Nanometer Scale Patterning and Processing

Spring 2016

Lecture 36

Nanoimprint Lithography (NIL) – Alignment in NIL

- Section 5

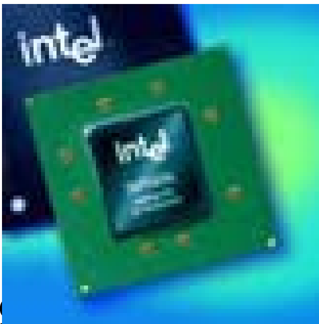
ALIGNMENT IN NIL

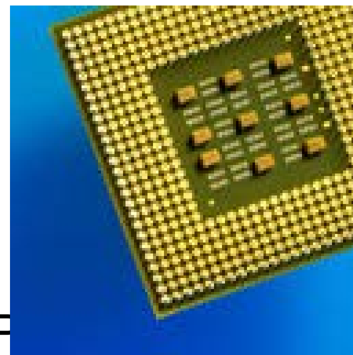
Alignment (overlay)

- Electronic devices such as transistors/chips require multiple levels of materials and processing.
  - For NIL, there is no distortion due to lens since no lens is used.

Challenges for sub-100nm alignment:

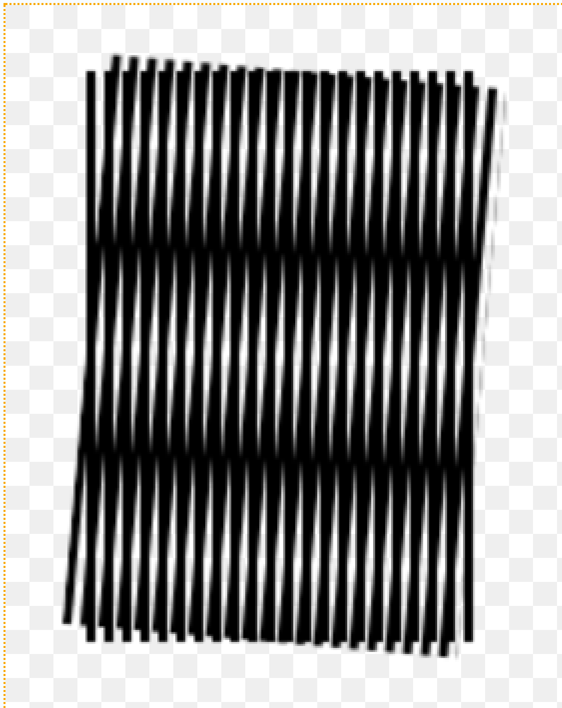
- Smaller error budget for mold pattern placement since it is 1×.
- Alignment mark fabrication error has to be <10nm (pattern placement error).
- Features are too small to be seen optically ~10nm.
- Alignment is sensitive to the gap between mold and substrate.
- Mold distortion/drift due to pressure, temperature and defects is big problem.
  - Generally, alignment for NIL is much more difficult than other lithographies.
  - Thermal NIL is worse due to thermal expansion mismatch.





Possible alignment methods

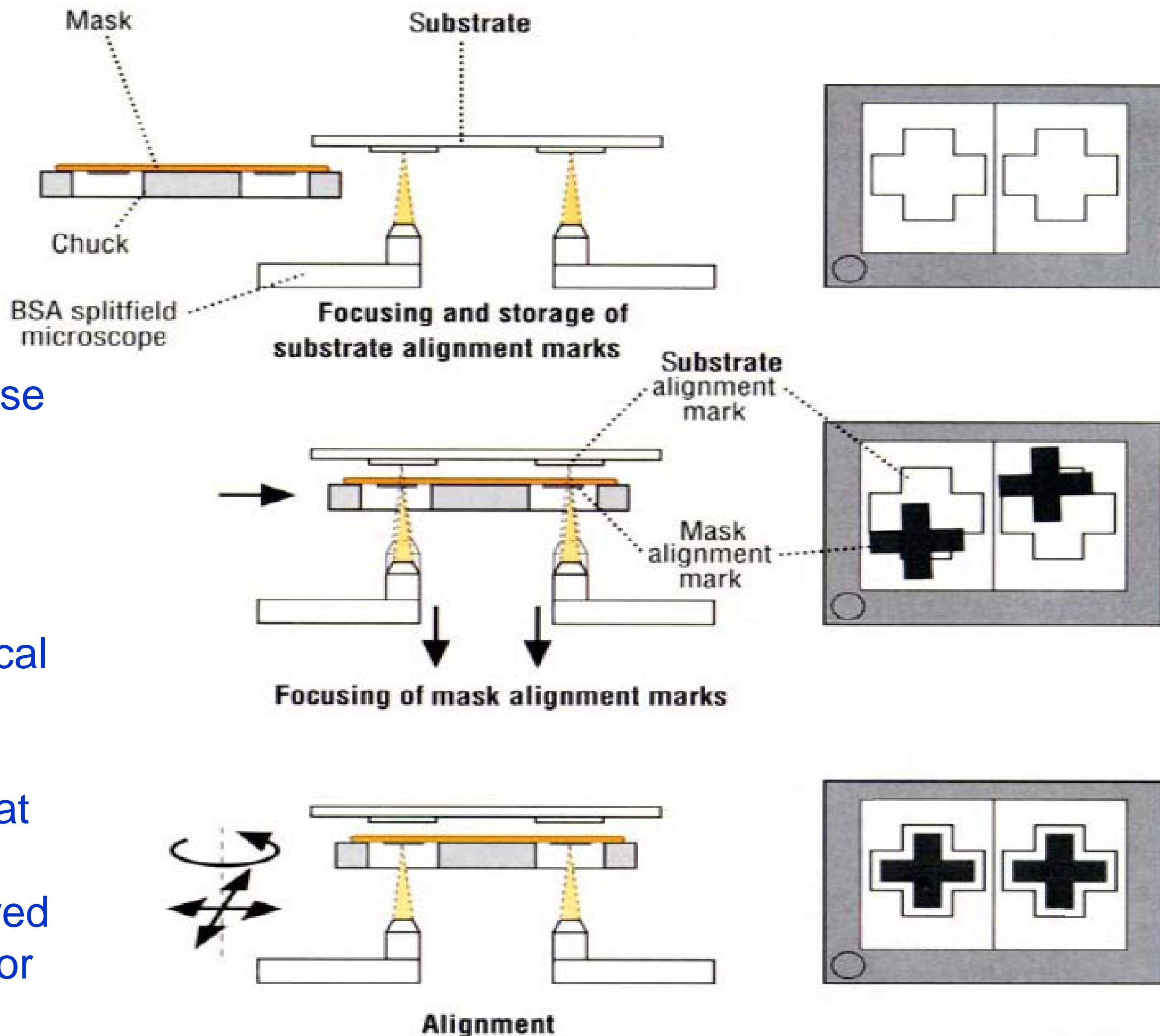
- Direct imaging, as in optical lithography.
- Amplitude-sensitive schemes.
- Phase-sensitive schemes.
  - Temporal phase detecting.
  - Spatial phase detecting – Moiré pattern (simple, insensitive to gap)



(Wikipedia) In physics, a moiré pattern is an interference pattern created, for example, when two grids are overlaid at an angle, or when they have slightly different mesh sizes.

A moiré pattern, formed by two sets of parallel lines, one set inclined at an angle of 5° to the other.

Direct imaging

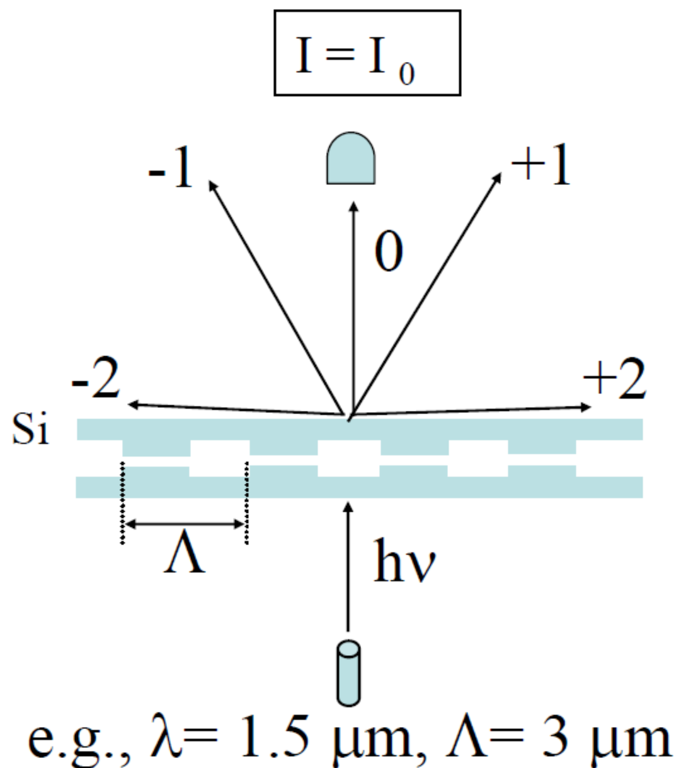


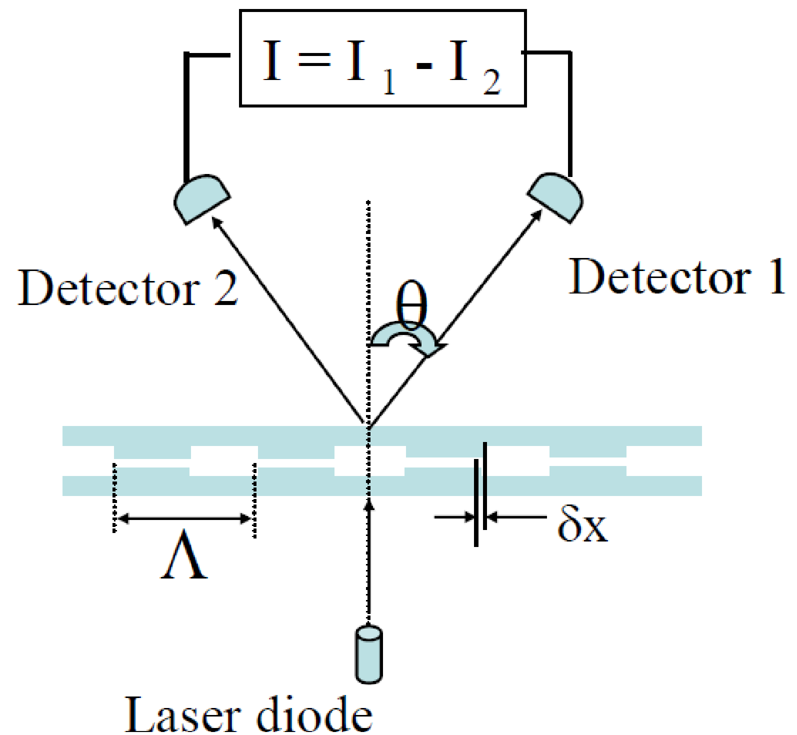
- Backside alignment because silicon substrates are not transparent to visible light.
- Sub-micron precision is demonstrated.
- Precision is limited by optical resolution and thermal, mechanical noises.
- For thermal (or UV) NIL that requires high pressure, alignment is easily destroyed due to lateral drift of mold or substrate.

Amplitude sensitive alignment scheme

•**Method-1**: Measure the zero order diffraction patterns of two gratings with the same period

•**Method-2**: Measure the first order diffraction patterns of two gratings with the same period





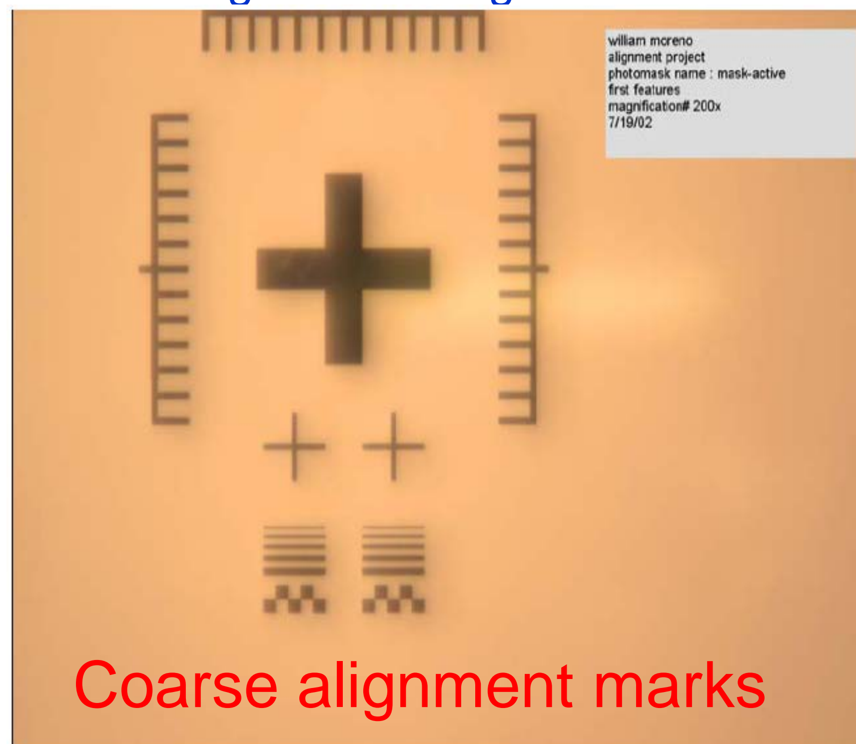
Maximum signal when aligned.

Minimum signal when aligned ($I_1=I_2$)

William Moreno, Princeton

Two step alignment using cross marks and Moiré patterns

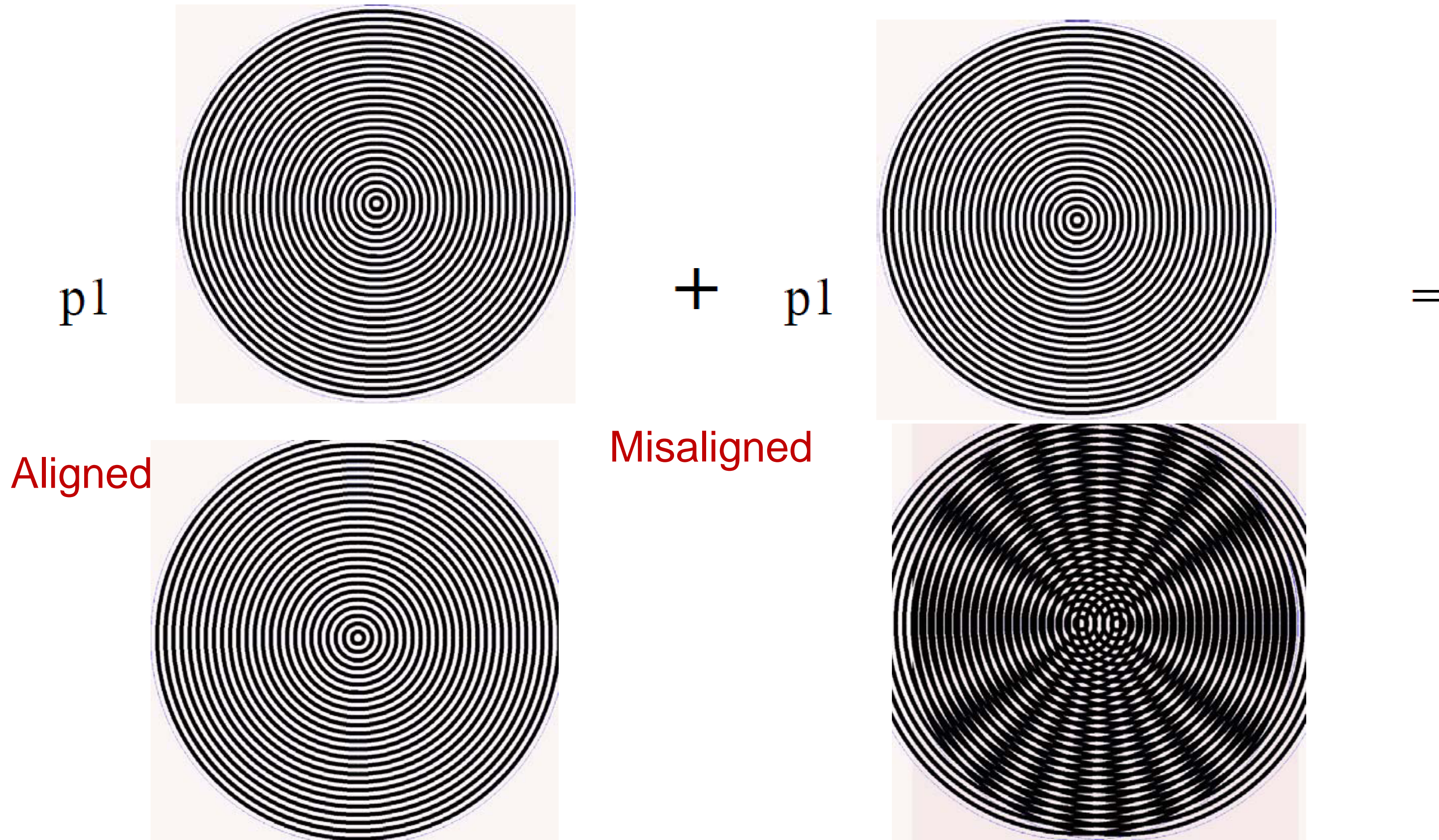
Moiré patterns: optical image of superposition of two patterns.
Advantage: slight displacement of one of the objects creates a magnified change in their Moiré patterns.
For sub-100nm alignment:
Coarse alignment using cross marks and boxes or circular gratings.
Fine alignment using interferometric spatial phase matching (Moiré).



Optical image (200x)

- Same as alignment in contact/proximity optical lithography.
- Cross mark provide alignment of ~0.5μm.
- Cross marks are relatively big and easy to locate.

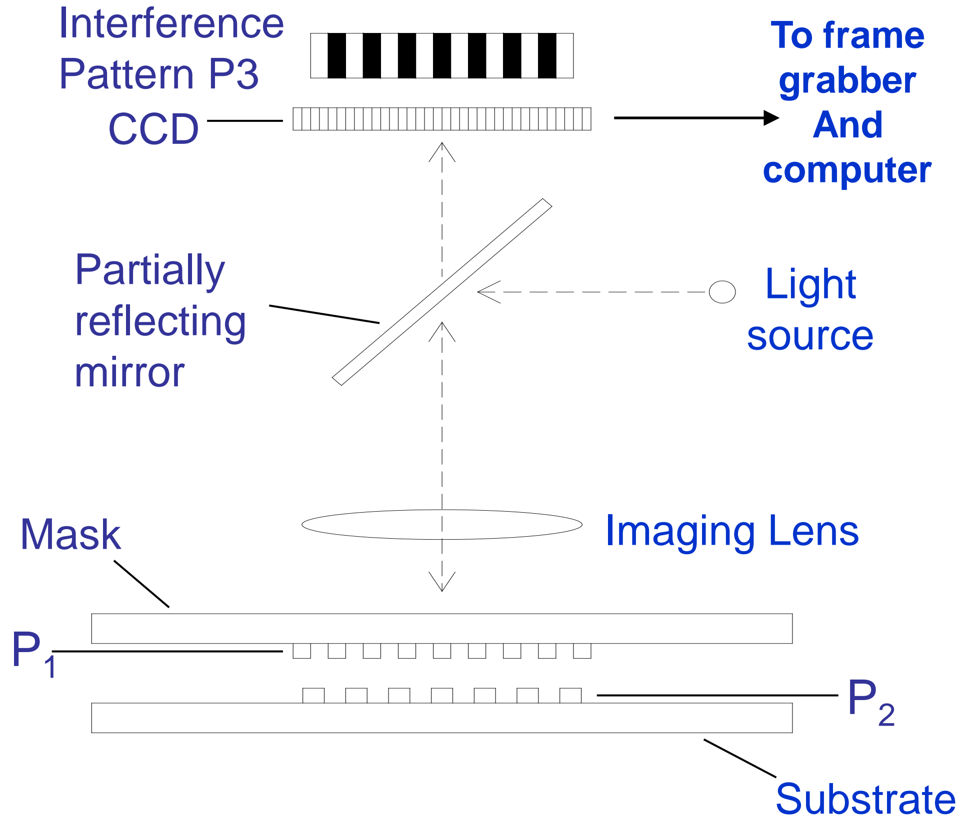
Circular gratings

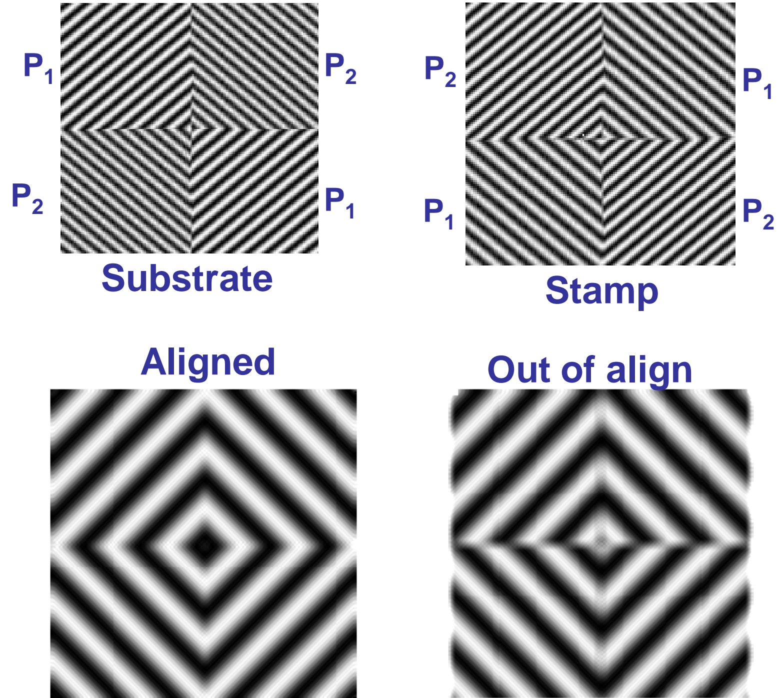


Circular patterns produce more precision for the coarse alignment in the x and y axis. They are more sensitive to displacement than cross marks.
M. King and D. Berry were the first who start alignment using moiré concentric circles in 1972 (Appl. Opt.11. 2455).

Fine alignment using Moiré: concept and simulation

Sub-10 nm alignment accuracy

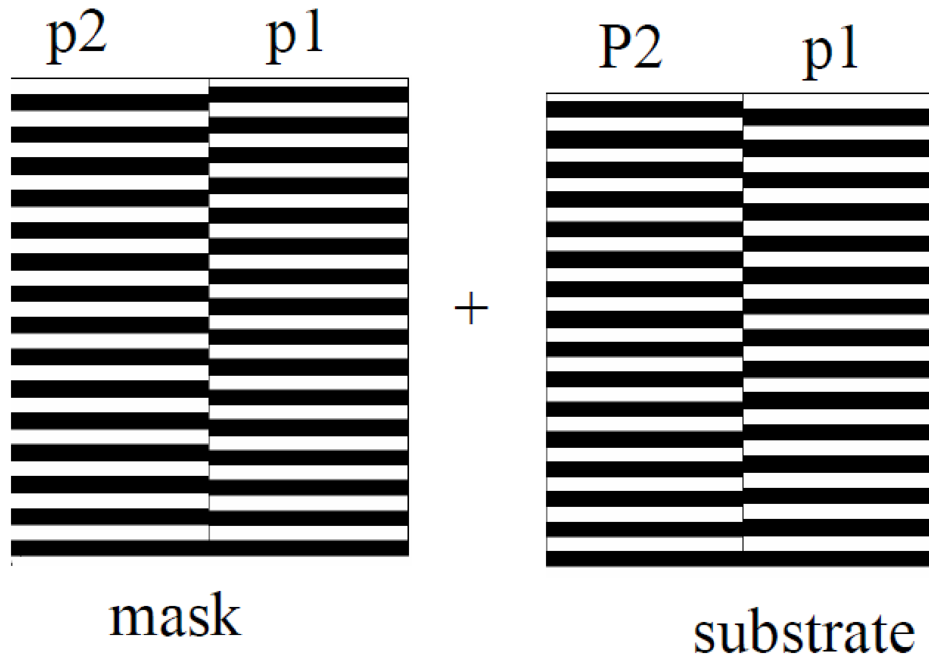




Simulations of alignment/misalignment

$$P_3 = (P_1 \times P_2) / |P_1 - P_2|$$

Interferometric spatial phase matching of linear gratings

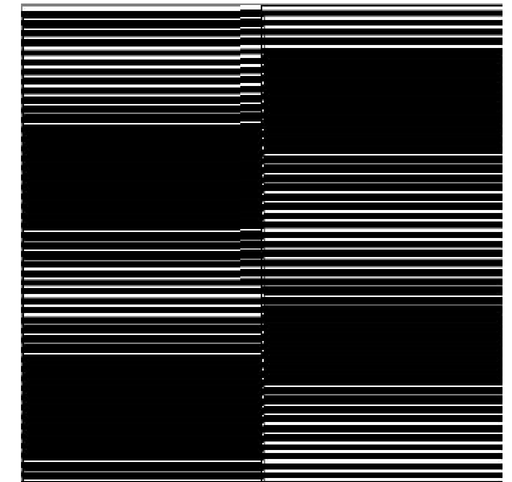


aligned

P3

Not aligned

p3



Pre-alignment $< P_{1,2}/2 \sim 2\mu$

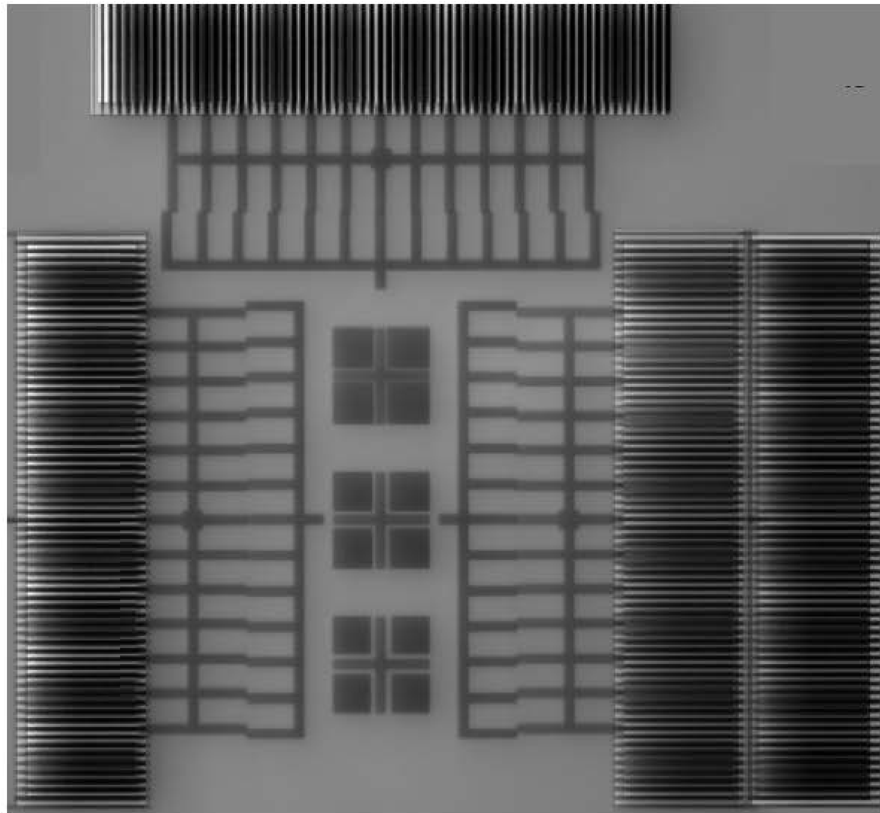
is required

Challenges:

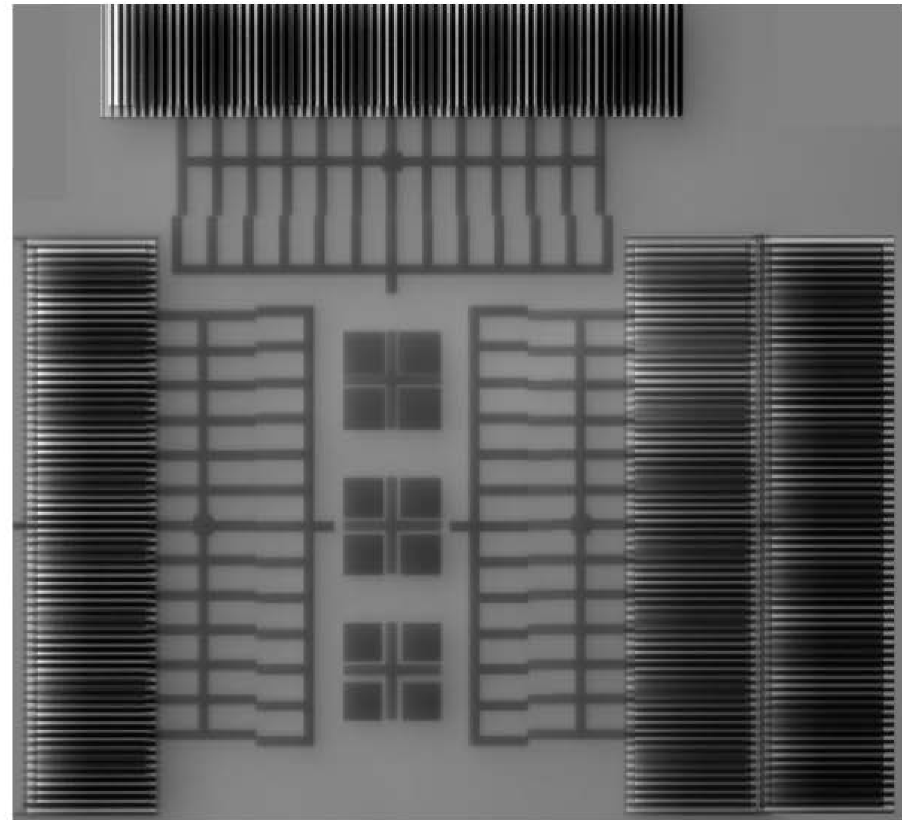
- Precise alignment in tilting.
- Grating fabrication error need to be very small, smaller than 10nm.

E. Moon, J. Vac. Sci. Tech. 1993A. MoelJ. Vac. Sci. Tech. 1995

Moiré alignment marks for NIL



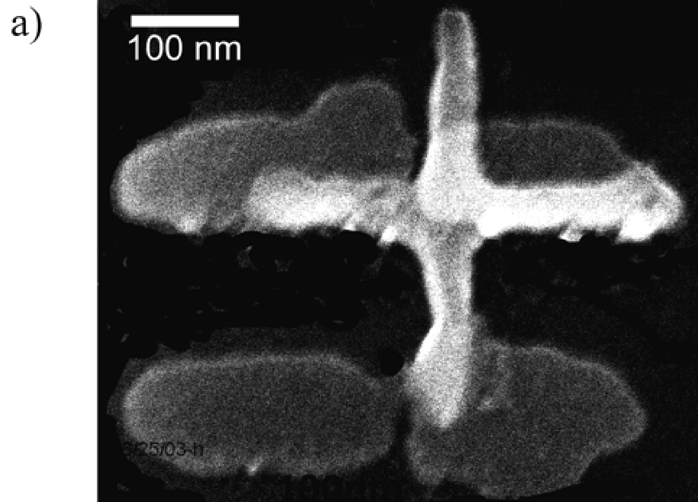
aligned



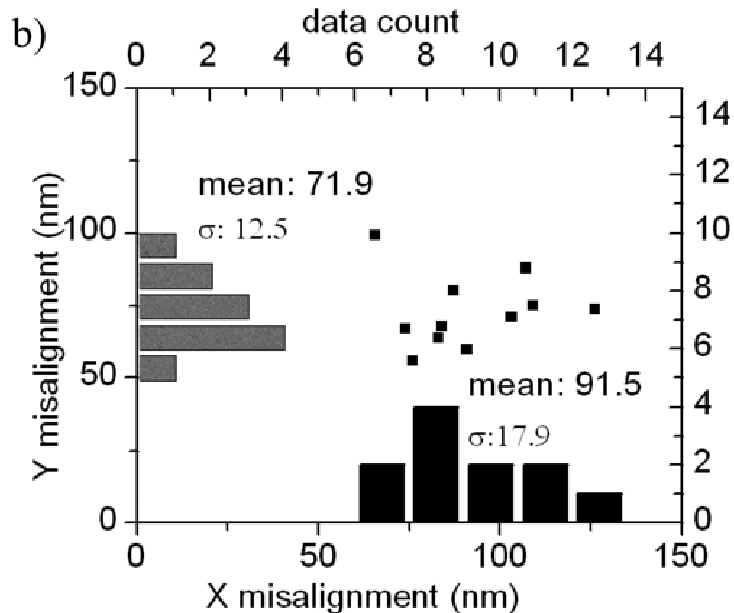
misaligned

Result of sub-100nm alignment in NIL

a)



b)



For UV-NIL, sub-100nm alignment can be achieved readily, but this is still too far away from requirement for IC production (few nm).

"Sub-20-nm Alignment in Nanoimprint Lithography Using Moiré Fringe", Li, Nano Lett., 2006.