EE 143
Microfabrication Technology
Spring 2010

Prof. Clark T.-C. Nguyen

Dept. of Electrical Engineering & Computer Sciences
University of California at Berkeley
Berkeley, CA 94720

Lecture Module 1: Lithography

Lithography

Lithography

Lithography

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

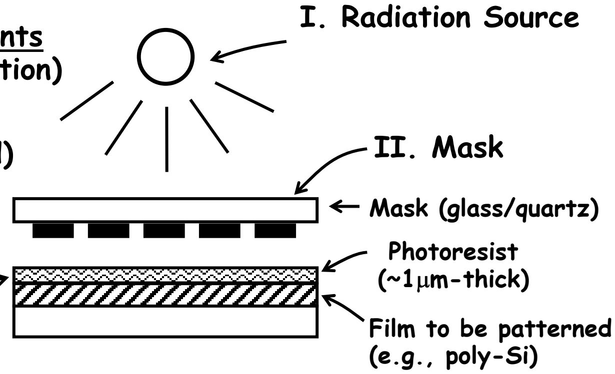
Four Main Components
(that affect resolution)

I. Radiation Source

Designated pattern
(clear or dark field)
emulsion chrome

- Generated from layout

II. Mask



III. Photoresist

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

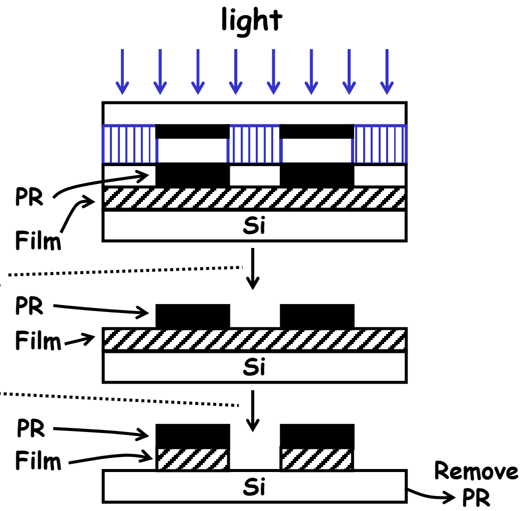
Lithography (cont.)

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

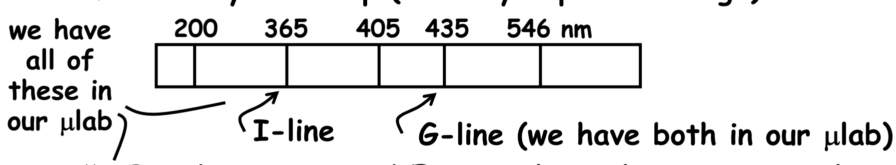
- Several types: optical (visible, UV, deep UV light), e-beam, X-ray, ion beam

  The shorter the wavelength → Better the resolution

  (optical) 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)



- 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

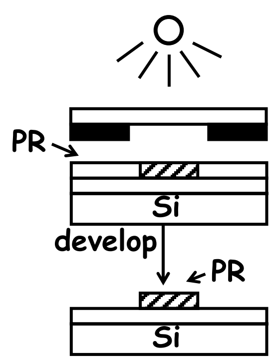
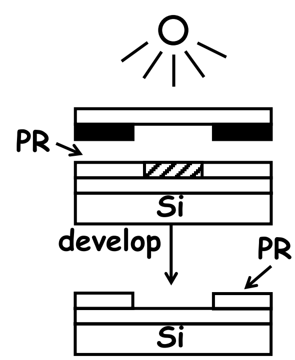
↓ tape ⟶ mask generator

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)

	Negative	Positive
Pictorial Description:		
Exposed Area:	remains	removed

III. Photoresist (optical)

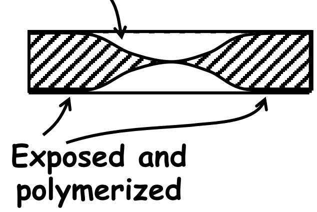
	Negative	Positive
Mechanism:	photoactivation ↓ Polymerization (long, linked Carbon chains) ↓ Developer solvent removes unexposed PR	photoactivation ↓ Converts exposed PR to organic acid ↓ Alkaline developer (e.g.,kOH) removes acid

III. Photoresist (optical)

Issues:

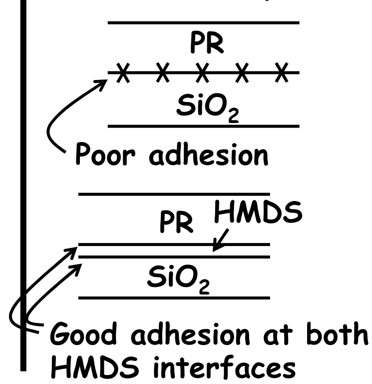
Negative

Polymerized PR swells in solvent → bridging problem



Positive

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

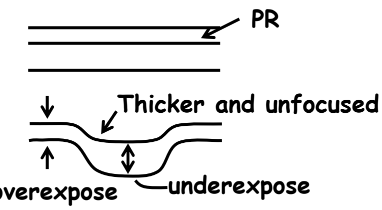


Typical Procedure for Lithography

- **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**

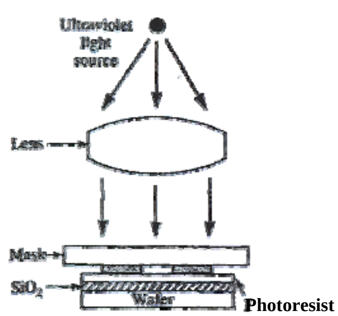
Oxygen plasma (low power ~ 50W) (Descum)

Topography very important:



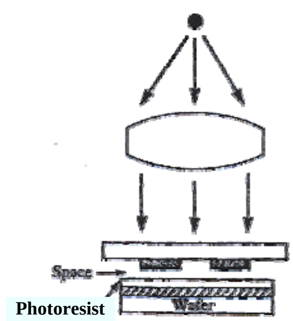
IV. Exposure System/Optics

Contact Printing



- Mask in contact with wafer
- *Problem*: mask pattern can become damaged with each exposure → must make a new mask after x number of exposures

Proximity Printing

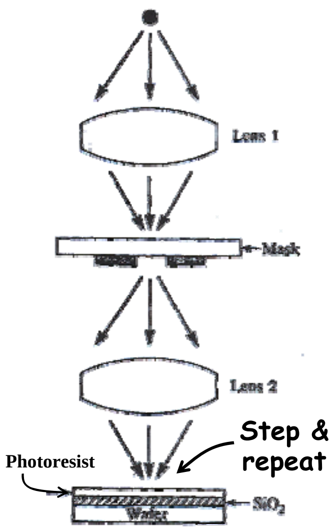


- Mask in very close proximity but not touching

- 1X printing very useful for MEMS → can expose surfaces with large topography (where reduction printers cannot)

IV. Exposure System/Optics

Projection Printing



- Dominates in IC transistor fabrication
- 5X or 10X reduction typical
- Mask minimum features can be larger than the actual printed features by the focused reduction factor → less expensive mask costs
- Less susceptible to thermal variation (in the mask) than 1X printing
- Can use focusing tricks to improve yield: