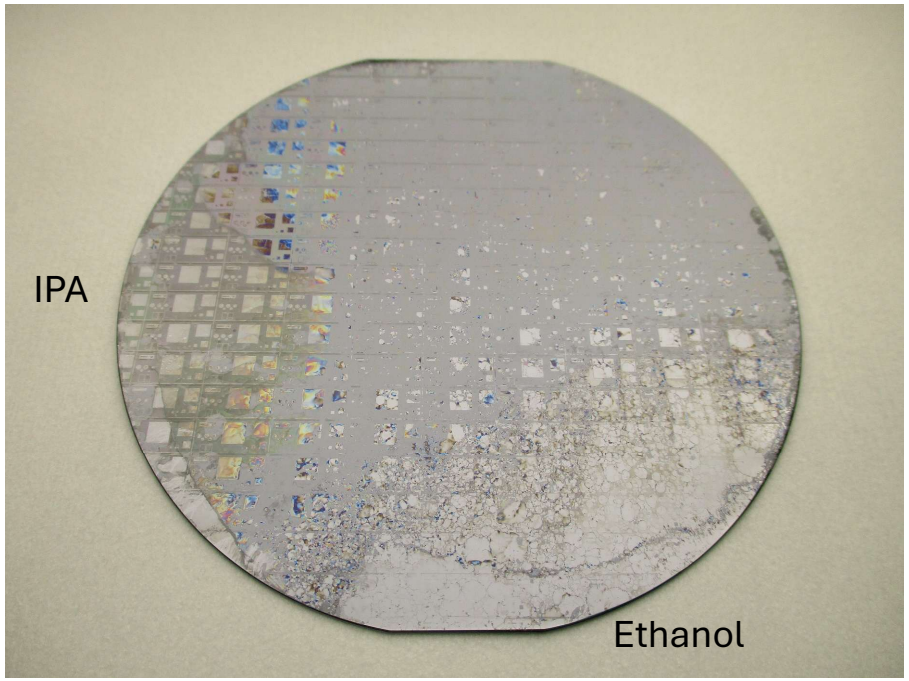
Testing if the negative UV resist nLOF can be developed using organic solvent

Thomas Anhøj, DTU Nanolab, August 2024

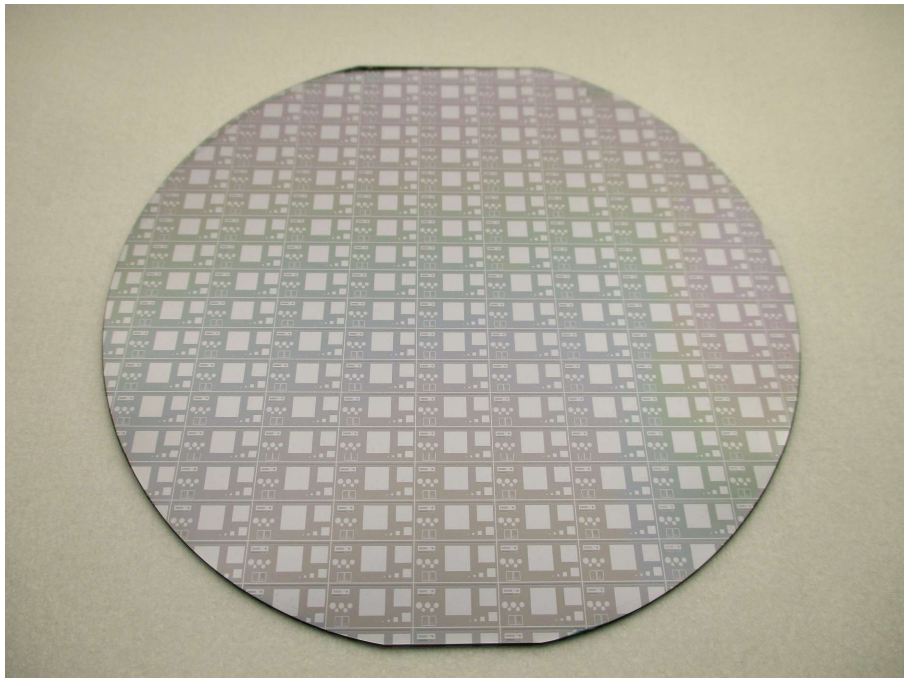
First test, Wafer 07

- 2µm AZ nLOF 2020 coated on silicon (3300rpm, 30s. Soft bake: 110°C, 60s)
- Exposed using mask aligner (121mJ/cm^2 @365nm)
- Post-exposure bake (PEB) 110°C, 60s
- Development
  - Ethanol from spray bottle → completely dissolves everything
  - IPA from spray bottle → dissolves the un-exposed areas faster than the exposed areas



First test, Wafer 08

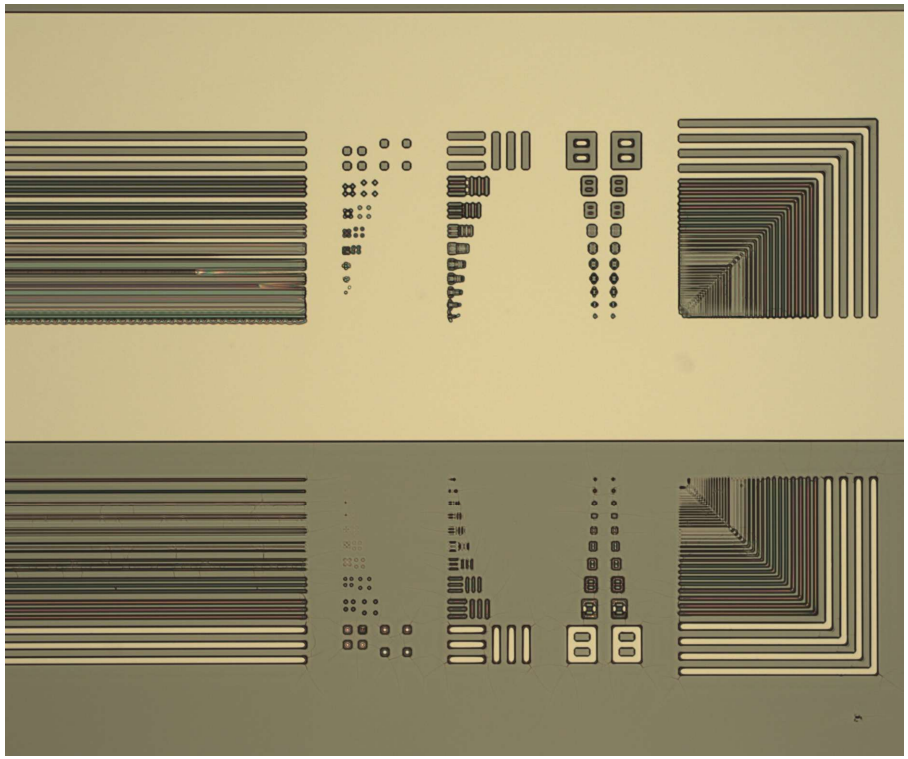
- 2µm AZ nLOF 2020 coated on silicon (3300rpm, 30s. Soft bake: 110°C, 60s)
- Exposed using mask aligner (121mJ/cm^2 @365nm)
- Post-exposure bake (PEB):
  - First 110°C, 60s
  - Later 120°C, 120s
- Development
  - IPA from spray bottle → dissolves only un-exposed areas, but leaves residues
  - Ethanol from spray bottle → dissolves only un-exposed areas, looks cleaner
- Second development: 5-10s ethanol from spray bottle followed by 10s rinse with IPA from spray bottle, dried with N_2-gun



This looks promising :-)

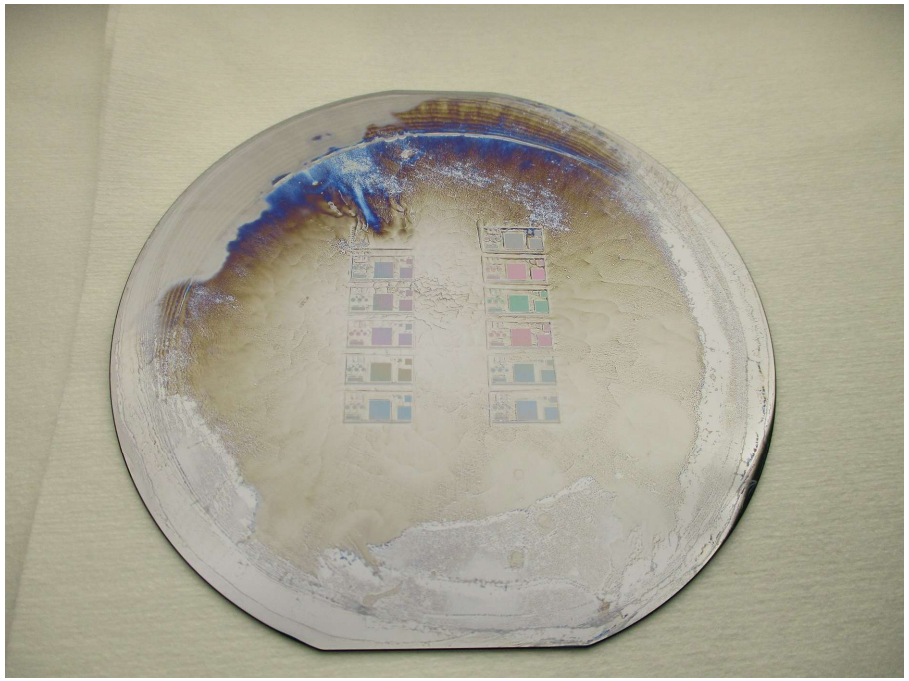
Conclusions from first test

- Ethanol is more aggressive than IPA
- Standard processing with PEB at 110°C doesn't survive solvent development
- PEB at 120°C seems to be viable
- Resolution is at least 10µm (influenced by proximity gap effect due to dirty mask)



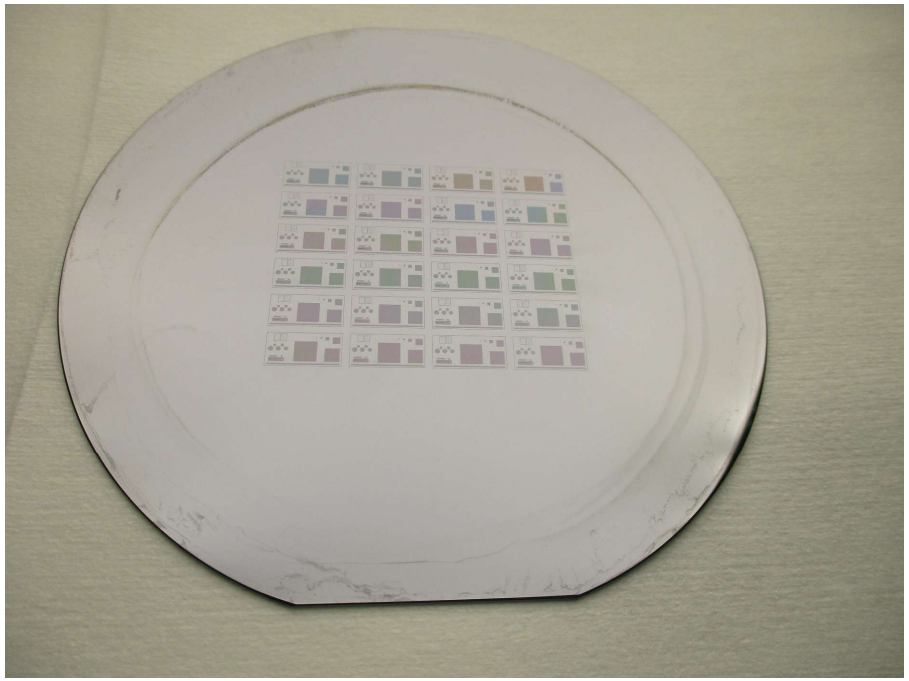
Second test, Wafer 11

- 2µm AZ nLOF 2020 coated on silicon (3300rpm, 30s. Soft bake: 110°C, 60s)
- Exposed using maskless aligner (100-320mJ/cm^2 @365nm)
- Post-exposure bake (PEB) 110°C, 120s
- Development: 10s ethanol in beaker followed by 10s IPA rinse in beaker, dried with N_2-gun → residues bleed from the exposed areas



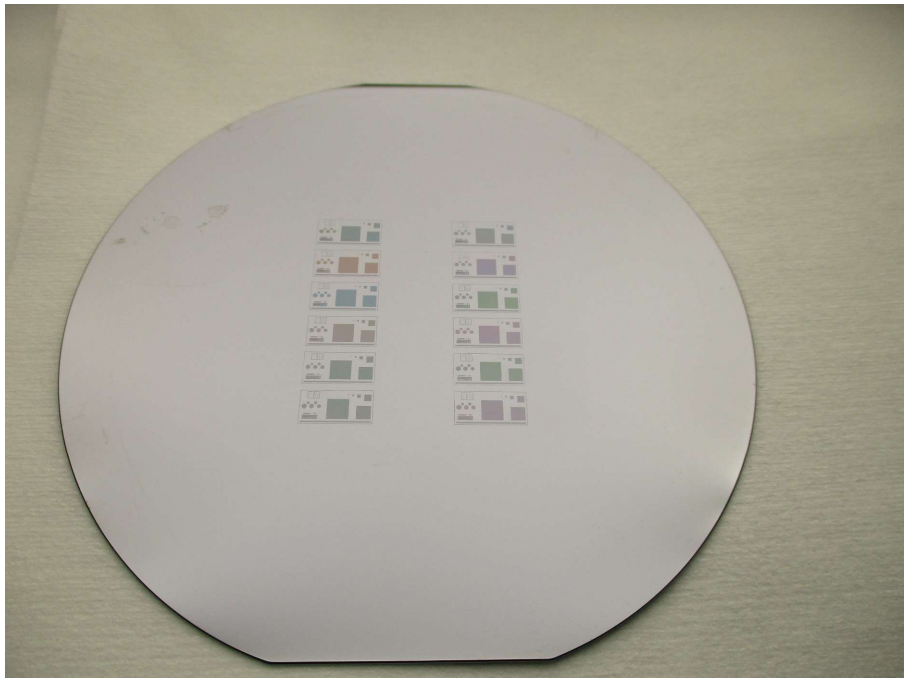
Second test, Wafer 10

- 2µm AZ nLOF 2020 coated on silicon (3300rpm, 30s. Soft bake: 110°C, 60s)
- Exposed using maskless aligner (100-330mJ/cm^2 @365nm)
- Post-exposure bake (PEB) 120°C, 120s
- Development:
  - 10s ethanol in beaker followed by 10s IPA rinse in beaker, dried with N_2-gun → residues after drying (looked like wafer 11)
  - Rinsed with ethanol from spray bottle and dried → most residues gone

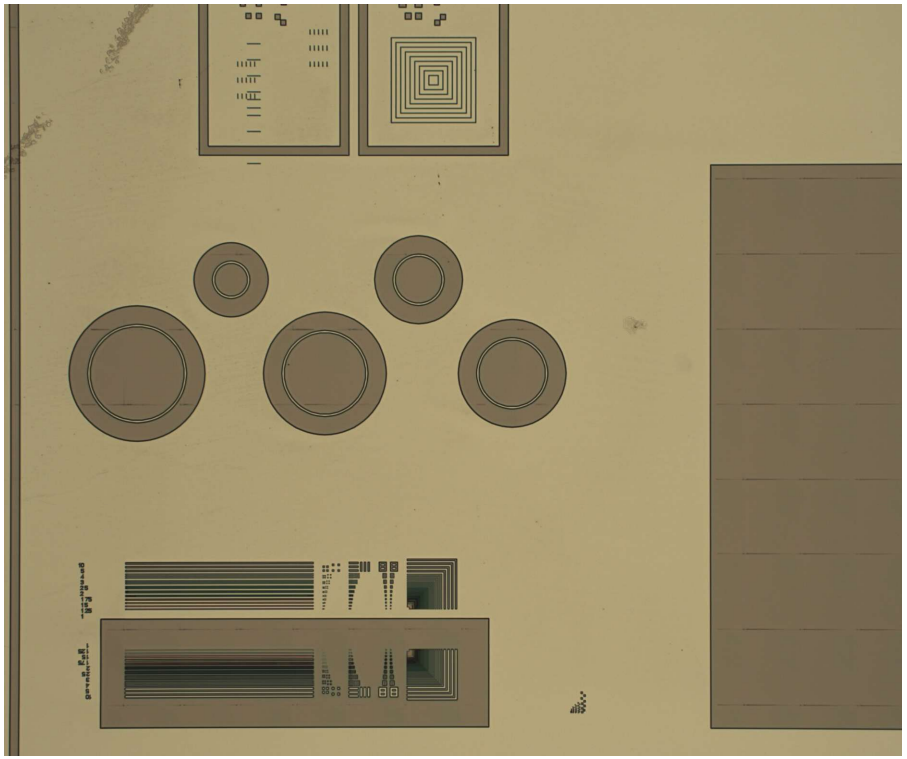


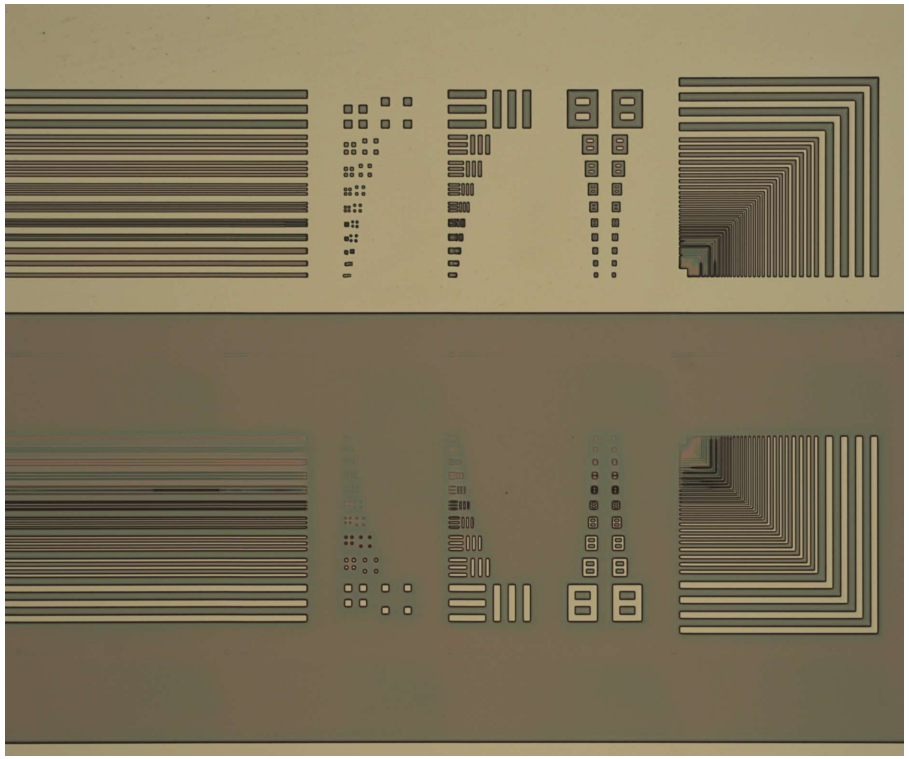
Second test, Wafer 12

- 2µm AZ nLOF 2020 coated on silicon (3300rpm, 30s. Soft bake: 110°C, 60s)
- Exposed using maskless aligner (100-320mJ/cm^2 @365nm)
- Post-exposure bake (PEB) 120°C, 120s
- Development: 15s ethanol in beaker then 1s IPA rinse in beaker (mistake) followed by 10s rinse with ethanol from spray bottle, dried with N_2-gun → no residues, but some structures show signs of delamination



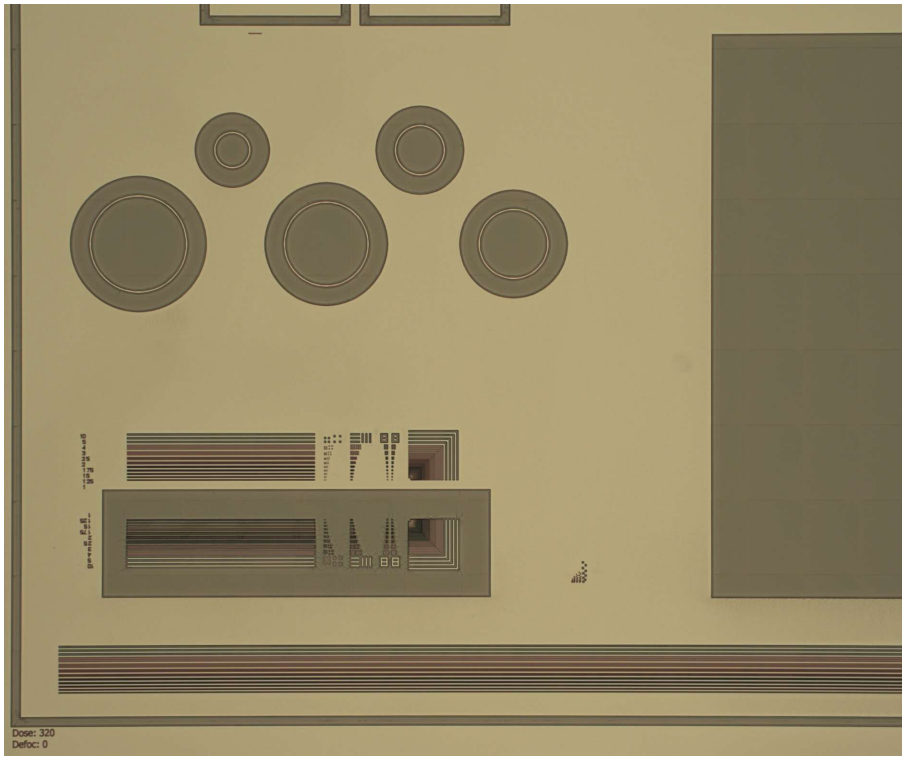
Wafer 10, OM pictures (normal dose)

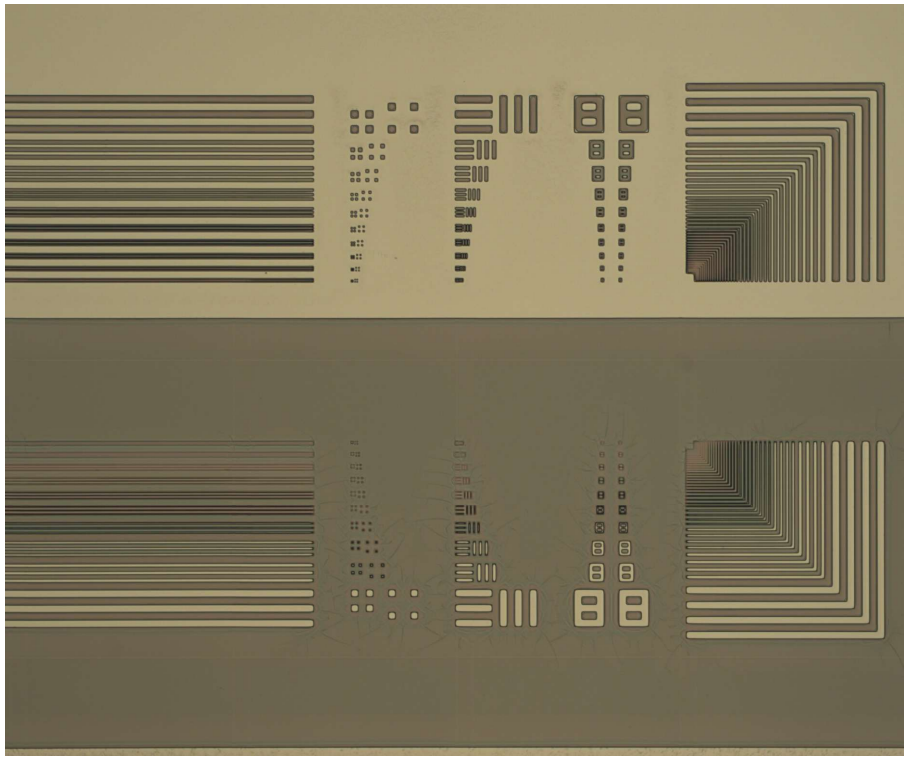




Measured thickness: 1.49µm

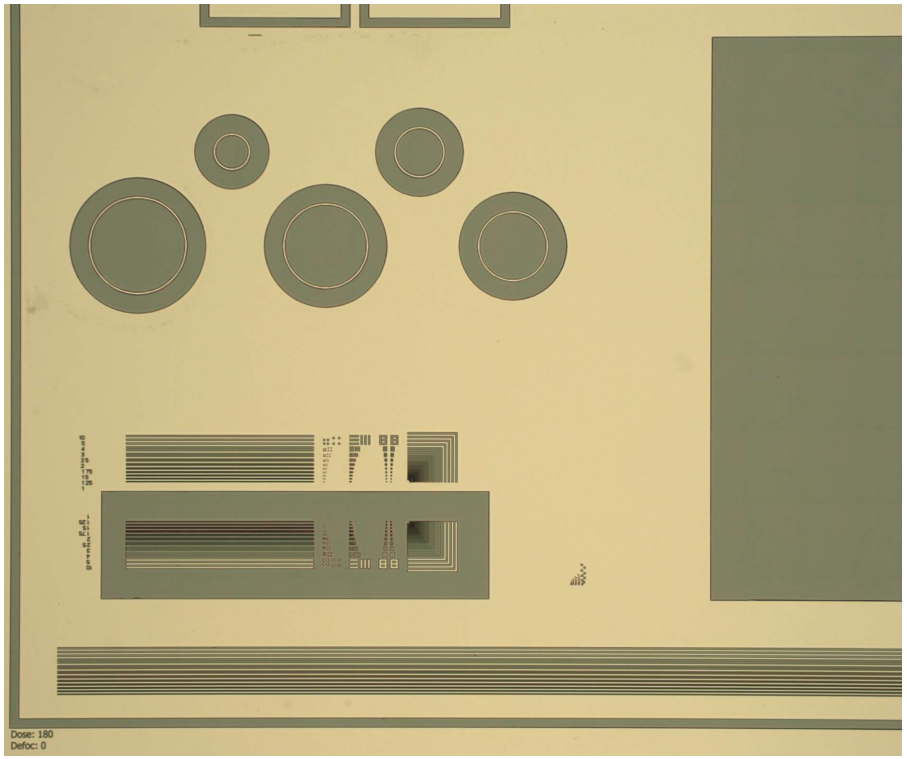
Wafer 10, OM pictures (higher dose)

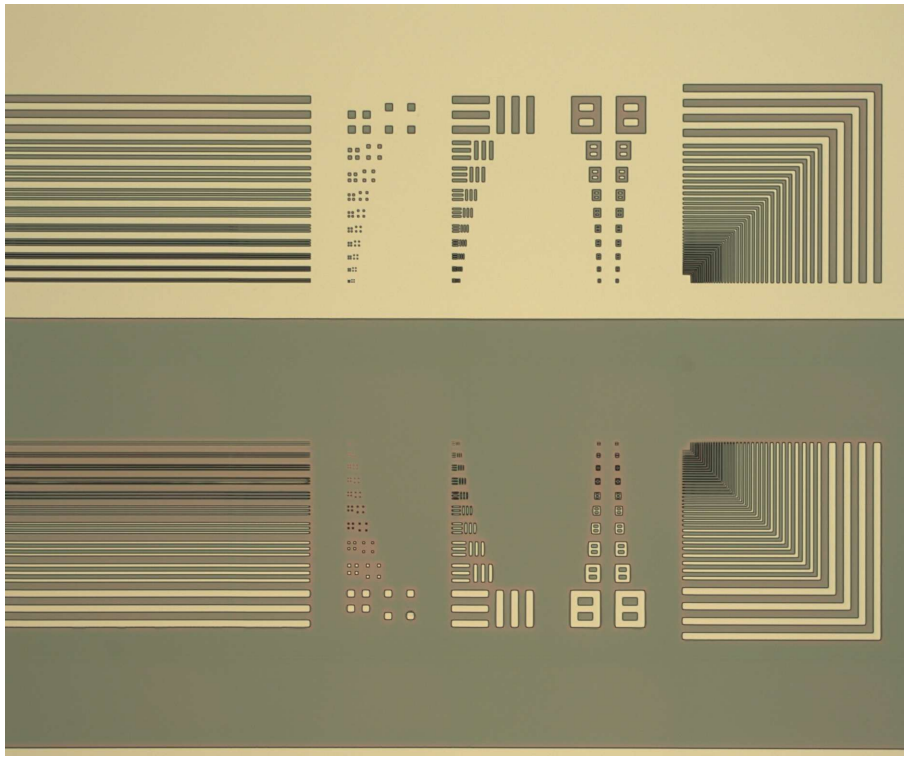




Measured thickness: 1.64µm

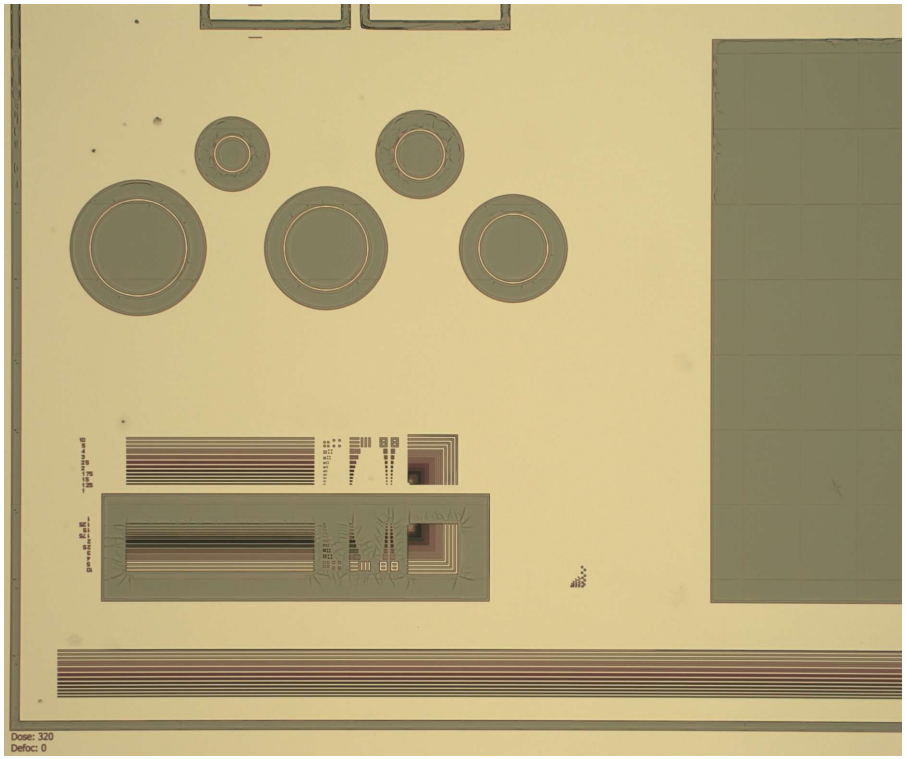
Wafer 12, OM pictures (normal dose)

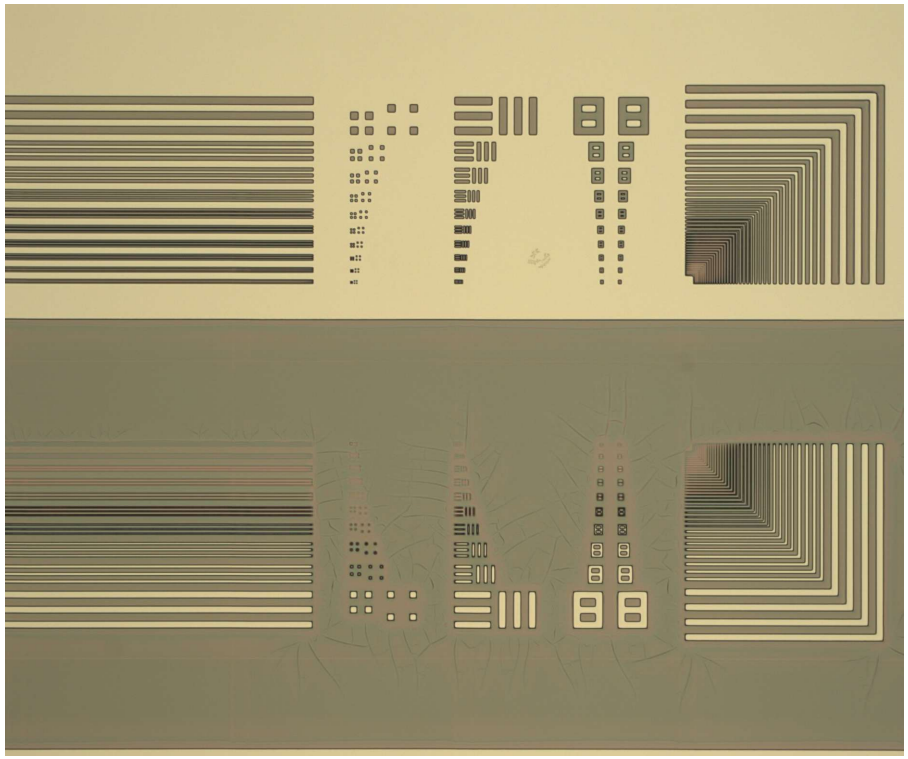




Measured thickness: 1.41µm

Wafer 12, OM pictures (higher dose)





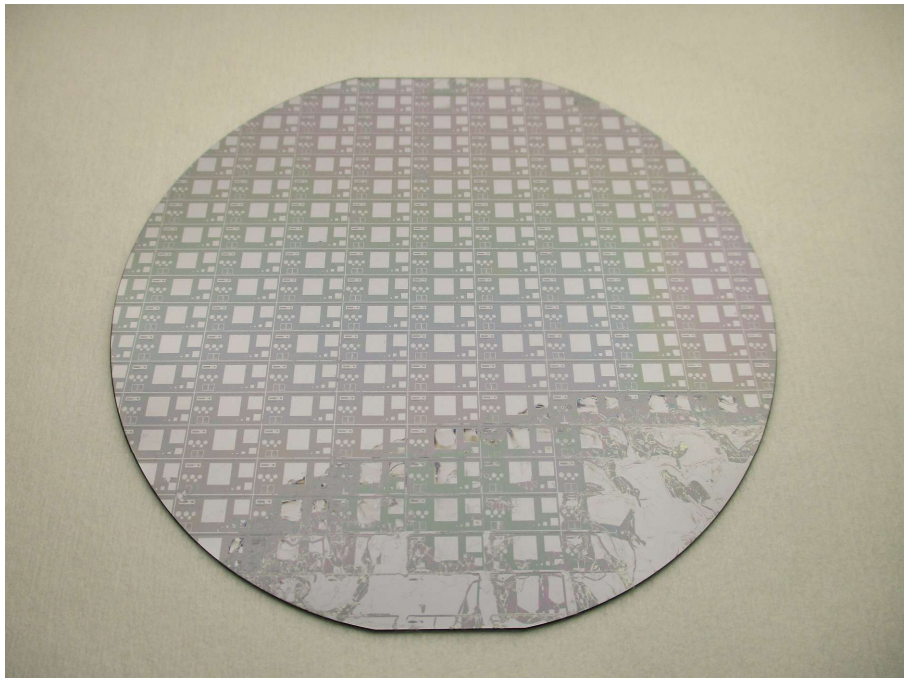
Measured thickness: 1.65µm

Conclusions from second test

- PEB at 110°C:
  - The cross-linked (exposed) resist is too soluble in ethanol, causing excessive erosion and unstable structures. Higher dose improves stability, but also introduces cracking.
- PEB at 120°C:
  - When processing in a beaker, rinsing in IPA leaves residues
  - Development and rinse with ethanol only seems to be the way to go, but too long time (>20s) causes delamination
  - Resolution is 3-4µm
  - Thickness is reduced by ~0.5µm in 10-20s, compared to ~0.2µm in 60s with aqueous developer. Higher dose reduces erosion but introduces cracks.

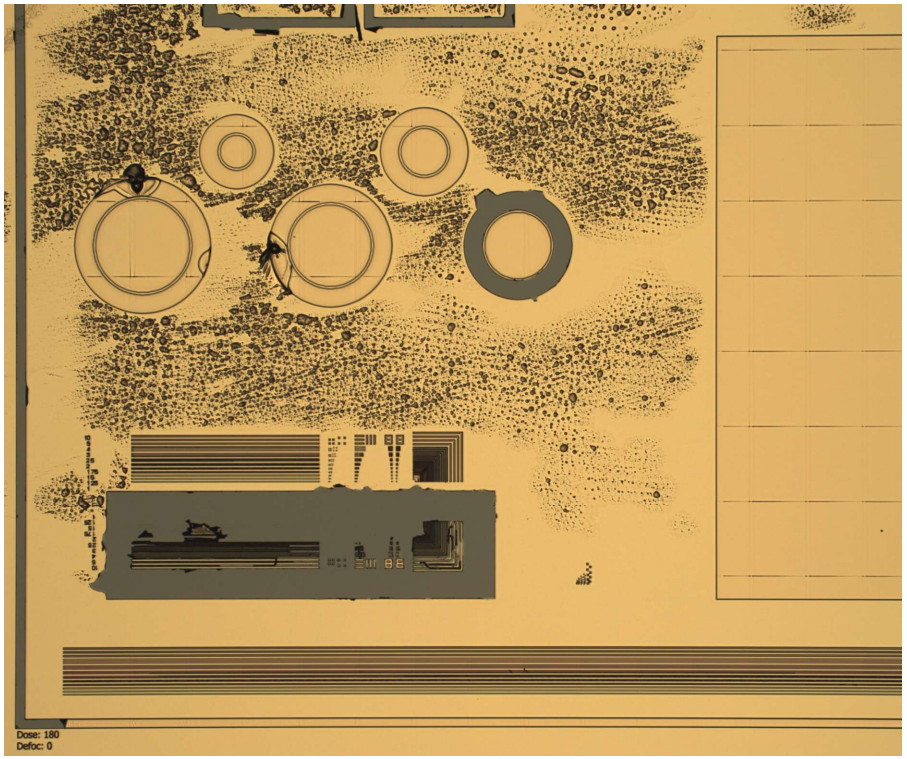
Lift-off test

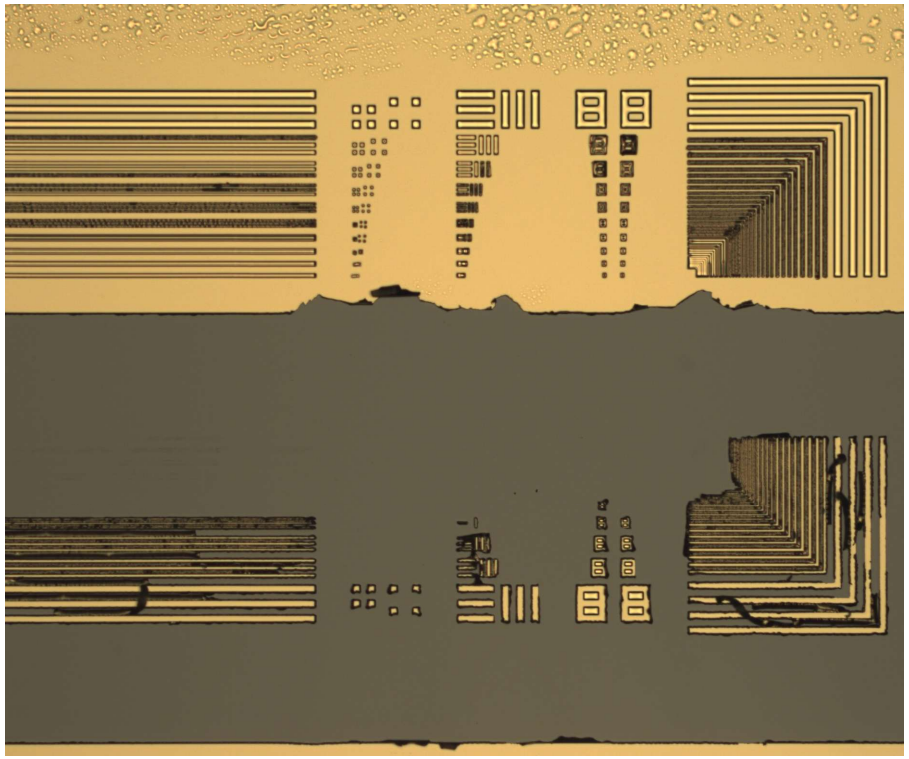
- Wafer 08: test of acetone as lift-off solvent →
- Wafer 10 + 12:
  - Metallization: 5nm Ti + 50nm Au deposited using e-beam evaporation
  - Lift-off using NMP @ 46°C:
    - 1 min soak → lift-off started
    - Continued with US agitation for a total of 7 min → Wafer 12 almost done after 3 min; Wafer 10 slower



Wafer 08 after spraying with acetone + N_2 drying.

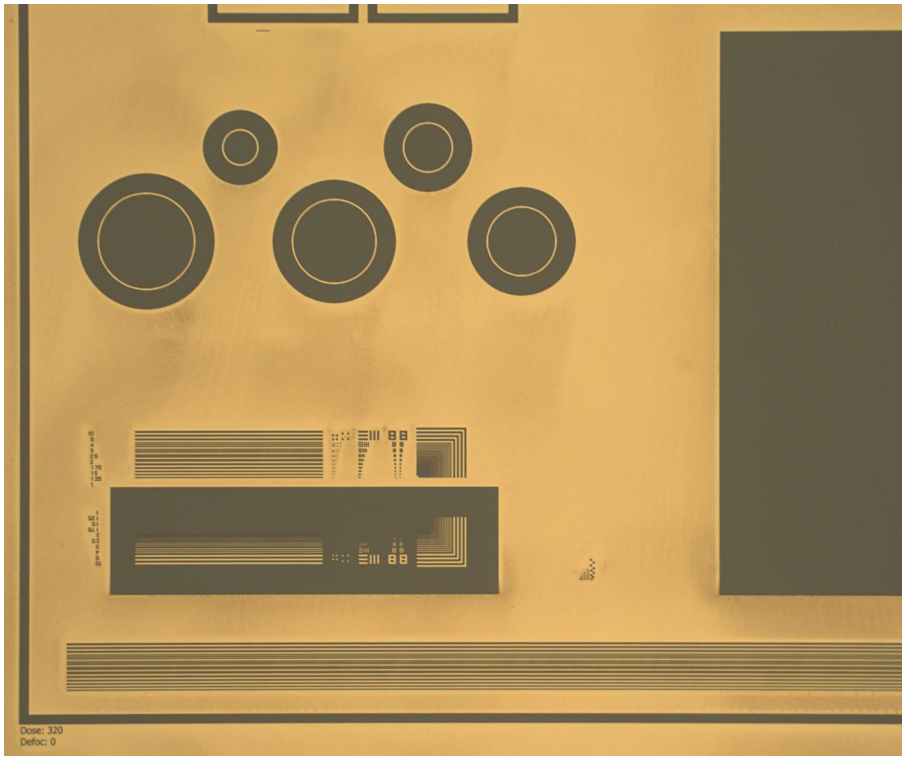
Wafer 10 after lift-off (normal dose)

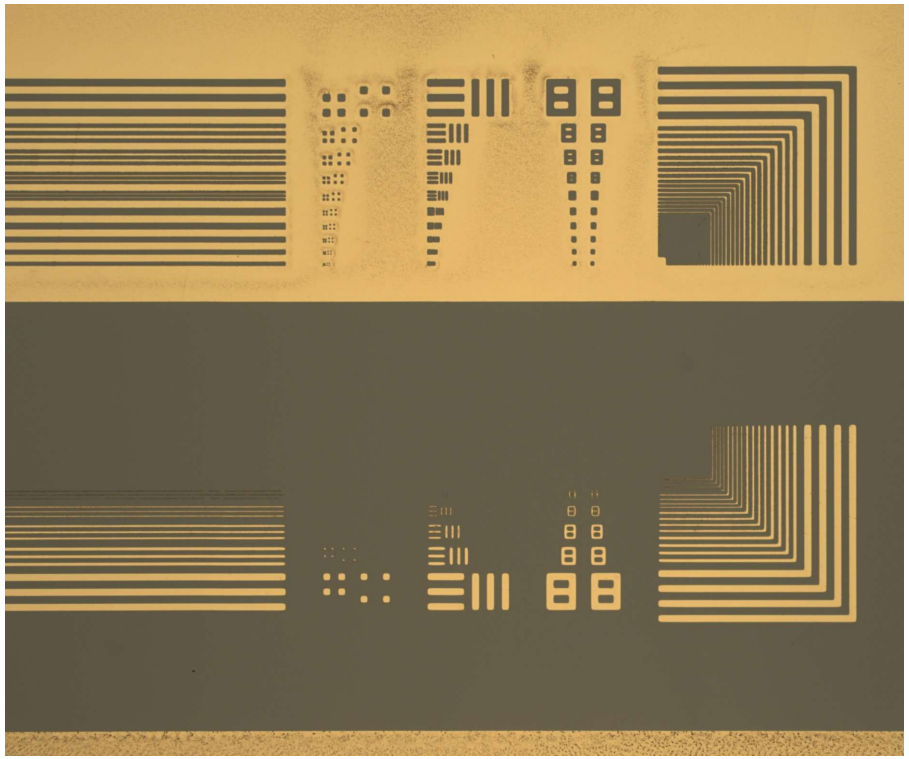




Delamination of the metal, probably due to resist residues after development. Lift-off incomplete, probably due to the profile of the resist, or residues collecting at edges during drying.

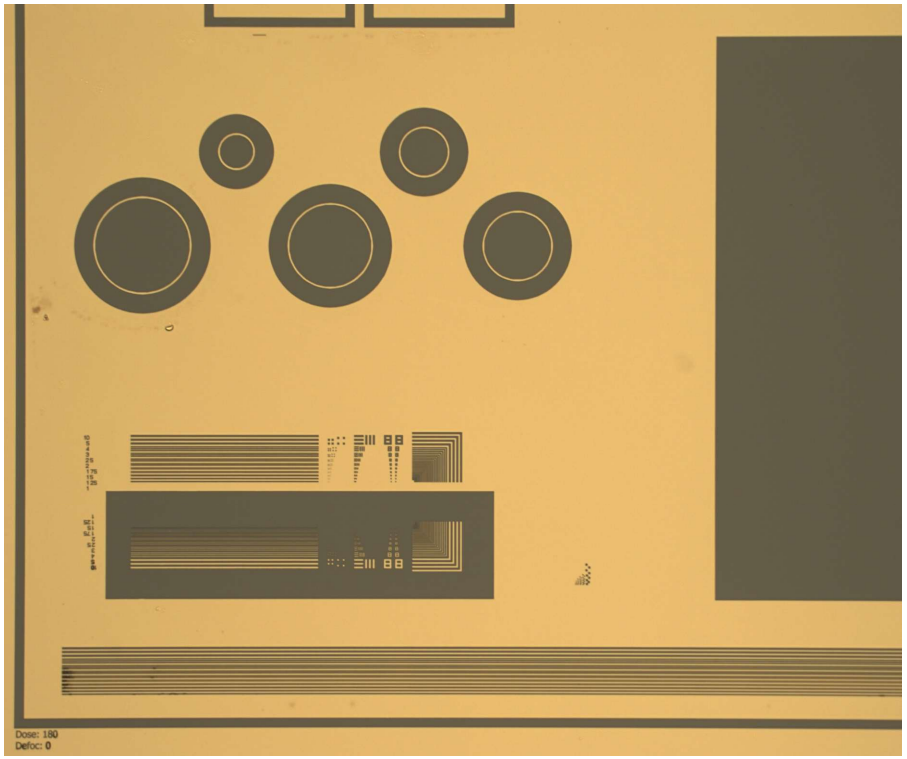
Wafer 10 after lift-off (higher dose)

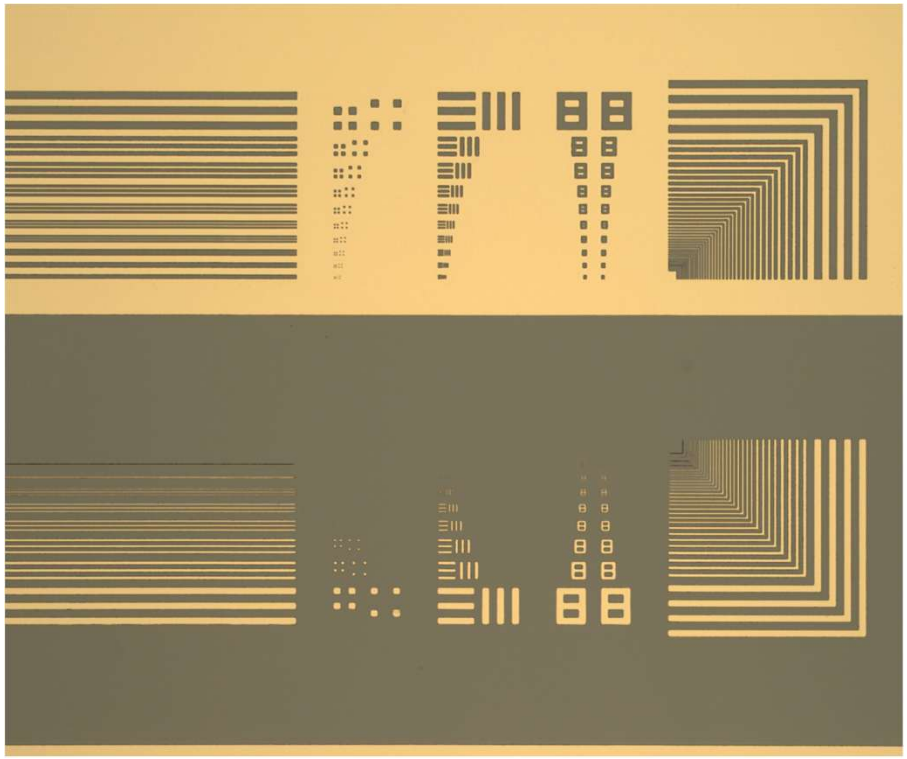




Higher dose looks better, but there is still evidence of residues below the metal.

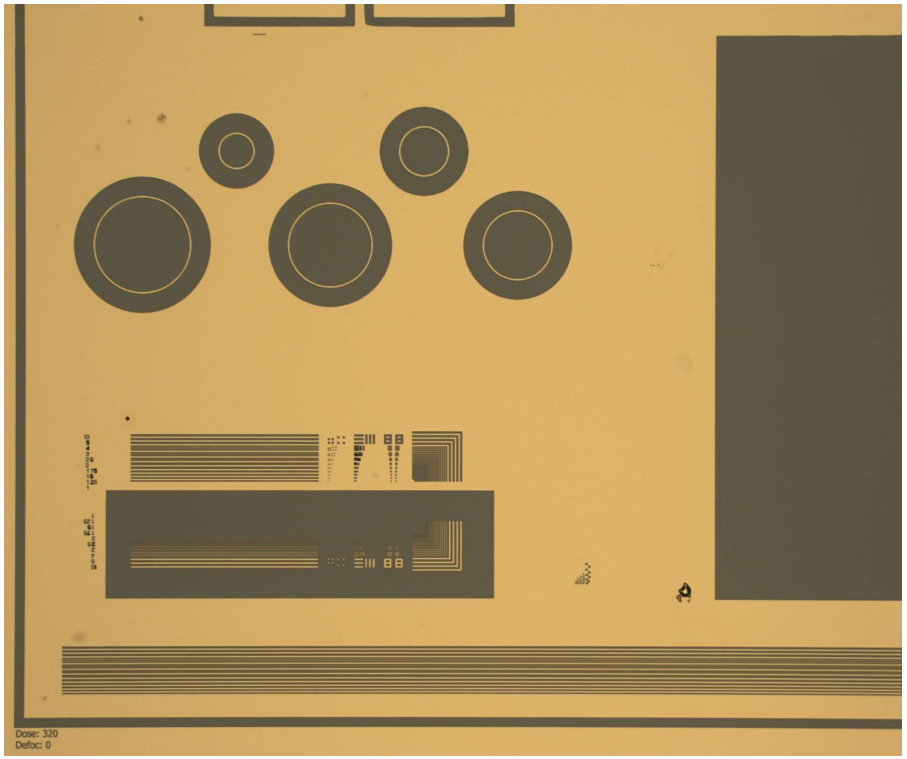
Wafer 12 after lift-off (normal dose)

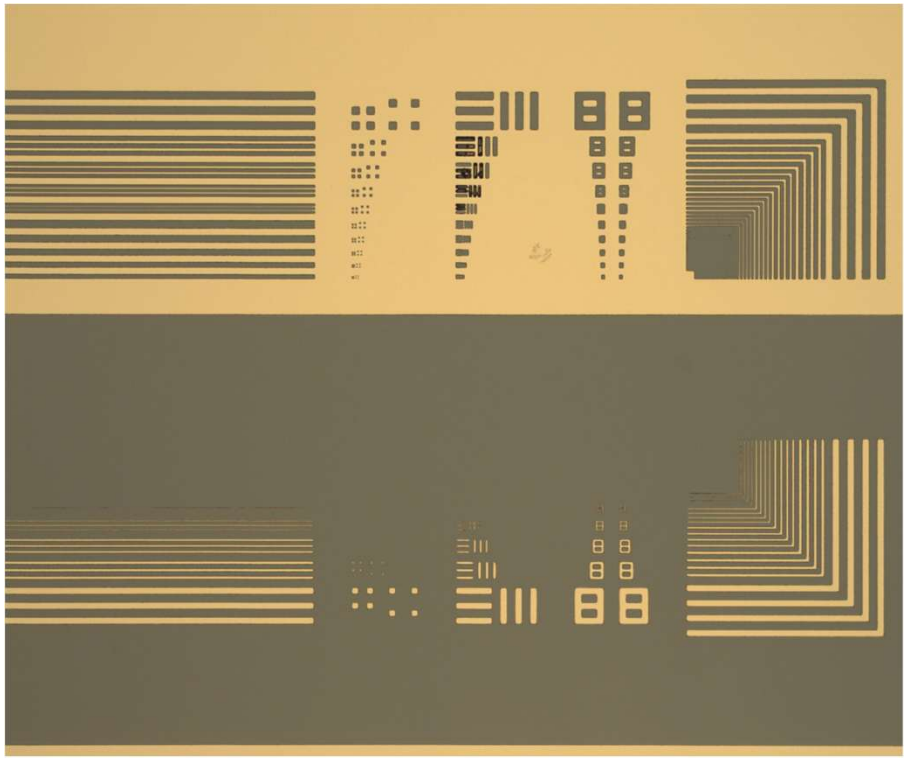




Edges are fuzzy, probably due to the profile of the resist (metal depositing up the sidewall of the resist, causing dangling metal on edges after lift-off).

Wafer 12 after lift-off (higher dose)





Loss of resolution due to higher dose, edges still fuzzy. Some small opening did not lift.

Conclusions from lift-off test

- Lift-off is probably not possible with acetone (this was expected due to the higher PEB temperature)
- Lift-off with NMP works (but is not perfect)
- Again, ethanol development + ethanol rinse works best
- Residues after development (”scumming”) is a problem. Some kind of surface cleaning after development (de-scum) is needed
- Only ethanol and IPA were tested (plus quick test of acetone and PGMEA, both probably too aggressive). Other solvents may be less aggressive on the cross-linked resist and yield better result