Lecture 9

Microfabrication – Pattern Transfer (II)

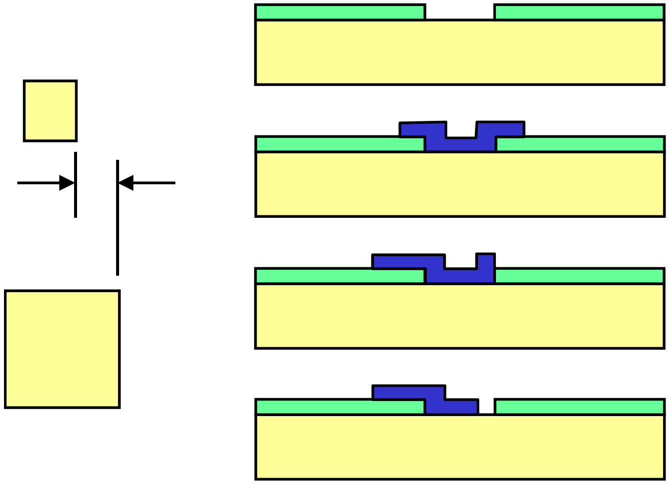
- Design Rules

- Mask Making
  - Photomasks
  - Electron-Beam Lithography
  - Comparison of Masks

- Double-Sided Lithography
- Soft Lithography

Design Rules

- When designing a complete process, each layer must be aligned to the previously patterned features.
- Because there can be small misalignment at each step, robust process design calls for the use of minimum mandatory offsets between mask features in successive layers.



Feature
on Mask 1

Mandatory
Overlap
Design Rule

Feature
on Mask 2

After patterning
with Mask 1

After Mask2:
Perfect alignment

After Mask2:
Barely unacceptable
misalignment

After Mask2:
Unacceptable
misalignment

Illustrating design rules that permit successful fabrication of devices in the presence of misalignment errors.

Photomasks

- Two basic methods: optical pattern generator and electron-beam lithography.
- Both start with fused silica(amorphous quartz) plates(5 inch square plates) that have been coated with a thin chromium layer, and then with a photoresist.
- Optical pattern generator requires an optical photoresist.
- It has sets of shuttles that permit the exposure of rectangular-shaped regions.
- A rectangle is exposed, the wafer is repositioned, and another rectangle is exposed.
- This process continues until the entire mask pattern is created in photoresist.
- The resist is then developed and baked, the chromium etched into the correct pattern.
- The resist is removed, leaving a chrome-on-quartz mask.
- Emulsion masks are cheaper to make, but are easily damaged.

Electron-Beam Lithography

- To use an electron-beam lithography machine to write the required pattern into an electron resist.
- Electron-beam resist(a polymer) is transparent to light, but can be depolymerized by the penetration of an electron beam, rendering the material locally soluble.
- A typical electron resist is poly-methylmethacrylate(PMMA).
- It behaves much like a positive photoresist, in that it is removed where the e-beam exposure occurs.
- Following exposure, the resist developed, the chromium is etched, and the resist is removed.
- A major advantage of e-beam masks is that there are few restrictions on the shapes of features. For examples, curved structures.

Mask Qualities vs. Etching Properties

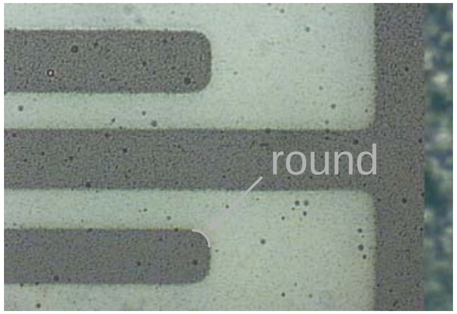
	Film Mask	Emulsion mask	E-beam mask
resolution	50㎛	10㎛	1㎛
tolerance	7-8㎛	2-3㎛	0.2㎛
cost	$25	$125	$1400
contrast	bad	good	excellent
cleaning	no	no	yes
# of usage	several	less than 20	unlimited if cleaned
hardness	flexible	hard	hard

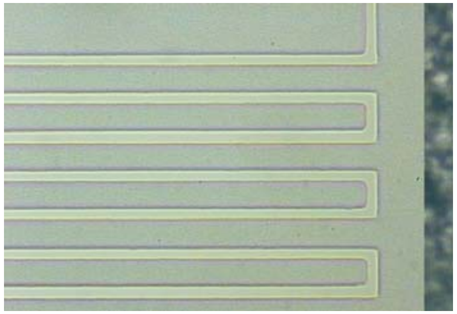
- Mask qualities on etching properties
  - Resolution, CD tolerance, edge sharpness
  - Roughness on vertical sidewall profile
- Result in selectivity

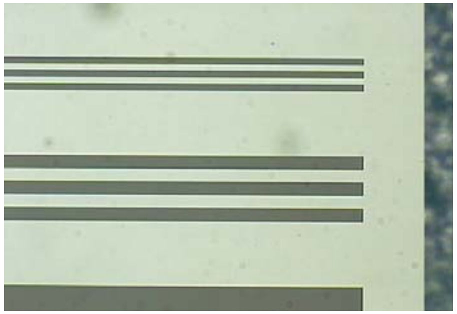
Comparison of Mask Qualities

Film Mask | Emulsion Mask | E-beam Mask

Magnification
×100





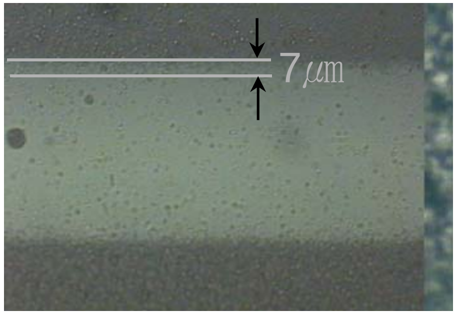


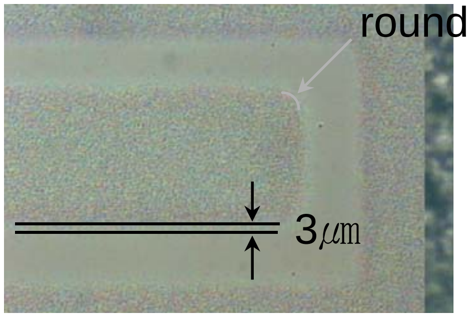
100㎛ width
50㎛ gap

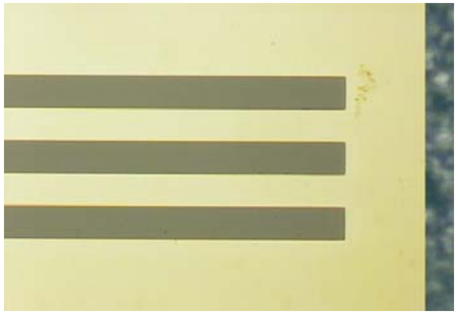
40㎛ width
20㎛ gap

10㎛ width
10㎛ gap

Magnification
×500







Double-Sided Lithography

- Many MEMS devices require patterning on both sides of a wafer.
- To achieve the required positional alignment between front and back side, special tooling is required.
- One first aligns the back-side mask to fiducial marks on the tool, then places the wafer over mask, and aligns the wafer to the tool using alignment features on the front.
- Within alignment tolerances, the wafer and bask-side mask are then aligned to each other.
- The bask side of the wafer is then exposed from the back.

Soft Lithography

- Micro stamp.
- It uses a molded polymeric body to accomplish physical pattern transfer, just like a rubber stamp used to press onto an ink pad then onto paper.
- The mold is formed by casting a silicone rubber, poly dimethysiloxane (PDMS), onto a master that contains the desired relief pattern.
- The master can be formed by conventional lithography and etching.
- The molded parts are stripped from the master, and are then used as flexible printing devices, especially for non-planar substrates.
- When coated with the material to be transferred(typically a thin organic film, such as a self-assembled monolayer (SAM)), then pressed onto the desired surface, patterned material transfer can be achieved.