Nanometer Scale Patterning and Processing

Spring 2016

Lecture 35

Nanoimprint Lithography (NIL) – UV Assisted Nanoimprint

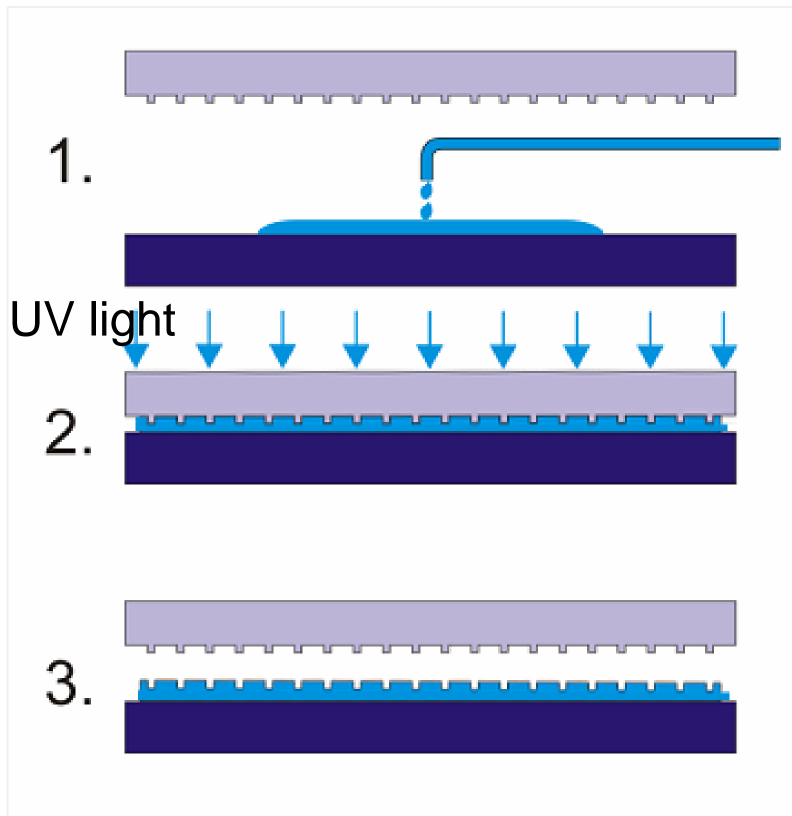
PURDUE UNIVERSITY

- Section 4

UV ASSISTED NANOIMPRINT

UV-NIL

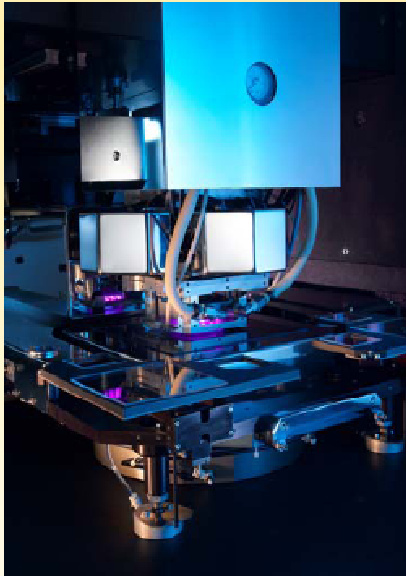
UV-NIL using dispensing resist



- Rome temperature, low pressure (1 - few atm).
- Liquid resist consisting monomer, photo-initiator, coupling agent, surfactant…
- Resist cross-link (become solid) upon UV illumination.
- Mold (or substrate) needs to be transparent to UV.
- Easy for alignment than thermal NIL, closer to optical lithography.
- But resist side, thermal NIL resist is closer to optical lithography resist. For example, PMMA and SU-8 is both a photo-resist (PMMA for DUV lithography) and thermal NIL resist.
- In fact, UV-NIL resist is closer to UV-curable glue.

Step and flash UV-NIL

UV NIL: S-FIL (Step and Flash)



Source: Suss MicroTec

Mold

Resist is not applied by spin-coating; but drops by “inkjet”, less uniform thickness!!

(for alignment)

CCD OPTICS

“Inkjet” system

UV Polymer

Substrate

UV Exposure

Separation

Step

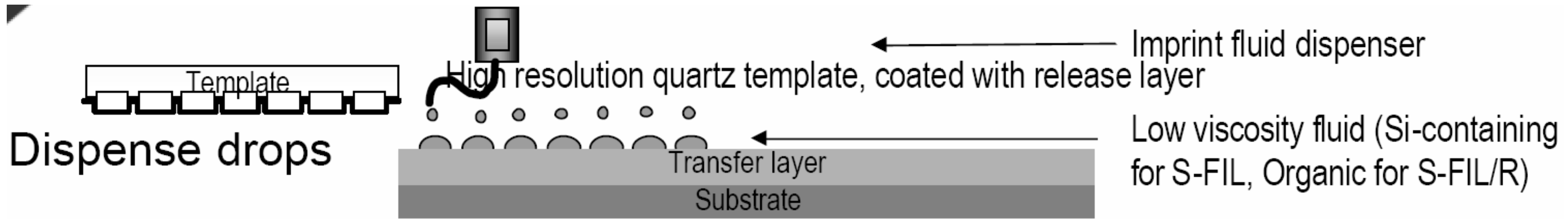
CCD OPTICS

UV Polymer
- fast curing
- adhesion properties
- residual layer thickness
- etch resistance

Process technology
- structure transfer in the substrate
- overlay

- Technology commercialized by Molecular Imprint Inc.
- Resembles DUV stepper, die by die patterning (no need of a BIG expensive mold).
- More favored by the semiconductor industry or wherever mold is too expensive.

SFIL Process and Apparatus



UV Light

Self-Leveling Flexure

UV Curable Solution Dispensed in Droplets

Stage

Template

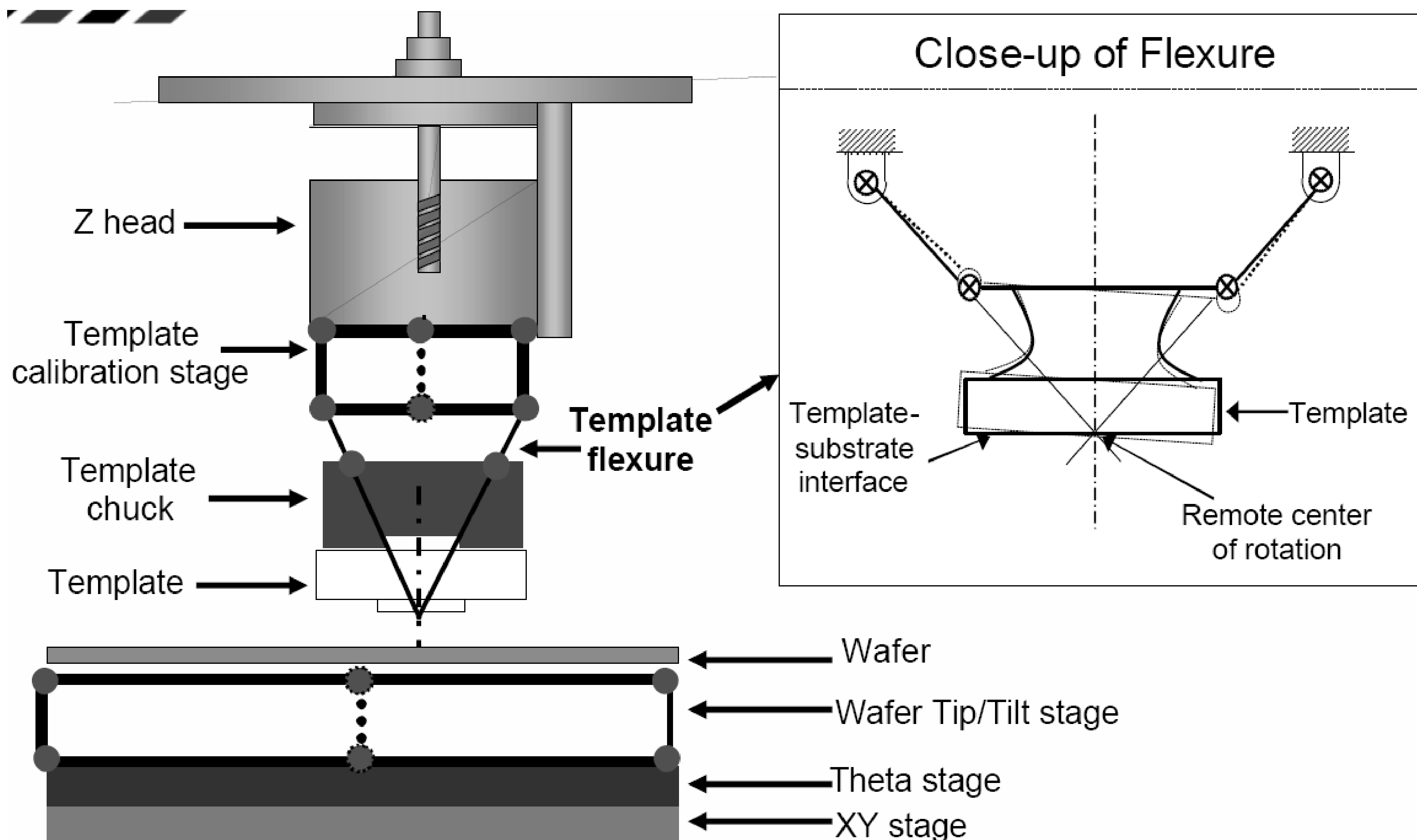
Wafer

} 15 μm mesa

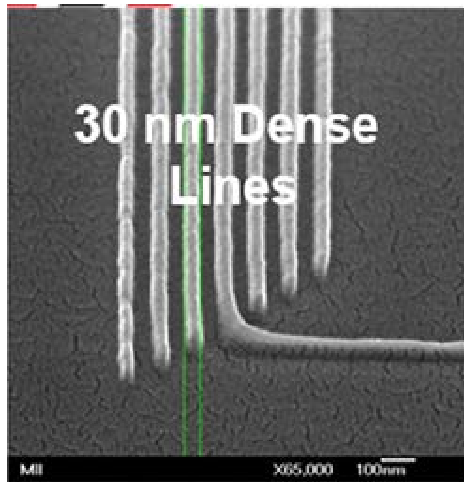
100 to 200 nm feature depth

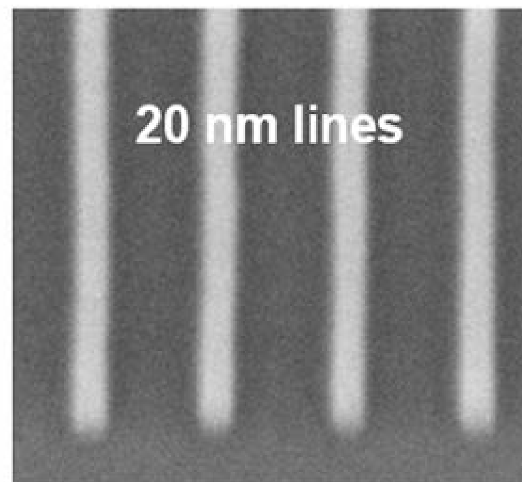
Template

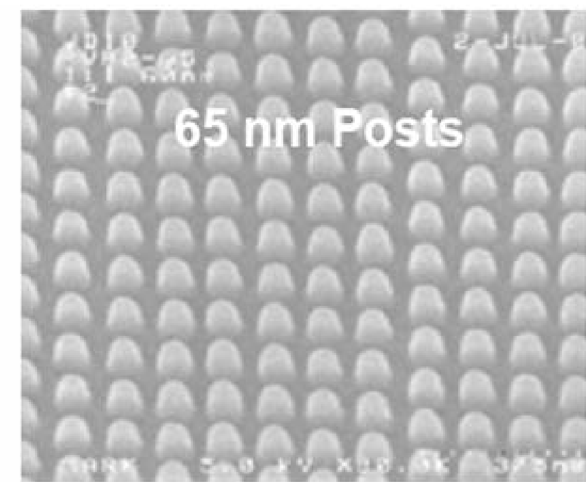
SFIL-Nanoimprint Head (Self-Leveled)

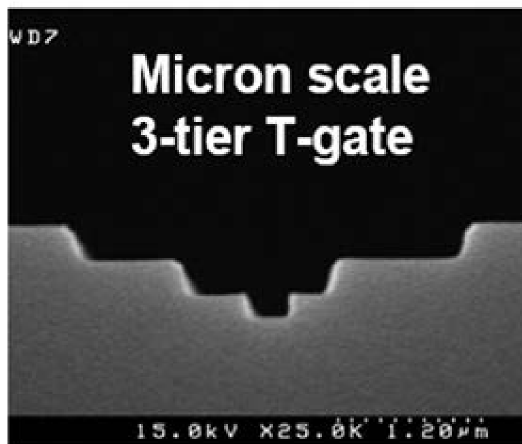


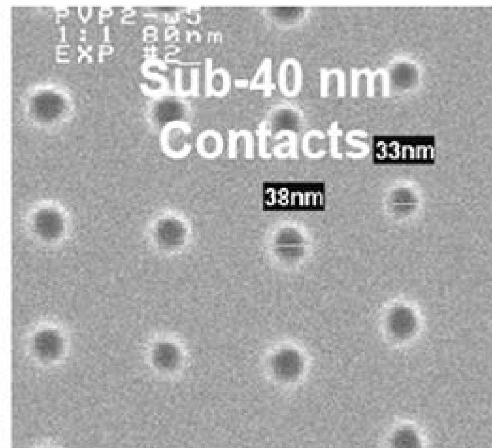
Some examples of step and flash NIL

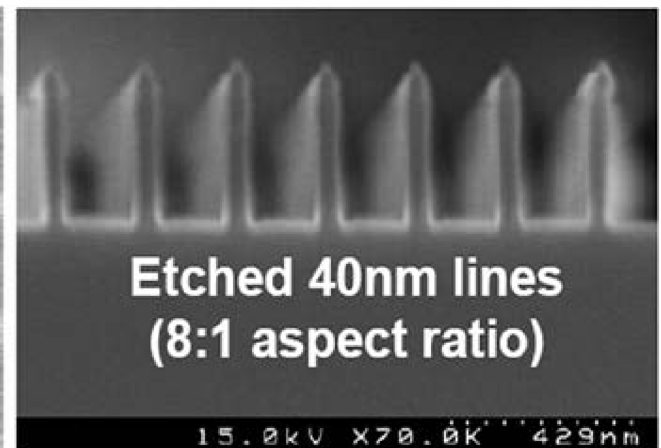






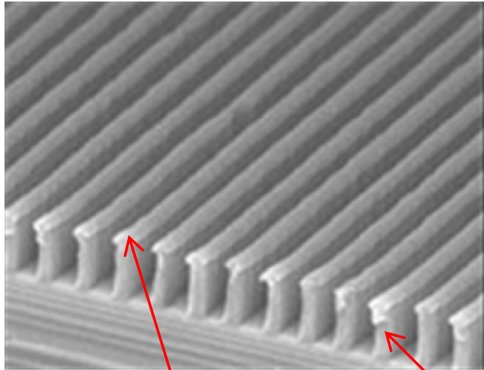






In principle, UV-NIL has lower resolution than thermal NIL due to resist shrinkage (~10%) upon cross-linking. In practice, UV-NIL has demonstrated similar resolution to thermal NIL.

UV-NIL using Spin-On Resist



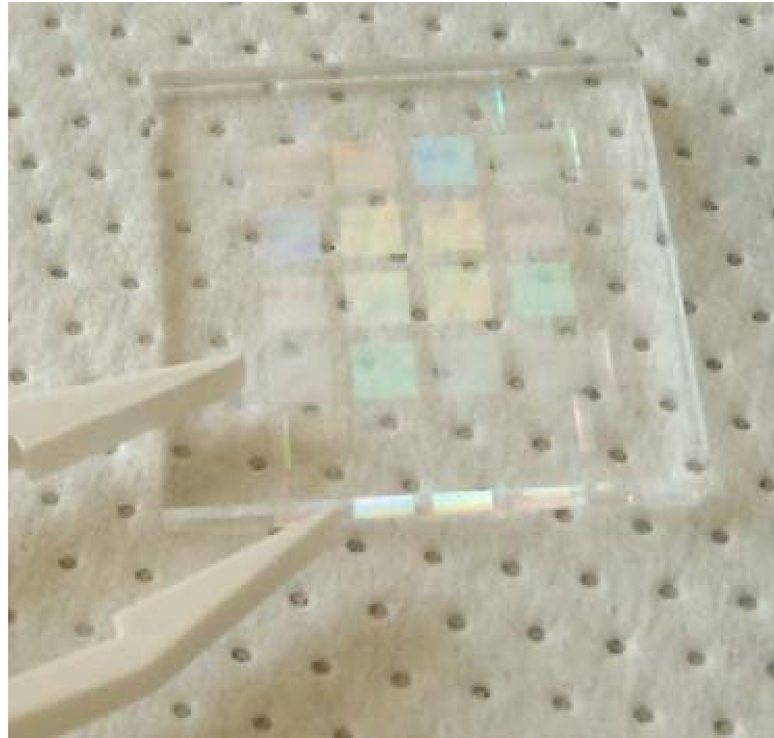
NXR-2000 Series, Photo-Curable Resists

- Sub-5 nm demonstrated resolution and wafer-scale uniformity
- Room temperature operation
- Super-low viscosity
- Spin-on or resist-drop dispensing
- Excellent etching resistance
- Low UV-curing dosage

UV-resist   Under-layer (PMMA, ARC…)

- Typically bi-layer system, thin UV-resist layer to minimize shrinkage effects.
- Resist contains Si, so can be used as a hard mask for etching under-layer with O_2 plasma.
- Spin-on resist is not suitable for step-and-flash NIL, because it must be imprinted quickly in one shot (liquid resist not as stable as thermal NIL resist in air, and it takes in dust quickly).
- For R&D, spin-on resist is much more reliable than step-and-flash NIL, because the amplitude and uniformity of residual layer thickness is a big issue for drop-dispensed resist.

PDMS mold for UV-NIL



- Transparent mold (also called stamp or template) in PDMS.
- Flexible and soft for conformal contact to non-flat substrate.
- But not for high resolution (<100nm), because PDMS is not hard enough and its nanostructure will deform under pressure.
- One solution is using bi-layer, pattern in *hard*-PDMS or PMMA, which is spun on (regular soft) PDMS.
- After oxygen plasma treatment, PDMS surface is like SiO_2, so it is easy for silane anti-sticking treatment.

ZEP-520 mold (ZEP is an e-beam lithography resist)

Because UV-NIL uses low pressure and room temperature, thermoplastic EBL resist such as PMMA and ZEP-520 can be used as a mold right after EBL and development. (may need anti-sticking surface treatment with silane, though not reliable on ZEP or PMMA.)

Minimizing linewidth roughness in Step and Flash Imprint Lithography

Niyaz Khusnatdinov[a], Gerard M. Schmid[a], Cynthia B. Brooks[a], Dwayne LaBrake[a], Douglas J. Resnick[a,*], Mark W. Hart[b], Kailash Gopalakrishnan[b], Rohit Shenoy[b], Ron Jih[b], Ying Zhang[c], Edmund Sikorski[c], Mary Beth Rothwell[c], Jordan Owens[d], Arnie Ford[d]

[a] Molecular Imprints, Inc., 1807C West Braker Lane, Austin, TX 78758, USA
[b] IBM Almaden Research Center, 650 Harry Road San Jose, CA 95120-6099, USA
[c] IBM Thomas J. Watson Research Center, 1101 Kitchawan Road, Route 134, Yorktown Heights, NY 10598-0218, USA
[d] Sematech ATDF, 2706 Montopolis Drive, Austin, TX 78741-6499, USA

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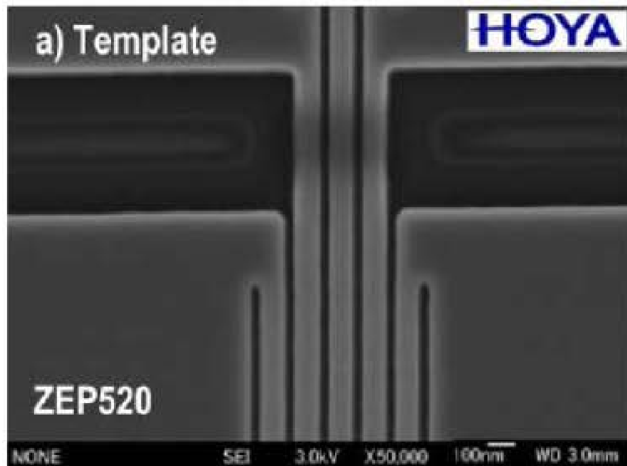
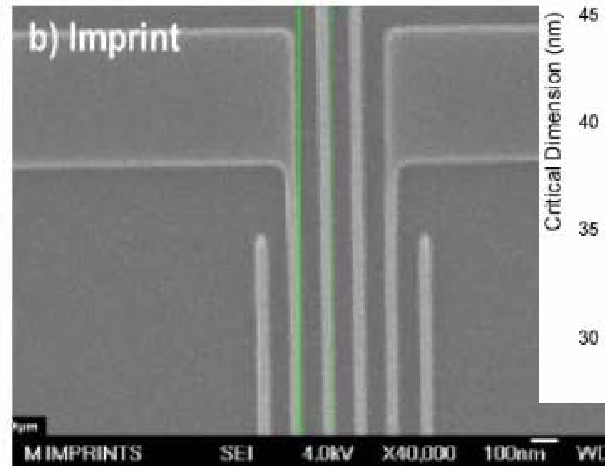
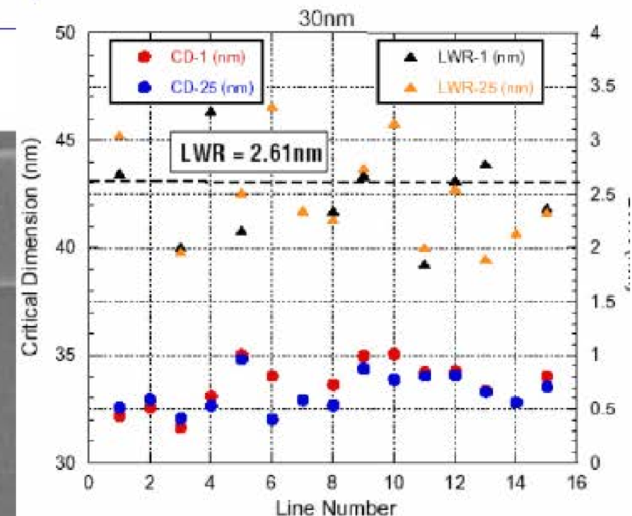
Total agreement for both resolution (LW=CD) and linewidth roughness (LWR) on the master mold in the resist after NIL

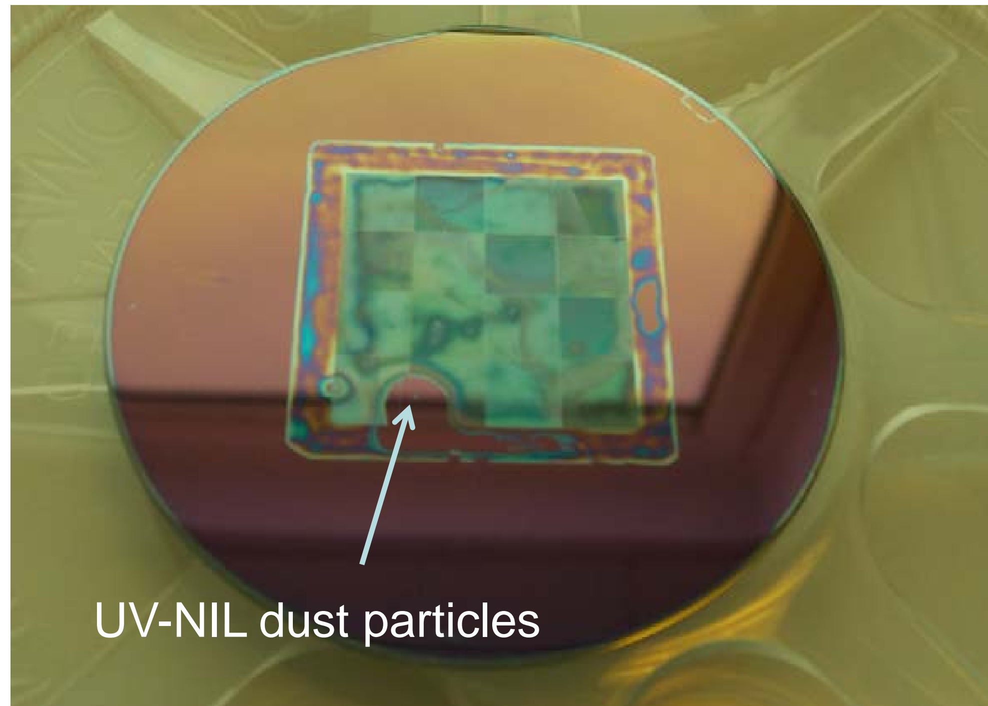
LW=30nm and LWR=3.5nm







Dust Issue

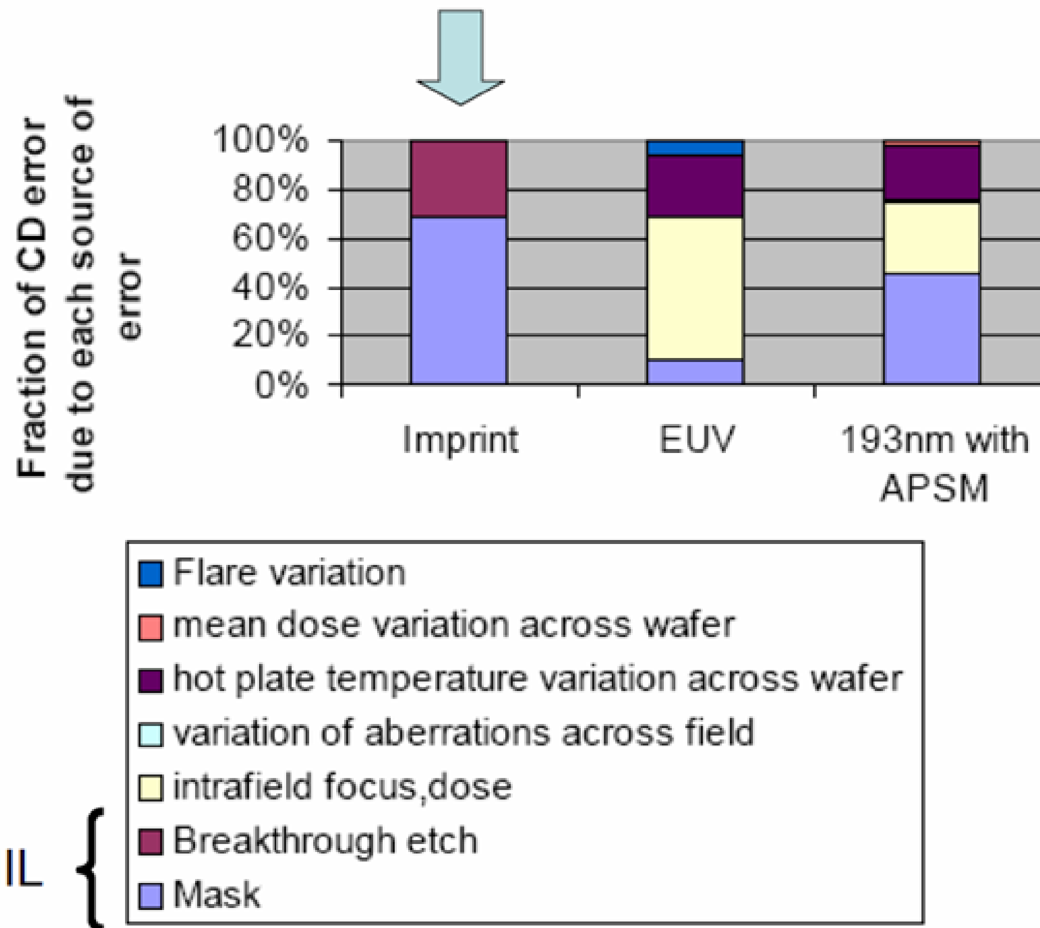


Dust is a bigger issue for UV-NIL than for thermal NIL because:

- The *liquid* resist takes in dust easily from air, and the dust cannot be blown away.
- The pressure is lower, leading to larger defect area with same size of dust particle.
- So sometimes, UV-NIL is done at higher pressure to reduce defect area.

Critical dimension (CD) control in NIL

CD control error budget comparison



Advantage of NIL for CD control:

- No diffraction or proximity effects.
- No lens aberrations.

Disadvantage of NIL for CD control:

- 1× mask, so CD error on mask is printed onto resist without reduction.
- Need a breakthrough etch of the residue layer, which adds CD error due to lateral etch.
- But this error could be compensated in mask (mold) design.

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