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EE C245 – ME C218
Introduction to MEMS Design
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Lecture Module 4: Lithography, Etching, & Doping

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Lecture Outline

- Reading: Senturia, Chpt. 3; Jaeger, Chpt. 2, 4, 5
  - Lithography
  - Etching
    - Wet etching
    - Dry etching
  - Semiconductor Doping
    - Ion implantation
    - Diffusion

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Lithography

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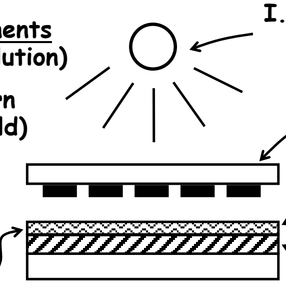
Lithography

Lithography
- Method for massive patterning of features on a wafer → pattern billions of devices in just a few steps

Four Main Components
(that affect resolution)

I. Radiation Source



Designated pattern
(clear or dark field)
emulsion chrome
- Generated from layout

III. Photoresist

IV. Exposure System ⟹ contact, step and repeat
optics → this is where the real art is!

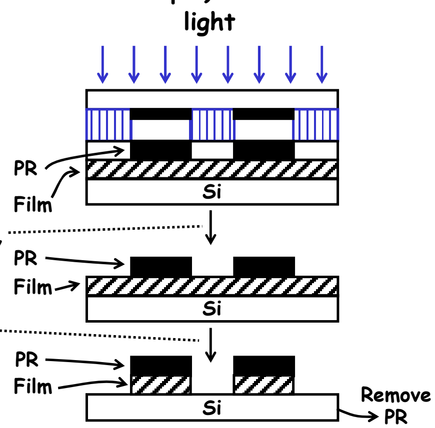
Lithography (cont.)

The basic Process – (Positive Resist Example)

Exposed PR ⟶ converts to another form after reaction with light (e.g., (+)-resist: polymer ⟶ organic acid)

Dip or spray wafer with developer ⟶ if (+) resist, developer is often a base

Etch ⟶ PR protects film; open areas of film get etched



Lithography (cont.)

With each masking step usually comes a film deposition, implantation and/or etch. Thus, the complexity of a process is often measured by # masks required.

NMOS: 4-6 masks
Bipolar: 8-15 masks
BICMOS: ~20 masks
CMOS: 8-28 masks
↖ Multi-level metallization

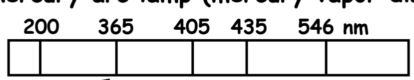
Comb-Drive Resonator: 3 masks
GHz Disk: 4 masks

Now, take a closer look at the 4 components:

I. Radiation Source

I. Radiation Source
- Several types: optical (visible, UV, deep UV light), e-beam, X-ray, ion beam
  The shorter the wavelength → Better the resolution
  Today's prime choice due to cost and throughput.
  (throughput: Can expose billions of devices at once!)

Optical Sources:
- Mercury arc lamp (mercury vapor discharge)



we have all of these in our μlab; I-line; G-line (we have both in our μlab)

- For deep UV, need Excimer laser (very expensive)
  Glass opaque, so must use quartz mask and lens

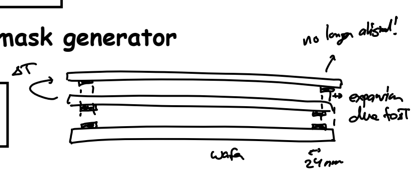
II. Mask

II. Mask → has become one of today's biggest bottlenecks!

Electronic computer representation of layout (e.g., CIF, GDSII) ⇨ A single file contains all layers

↓ tape ⟶ mask generator

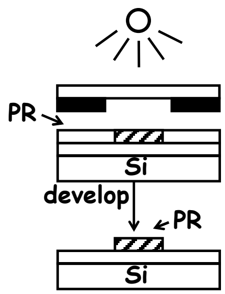
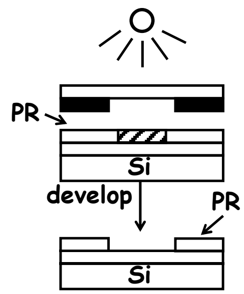
Masks for each layer



Mask Material:
- Fused silica (glass) ⟶ inexpensive, but larger thermal expansion coeff.
- Quartz ⟶ expensive, but smaller thermal expansion coeff. ✓

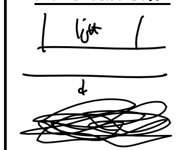
III. Photoresist (optical)

Pictorial Description:

	Negative	Positive
Pictorial Description:		
Exposed Area:	remains	removed

III. Photoresist (optical)

Mechanism:



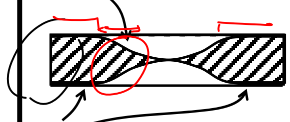
Negative	Positive
photoactivation ↓ Polymerization (long, linked Carbon chains) ↓ Developer solvent removes unexposed PR	photoactivation ↓ Converts exposed PR to organic acid ↓ Alkaline developer (e.g.,kOH) removes acid

III. Photoresist (optical)

Issues:

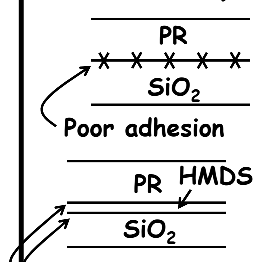
Negative

Polymerized PR swells in solvent → bridging problem



Positive

Doesn't adhere well to SiO_2
Need primer: HMDS (hexamethyl disilazane)



Typical Procedure for Lithography

- Clean Wafer — Very important step
- ↓ Dry Wafer — 30 min. @ 120°C pre-bake
- ↓ Deposit HMDS — (for oxide on wafer surface)
- ↓ Spin-on PR — 30-60 sec @ 1000-5000 rpm
- ↓ Soft Bake — 2 min @ 90°C; Improve adhesion and remove solvent from PR
- ↓ Align & Expose
- ↓ Develop → Descum → Post Bake

Oxygen plasma (low power ~ 50W) (Descum, Post Bake)

Topography very important: