Outline:

1. Photo resist materials
   - Main functions: Patteren formation + Etch Protection
   - 3 components of resist: Base, PAC, Solvent
   - Overview of TV resist

2. Key parameters
   - Sensitivity
   - Contrast

   ![Graph](image)

   \[ Y = \frac{1}{\log(D_{100}/D_0)} \]

   More sensitive + better contrast

3. How contrast effects image:

   ![Graph](image)

   \[ \Delta D_{\text{High}} \]

   \[ \Delta D_{\text{Low}} \]

   \[ \Delta D_{\text{Contrast}} \]

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1. Su-B: An example of high contrast

   If \( Y \) is too low, mask pattern will not be formed. Patteren formation governed by

   - CMTF (Critical Resistor Modulation Transfer Function)
   - MTF

2. Resist thickness affects contrast:

   \[ Y = \frac{1}{\beta + \alpha T_R} \]

   \( T_R \): Resist thickness

3. Resist Chemistry

4. Multilayer: Contrast Enhancement Layers

5. Photo resist Processing
Photoresist Materials (radiation-sensitive compounds)

Two Main Functions:

a) Precise Pattern Formation
b) Protection of the substrate during etch or ion implant

3. Components of Resists

- Resin: Matrix Molecule
  - Binder, establishes mechanical properties of the film
  - Insensitive to radiation

\[ \text{hv} \quad \text{O} \quad \rightarrow \quad \text{Solvent} \quad \text{PCME (propylene glycol monomethyl ether)} \]

- More soluble or chain scission
- Less soluble

- Actively involved
- Causes photochemical change to the resist

\[ \text{hv} \quad \text{O} \quad \rightarrow \quad + \quad - \]

- Solubilizes resist so that it can be spun coat onto wafer

- High boiling point of some other properties of alcohols, etc.
Brief overview of steps for UV resists:

1. UV light
2. Positivity
3. Cross-linked (higher viscosity)
4. Insoluble
5. Develop
6. More soluble or chain scission
7. Develop
Sensitivity of a resist $\delta$

$$\delta \approx \frac{\text{photo-induced events}}{\text{photo-absorbed} - \alpha(\lambda)}$$  [Absorption]

- Use $\lambda$ in range $\alpha(\lambda)$
- Keep $\alpha(\lambda)$ small at point $\lambda$

Important for determining dose needed to fully expose the resist.

- Contrast is a measure of PR's ability to distinguish light $k$ dark

Contrast $\gamma$ inflation:

- Resolution
- Resistor wall angle
- Line width

$\gamma$ (positive resist) $\rightarrow$ rate of chain scission/solubility per change in dose

$\gamma$ (negative) $\rightarrow$ rate of cross-linking, per change in dose

How do we measure $\gamma$?

- Exposure - response curve

Exposure $\rightarrow$ response curve

Practical Heat

$$\gamma = \frac{1}{\log\left(\frac{D_{10}}{D_0}\right)}$$  [PR]

Lowest dose to drive photochemistry
Critical Resist Modulation Transfer Function (CMTF)

\[ \text{CMTF} = \frac{D_{100} - D_0}{D_{100} + D_0} = \frac{10^{0.6} - 1}{10^{0.5} + 1} \]

Modulation Transfer Function (MTF)

\[ \text{MTF} = \frac{M_{\text{image}}}{M_{\text{mask}}} \]

\[ M = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}} \]

\[ \text{MTF} = \frac{M_{\text{image}}}{M_{\text{mask}}} \]

No imaging problems if \( \text{CMTF} > \text{MTF} \)
So, the more close a resist gets, the closer it becomes to being fully UV photochemically transformed.

The case of intensity is:

\[ I(z) = I_0 e^{-\alpha z} \]

\( \alpha \) = absorption coefficient

\( z \) = depth

So, intensity will be have deeper in resist.

- Do only of resist (two layers begin to get exposed first)
- Dio = \( \frac{1}{\text{absorbance}} \) gets larger for thick films

Leads to form:

\[ \frac{1}{\sigma} = \frac{1}{\eta + \sigma \text{thickness}} \]

\( \sigma \) = absorbance for thin films

- More contrast for thinner films
- More step coverage & etch resistance

Ideally, we want absorbance of PA to decrease after exposure @ \( \lambda \) of choice

More transparent after exposure.
Photoreactive Chemistry:

(i) + RA: 3.6 g/ml ac. DNQ / Novolac Resin
  - Resin
  - RA
  - Solvent

a) Resin: Novolac (new liquor) used to bind dye

Phenol - Formaldehyde Resins

\[
\text{C}_6\text{H}_4\text{OH} + \text{C}_2\text{H}_4\text{O} \rightarrow \text{(C}_6\text{H}_4\text{O})_n
\]

Bue soluble (15 mm/sec)

b) DNQ = diazonaphthoquinone
   - diazo - naphtho - quinone

  - Dissolution Inhibitor (Forbids Novolac from dissolving)

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Phptochemical transformation of

Base-Involvement: React with Norborne in triple (H-bonding?)

Carbene Intermediate

$\text{hv} + \text{destabilizes } N\equiv N$

Carboxylic Acid

Indene

ICA: It's an

Pure-Soluble (Acid)
(C) Solvent → PGE (high BP > 100°C, good solubility)

Base 8 TMAH in H₂O (0.26 N)

A base

2) - PR₃
   - Low resolution because of swelling.

(a) Resin: Cyclized synthetic rubber resin
   - Poly isoprene
   - Radiation insensitive
   - Soluble in non-polar solvents (e.g., toluene)

(b) 10-0 PAM:
   - bis-arylazide

\[
\text{N}_3 \quad \text{O} \quad \text{X} \quad \text{O} \quad \text{N}_3
\]
Cross-linking Chemistry:

\[ R-N_3 \xrightarrow{\text{hv}} R-N_2 + N_2 \]
\[ R-NH-C- \xrightarrow{\text{midre}} R-N=N-N-R \]

O2 will quench R-N3 reactive precursors

Other resists:

CAR (Chemically Amplified Resists) for DUV (D Sue-Mate no acid)

+ Baking J
Catalysis (iso-poor reaction/photo)
↓
Soluble j Most acid OH's
very high contrast

Diffusion enabled @ ln + 30 nm
Multilayer Resist:

- Place in different layers
- Mesh high and low
- Great for "lift-off" processes

Contrast Enhancement Layers:

- Like Bilayer, but CFL opaque
- Become transparent when D100 close
- Create contact mask with 0.15g resolution

where $g \to \infty$!!
Photosprint Processing:

1. Dehydrate → Prime → Spin on PR → Develop
   - PR: Adhesion promoter
   - Develop: Wash away unwanted chemicals
   - PR: Adhesion promoter

2. Post-dec → Post-bake → Post-dew + Photo sensitise
   - Post-bake: Increase sensitivity
   - Post-dew: Wash away chemicals
   - Photo sensitise: Improve solubility

3. Dehydrate:
   - 200-400°C makes water more hydrophobic
   - to improve PR adhesion

4. Prime:
   - HDMS: Hexamethyldisilazane
   - HC = Hydrosilane
   - Hydrophilic

5. Spinning:
   - (1) Clean 1 cleaner
   - (2) Filter PR w/ column filter
   - (3) Remove bubbles
   - (4) Dispense to 1 mm 2000-6000 rpm 1 min
thickness \( a \) \( \frac{V}{\omega} \rightarrow \) viscosity

5) Remove edge beads (Contact Litho)

6) Results:
   a. particles
   b. inhomogeneous evaporation (streaks)
   c. air bubble pinholes, air holes

3) Soft-bake (Precure) 100-120°C
   - Remove solvent: too short time \(
   \rightarrow \)
   - Too much time \( \rightarrow \) make PAC too sensitive

\[ \text{Narrow window} \]

6) Exposure: over
   - Standing waves

8.13
Funky-beer: Interference leads to I(thickness)

\[ D_{100} \]

- Stop edges have non-uniform PR thickness

a) Post-Develop:
- DNA/Novolac Diffusion to smear Standing wave patterns
- CH, Amp, PEC (CAH) to drive catalytic

b) Post-Develop Bake:
- Harden patterned PR
- Improves SiO₂ adhesion (good for wet etching, e.g., HF)

c) Photo-stabilization: \( \lambda < 320 \text{nm} + 110^\circ \text{C} \) for 1min
- Cross linking of resist
- Improves Etch resistance ~ 40\%B
- Hard to remove: O₂ plasma