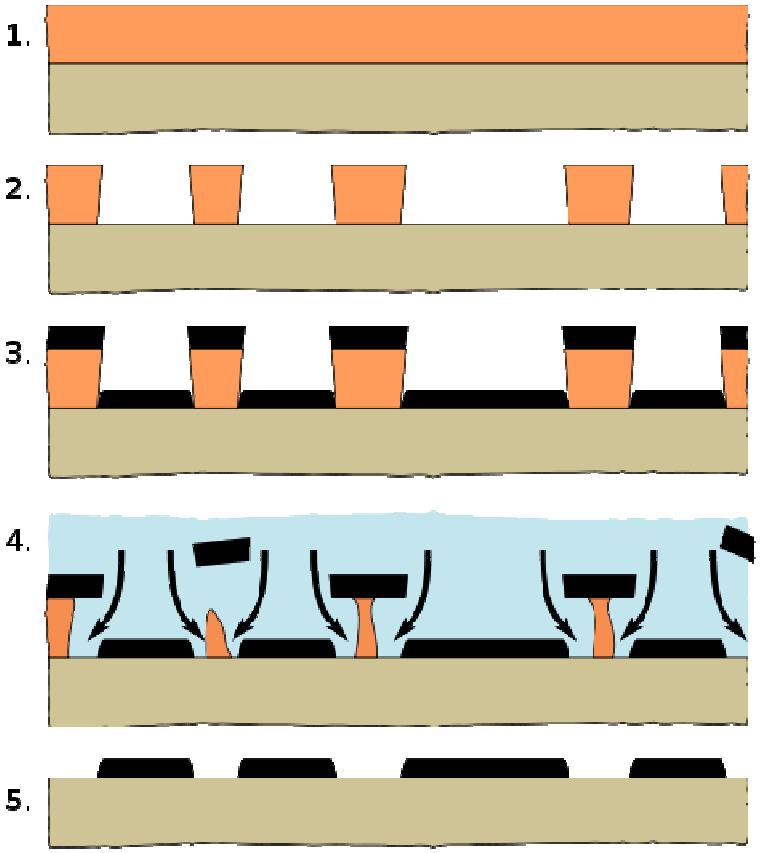
5.3 3D-lithography

5.1 metallization in the detector laboratory

rotatable substrate holder with 10 positions

target materials: gold, platinum, chrome, titanium, aluminium, carbon

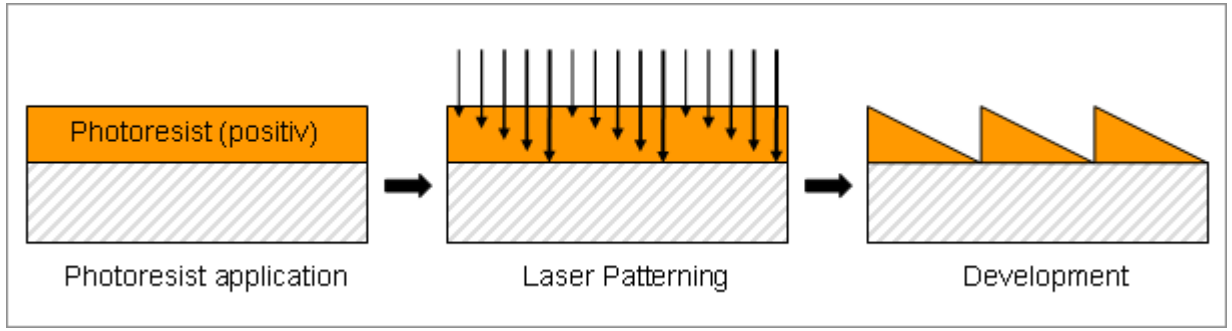
5.2 lift-off-process

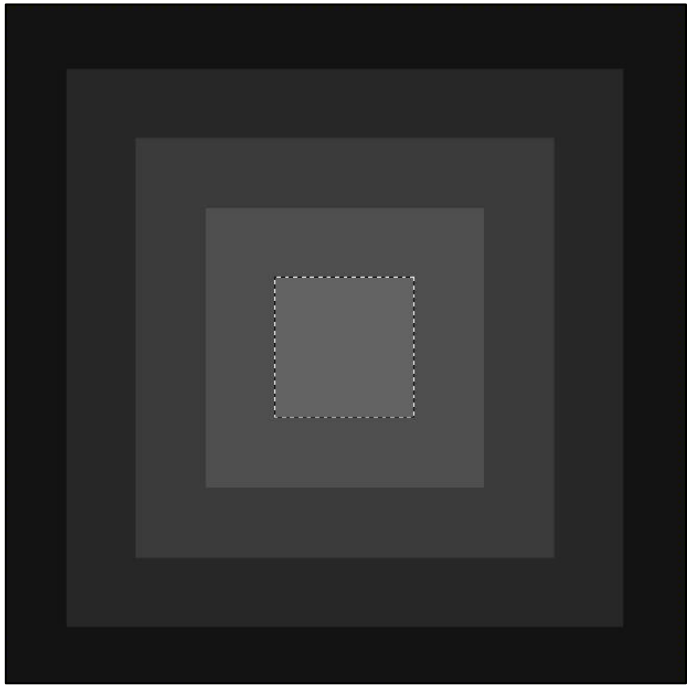


1. photoresist (negative)
   substrate
2. structuring with exposure and development
3. deposition of metal all over the substrate
4. removal of the photoresist and stripping of the unneeded metal layer
5. structured metal layer

[3]

5.3 3D-lithography





By using gray scale lithography it´s possible to create a 3D-microstructure in a thick layer of photoresist.
The resist is exposed with a variable dose and after the development process the 3D-structure will remain.

[4]

List of references

[1] Bornside, D.; Macosko, C.; and Scriven, L. "On the Modelling of Spin Coating“,Journal of Imaging Technology, Vol. 13, Aug. 1987, p. 122.

[2] Gregory A. Luurtsema: „Spin coating for rectangular substrates“, July 1997

[3] Wikipedia

[4] Heidelberg Instruments Mikrotechnik GmbH

Thank you for your attention!