Photolithography Practical Issues – illustrations & explanations

Prepared by Dr. Boris Yofis

Photolithography process failures – illustrated & explained

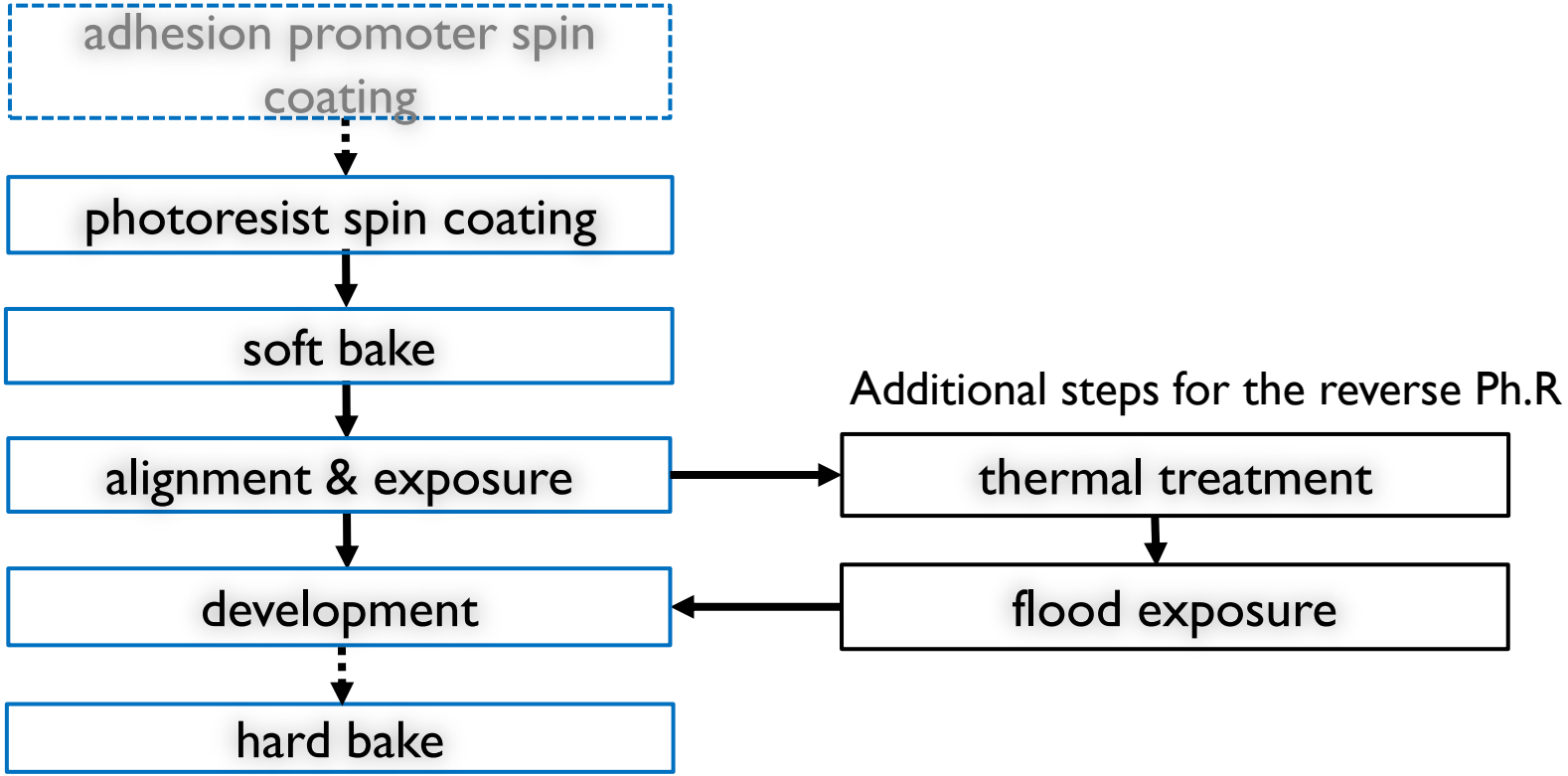
- The presentation describes the using both positive and reverse photoresists (PhR).
- The presentation mainly concerns the important practical issues rarely discussed in the literature.
- For the convenience, the main set of illustrations, is presented as a sequence of the photolithography steps in the following manner:

-Goal of a step.

-The step short description.

-Typical errors leading to failures.

General Photolithography Procedure



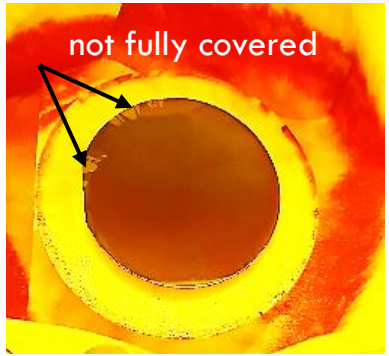
Photoresist Spin Coating

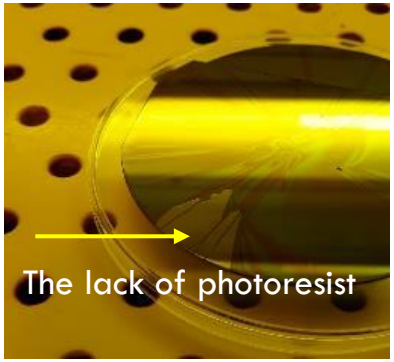
- Process goal:
  - formation of the fully covering, uniform, defect free photoresist layer of the required thickness.
- Short description:
  - a some quantity of photoresist is applied to the surface of the sample and the spinner starts to rotate at a specified speed.
    2 stages of rotation:
    1. Slow rotation – for reliable coating of the sample surface by photoresist
    2. Fast rotation – for achieving of the photoresist specific thickness
- Typical problems:
  - Incomplete sample coating
  - Local non-uniformities (rays on the surface from the center to the edge).
  - Edge effects

Incomplete sample coating.

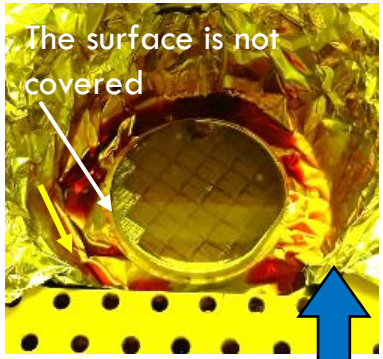
Resist is not at the center

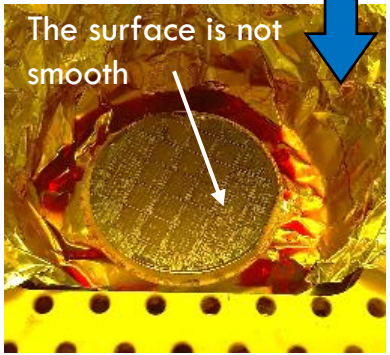
Resist deficit before spin





Resist deficit before spin





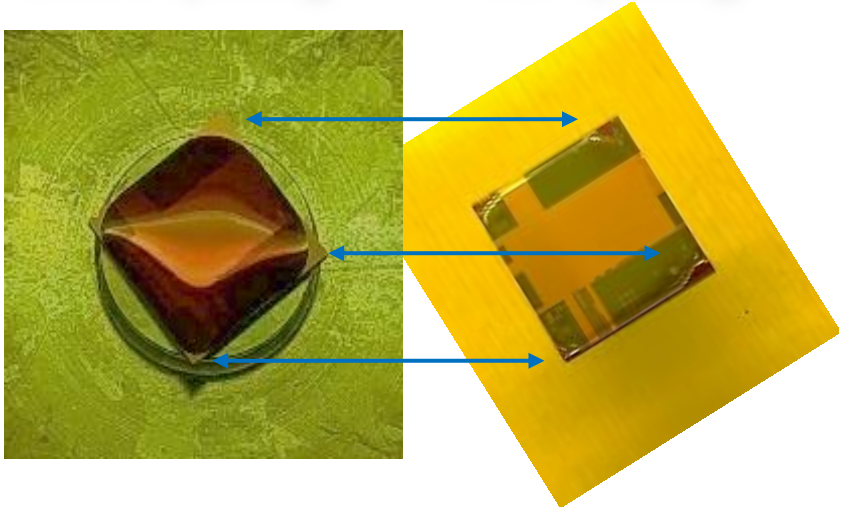
before the next photolithography

Incomplete sample coating

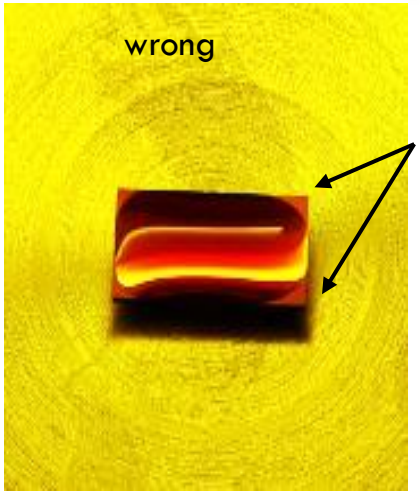
small and nonstandard samples must be fully covered by photoresist

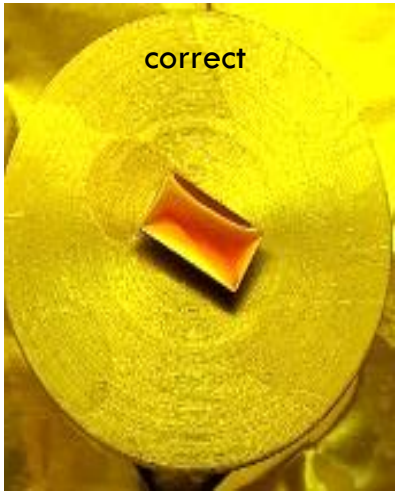
Before spinning

After spinning



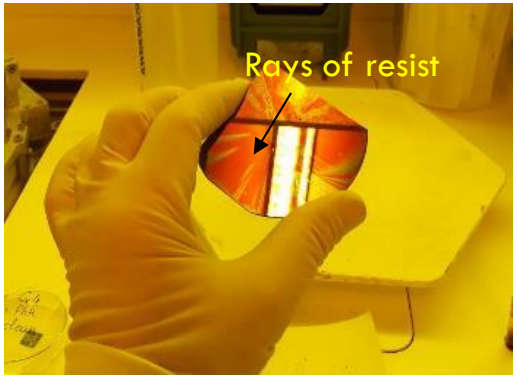
Before spin



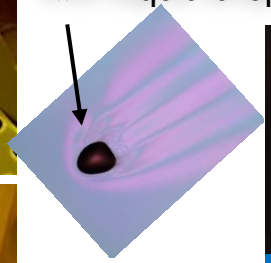


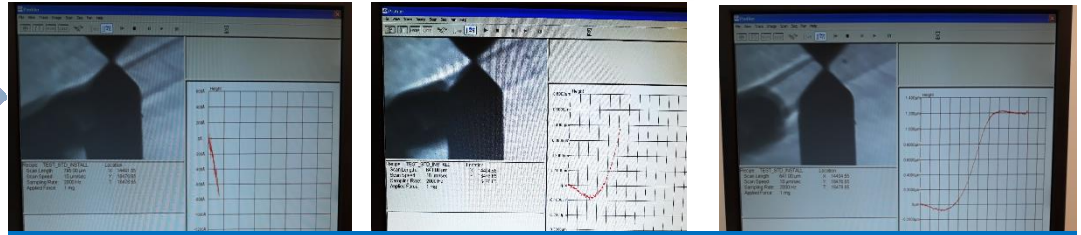
Local non-uniformity of the Photoresist

The defects are easily observed by examining the samples at different angles under the room light

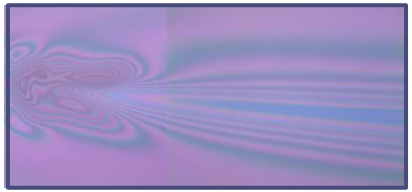


The cause of this effect is small particles or located on the surface of the sample or transferred by PhR. The second way is most often, and these particles are dry PhR remnants from the bottle neck or the tip of the pipette. These dry particles are similar with liquid drops. Second reason for the particles is chipping after scribing or dicing.



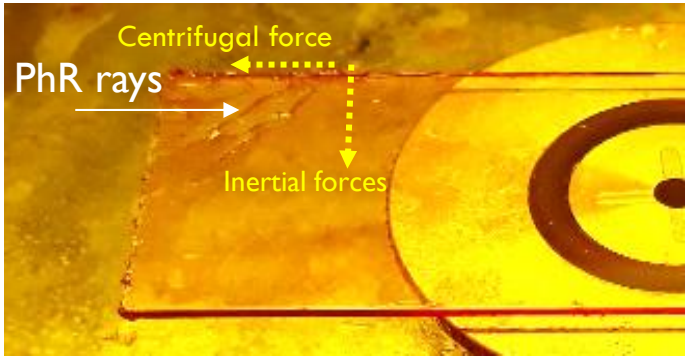


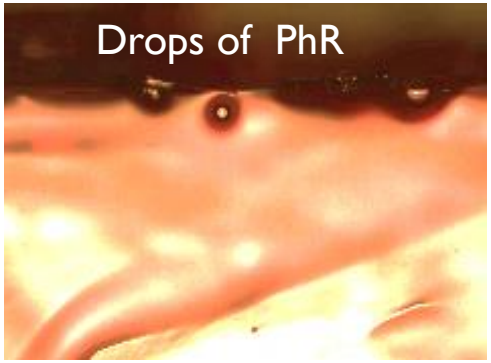
The thickness variation of PhR following the particle, measured by a profilometer

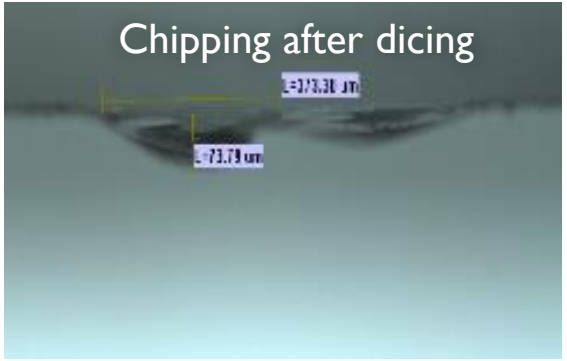


Sometimes this effect is observed without the presence of these particles. Experience allow suggests that even in this case there is the same reason, but in the second stage of rotation with increasing speed, the particle is washed away.

Local non-uniformity of the resist



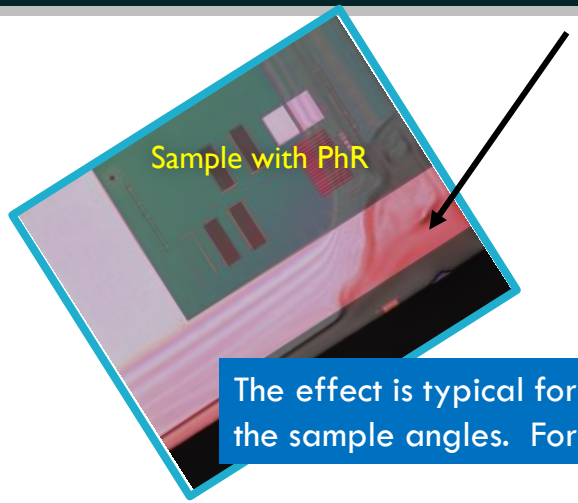




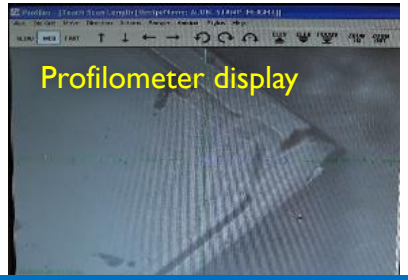
- The PhR drops are generated around the defects near the edge of the substrate during the slow spinning step.
- During the fast spinning step, the PhR droplets are spread in the form of the protruded rays

Solution - polished chamfers at the substrate edges

The edge effect - accumulation of resist near sample edges



leads to an increase in the thickness of the

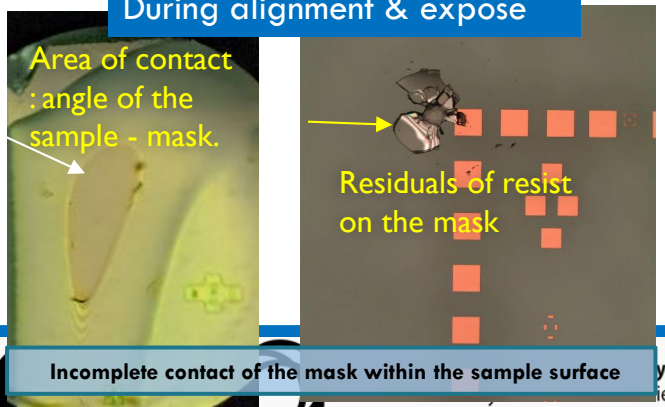


AZ 1505, spin 3000rpm the thickness increase is 5 microns.

The effect is typical for samples with a non-standard form. It is found to be very strong in the region of the sample angles. For the case of the wafers, the effect is a significant for the diameter of 3inch and less.

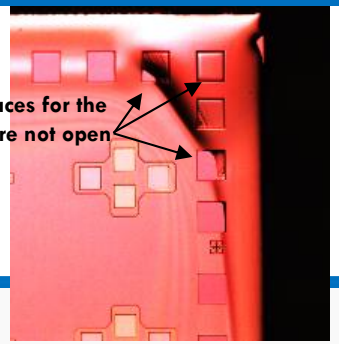
Influence of this error on the next steps.

During alignment & expose



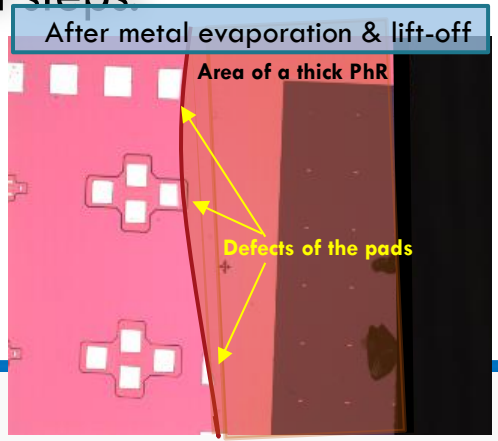
Incomplete contact of the mask within the sample surface

During development



There is not a development in area of a thick PhR

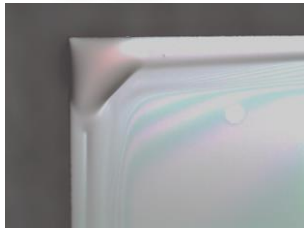
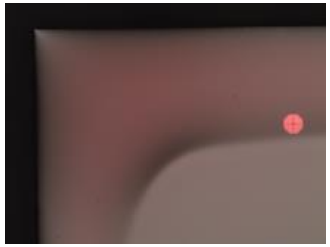
After metal evaporation & lift-off



The influence of some basic parameters. on the edge effect

Spinner rotation speed

Resist viscosity

	3000 rpm, 30 sec	5000 rpm, 30 sec	+ add step 5000rpm, 30 sec.	Use of HMDS 5000 rpm, 30 sec
AZ1505				
AZ5214E				
AZ 4562				

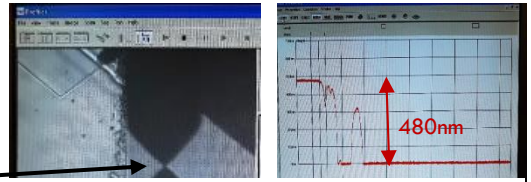
Remove the photoresist from the edge of the sample by expose and development.

This process is recommended to ensure that the mask is pressed against the sample

resist removal from angles only

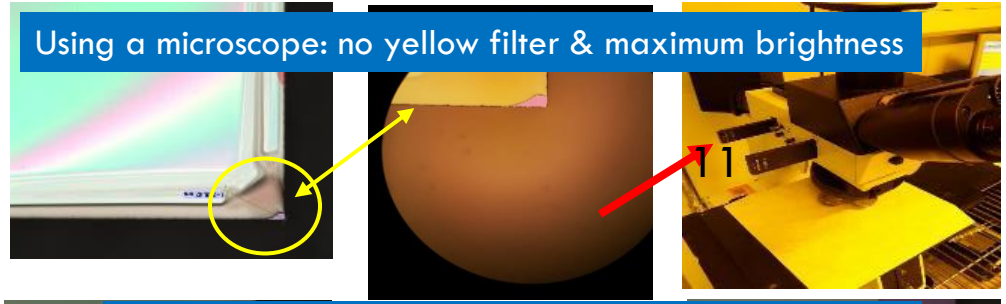
Using a shield & using shield mask aligner exposure

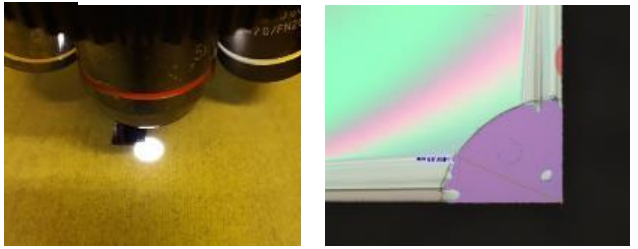
Profilometer



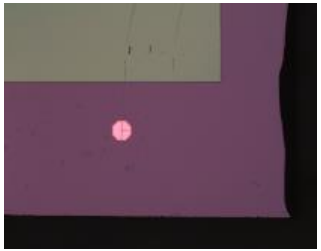
Thickness of PhR on surface equal to 0.48μ on angles up to 5μ

Using a microscope: no yellow filter & maximum brightness





Using a shield & using shield mask aligner exposure



Full resist removal from the edges

The conditions for exposure and development are chosen in each case, it is, approximately, possible to recommend: exposure 2-3 min, development 20 - 30 sec.

Soft bake: *Hot plate: 95 - 110°C 1 - 2 min ; Oven: 90 - 110°C 5 – 20 min.*

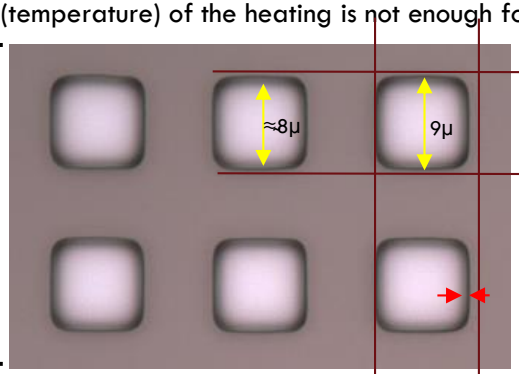
Goal of process is:

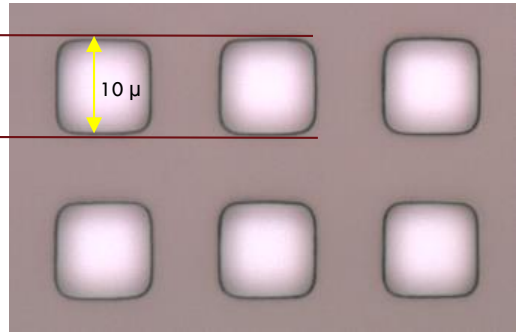
A removing (evaporation) of a solvent and a formation of PhR layer.

Typical problems of this phase:

The duration (temperature) of the heating is not enough for complete removal of the solvent.

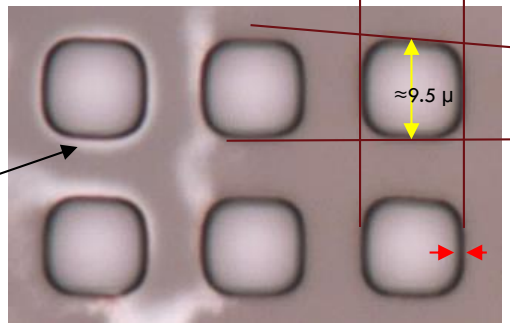
The same process with:
Soft bake: 100°C,
45 sec.
Edge of PhR is not sharp, dimension is decreased.
The increase in exposure time will not improve the pattern





Good result:
AZ 1518, h = 1,75μ
Soft bake: 110°C, 1 min
Exposer: 4.5 sec.
Development:
35 sec.

Increasing the development time leads to distortion of the pattern and PhR rising from edge



Very typical expansion of the feature edge - a big angle slope of the developed PhR

Alignment & Exposure

Goal of the step:

- Alignment between actual layer and the layer patterned before.

Short description:

- The sample and mask are placed within the mask aligner. The movable chuck with sample moves to achieve the proper alignment between sample and mask alignment marks.
- After alignment the PhR is exposed to UV light during the exposure time.

Typical errors leading to failure:

- Alignment imperfections –are detected using alignment marks.
- Contact imperfections between mask and sample – non-uniformities in patterned structures.

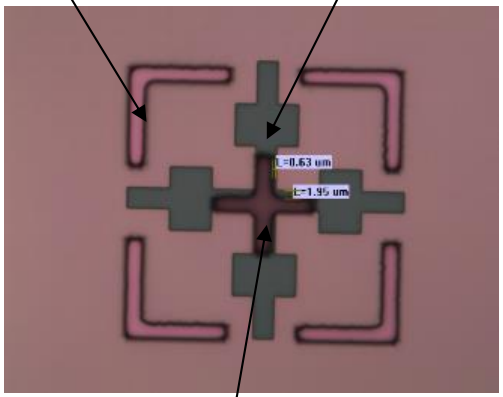
Alignment & Exposure

Alignment between marks for 3 sequential lithographic layers

Misaligned layers

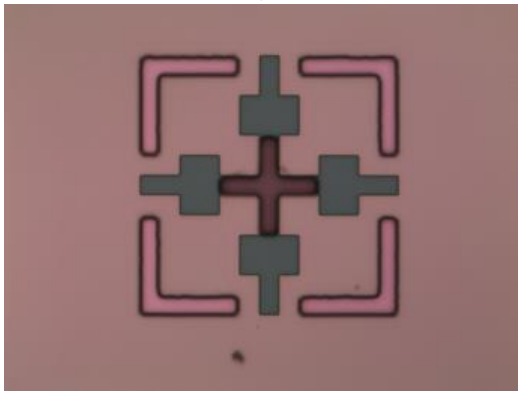
1st layer marks

2nd layer marks



3d layer marks

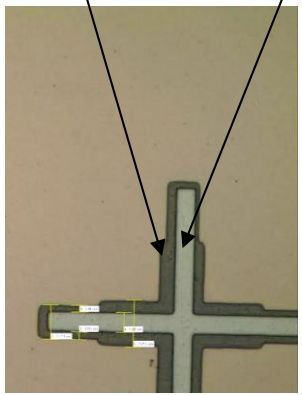
Perfect alignment



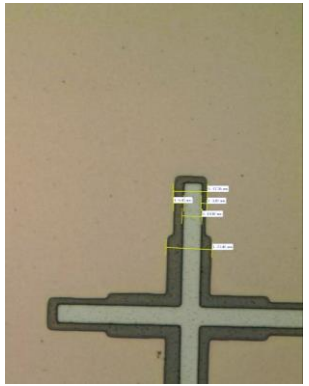
Alignment between two lithographic steps

1st step marks

2nd step marks



Y-shift

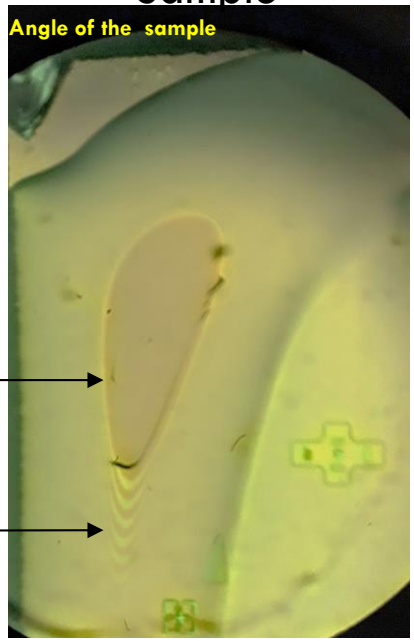


X-shift

The mask touch to sample is not good enough (or is non uniform, or there is distance)

Repetition from page 8

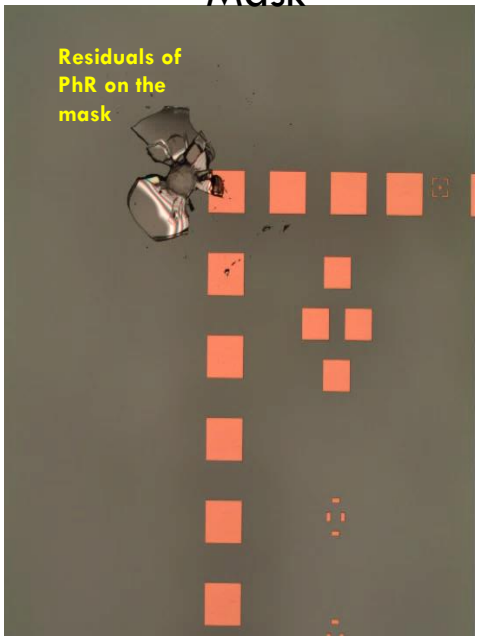
Sample



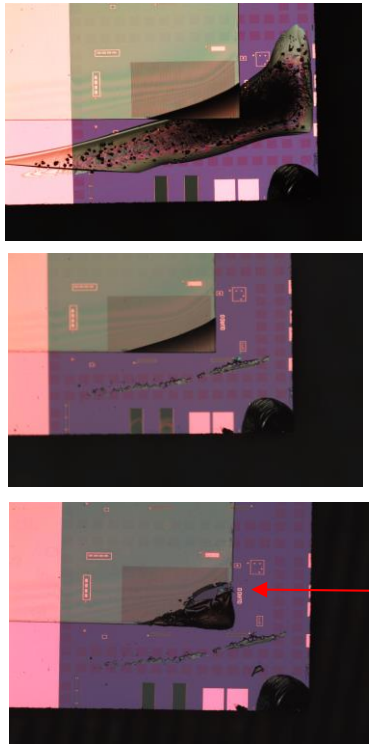
The area of the photoresist is broken by pressure

Sign of distance is Newton's Rings

Mask



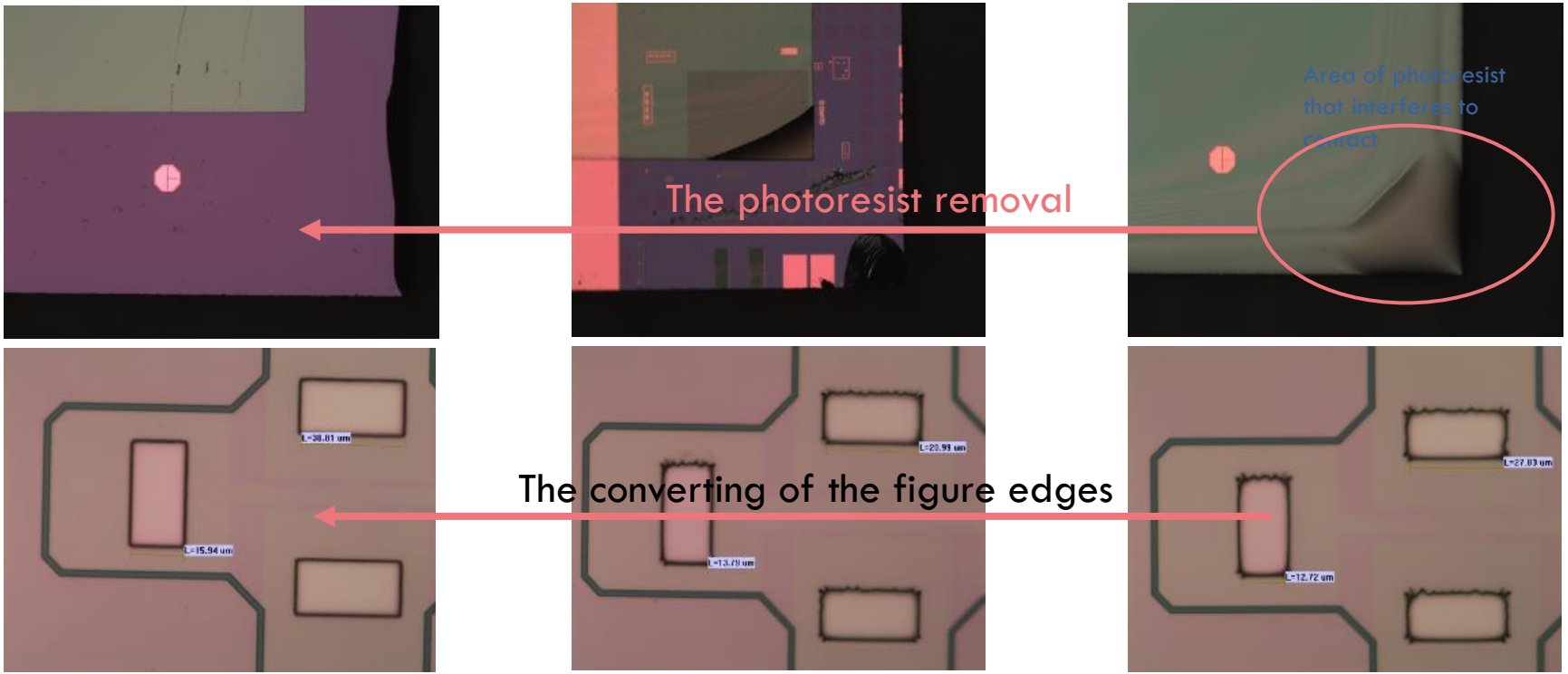
The removing of edge effect is not completed



The area of the photoresist is broken by pressure

The mask touch to sample is not good enough (or is non uniform, or there is distance)

(continuation)



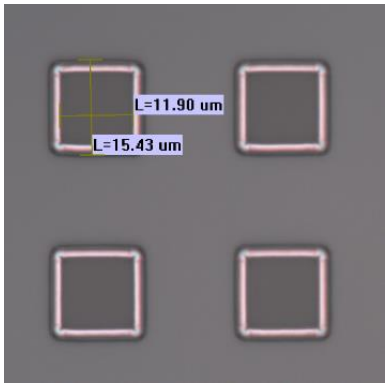
Development

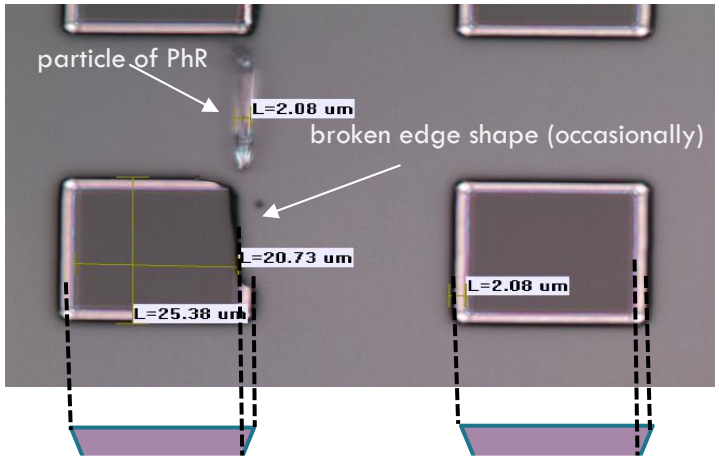
Goal of the step: to remove the soluble part of PhR; create pattern within PhR.

Description: the sample with resist is placed in a vessel (e.g. in Petri dish) with the developer for the specific time.

Typical errors leading to failure: Time of development is not right.

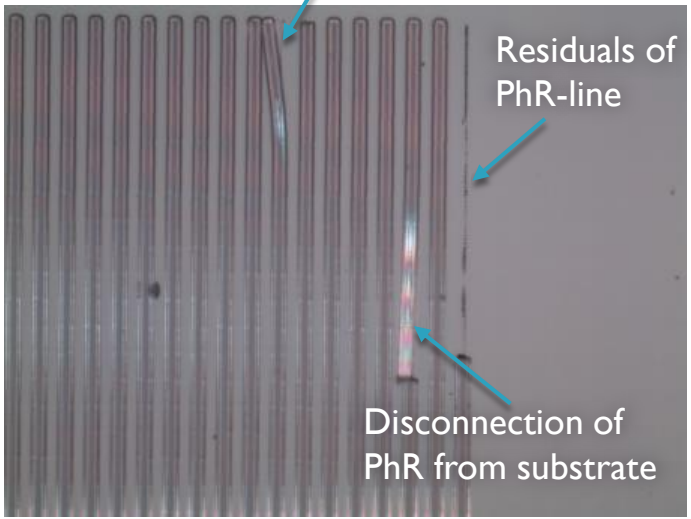
Top view of the revers PhR after development (Illustration for right development)

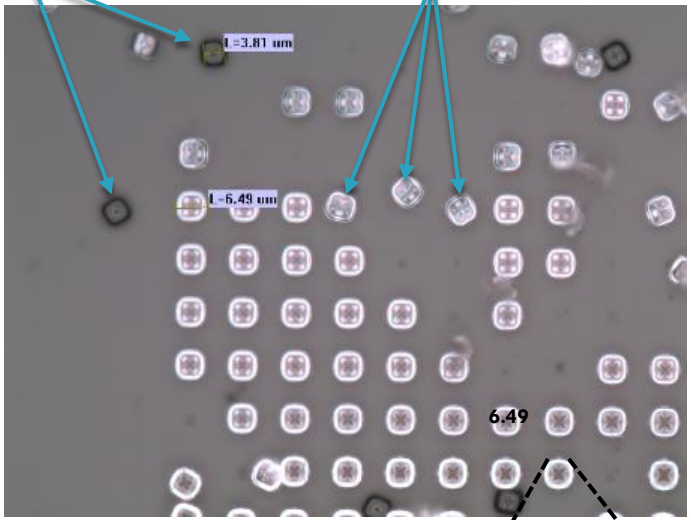




Development

Overdevelopment or the first exposure (reverse Ph.L.) is not enough (see also page 11)





Development

Underdeveloped PhR