The convergence of research and innovation.
Reticle (Photomask) Layout vs. Wafer Layout

Stepper vs. Contact Photolithography
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Stepper vs. Contact Litho.

Contact Alignment

- Places a reticle/mask in direct contact with a wafer.
- Benefit – can fill a single reticle with lots of varying designs, patterns entire wafer in one single exposure.
- Drawback – 1-2µm size variations across wafer, ~1-2µm minimum feature size.

Stepper Lithography

- Gives <1µm resolution and accuracy. Our DUV Stepper gives ~200nm resolution relatively easily, I-Line steppers ~500nm.
  - Wafer-Placement & Stitching accuracy is ≤20nm
- Drawback is the smaller exposure field size – you can’t expose a whole wafer in one shot, so filling a full-wafer with many different designs could require many (expensive) reticles.
  - Except: For repetitive pattern (eg. optical gratings), the Stitching capability allows for more variations to be included on a single reticle.
Contact Litho.

- **Contact Alignment** places a reticle/mask in direct contact with a wafer.
- Benefit – can fill a single reticle with lots of varying designs, patterns entire wafer in one exposure.
- Limits:– 1-2µm size variations across wafer, ~1-2µm minimum feature size, ~1µm alignment tolerance.
- Patterns are limited to the current mask plate – can not mix/match different mask plates easily.

* Image from Aaron R. Hawkins, Brigham Young University, “Contact Photolithography Alignment Tutorial” (online)
Stepper Litho.

- Fully motorized and computer programmed.
- Rely on highly accurate motorized wafer-placement and reticle placement.
- Laser-Interferometric wafer-stages allow for:
  - ≤ 20nm placement in a single exposure session
  - ≤ 50nm layer-to-layer alignment accuracy
- Automatic Focus/Tilt measurement on each die before exposure:
  - I-Line steppers: ~300-500nm minimum feature size
  - DUV stepper: ~200nm minimum features size
- The steppers can be programmed for flexible exposure maps:
  - Can expose multiple patterns on multiple reticles.
  - More complex programming, but highly flexible layouts. Wafer layout is different from reticle/photomask layout.

"Stepping" a single photomask pattern across a wafer. The same pattern is repeated, and/or different photomask regions can be stepped in sequence.

* Video from ASML, “Powering the next phase of semiconductor manufacturing” (online)
Stepper Litho: Reticle / Mask Layout

- Can place a number of different patterns onto the reticle, and then programmatically choose which ones will be shot onto the wafer, and where on the wafer they will be exposed.
- Example Reticle – a Glass (clear) plate with Chrome Patterns, defined by the CAD drawing you/we submit.

Multiple patterns (7), Size arbitrary
(within reticle size limit and coordinates/sizes should be well-defined)
Stepper Blade-Off

- Projection steppers can blade-off unwanted regions of the reticle, to select only a single pattern at a time for exposure.

Exposing only the “1” Image with motorized shutter blades

Stepper (step and repeat system)

- Die-by-die exposure
- Feature size (typically)
- 4x reduction

Shutter

Shutter is closed during focus and alignment and removed during wafer exposure

Reticle (may contain one or more die in the reticle field)

Projection lens (reduces the size of reticle field for presentation to the wafer surface)

Wafer stage controls position of wafer in X, Y, Z, \( \phi \)

* Stepper schematic from: Prof. Bo Cui, U. Waterloo, Class NE 343 Microfabrication and thin film technology, “Chapter 5 Lithography” (online)
Stepper Blade-Off

- Projection steppers can fill the wafer with different Patterns at different locations (on a fixed pitch though)

Expose Image #1:

- UV Light

Then Expose Image #2:

- (during same exposure session)

Wafer moves in X + Y to step/repeat the exposure

UV Light

These could be done in a single exposure “job” (“Layer”) – after all exposures are complete, you perform a single Develop step and proceed with your process.
Stepper Blade-Off

- You could also choose to shoot the entire reticle at one time and repeat that across the wafer.

UV Light

21x25mm

(not to scale)

100mm Diam.