EE 527 MICROFABRICATION

Lecture 15

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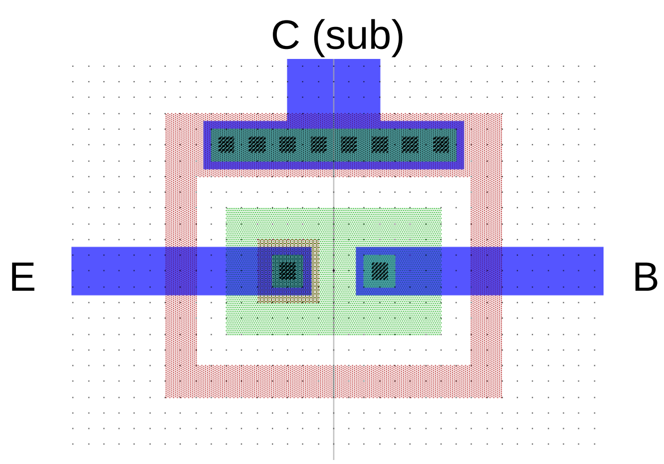
EE-527 M4 MASK SET: NPN BJT



A_E = 40 µm x 40 µm

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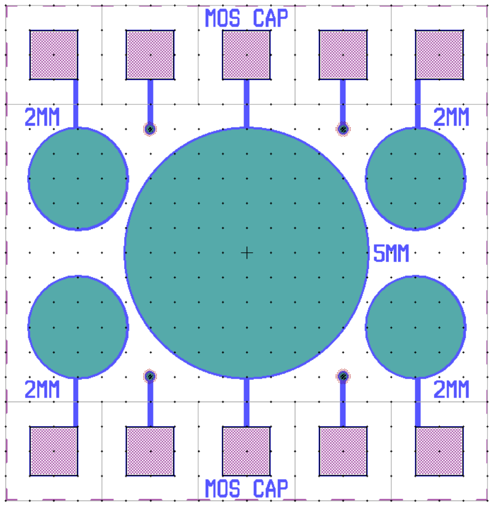
EE-527 M4 MASK SET: MOS C-V TEST CAPACITORS



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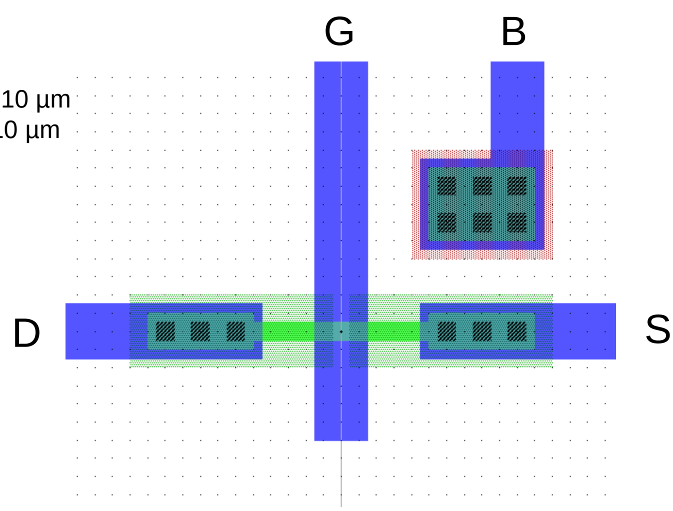
EE-527 M4 MASK SET: P-CHANNEL MOSFET

W = 10 µm
L = 10 µm



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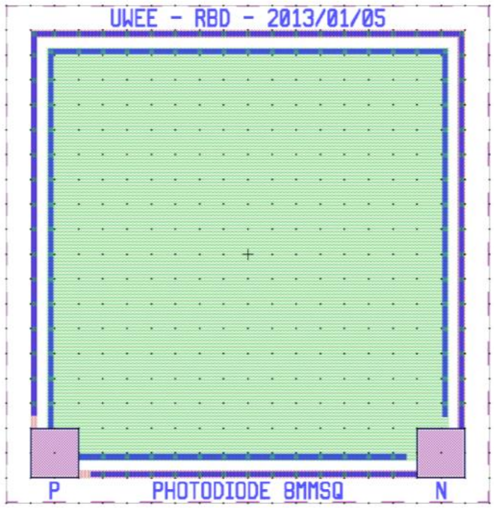
EE-527 M4 MASK SET: LARGE AREA PHOTODIODE



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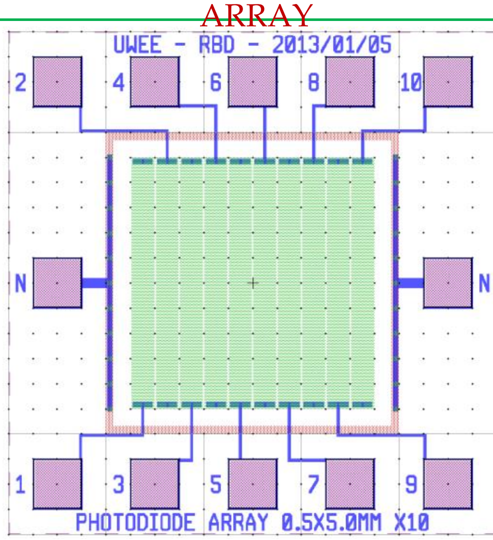
EE-527 M4 MASK SET: 10-ELEMENT PHOTODIODE ARRAY



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OPTICAL LITHOGRAPHY(CHAPTER 9)

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PHOTOLITHOGRAPHY

- Photo-litho-graphy: *latin*: light-stone-writing
- Photolithography is an optical means for transferring patterns onto a substrate. It is essentially the same process that is used in lithographic printing.
- Patterns are first transferred to an imagable photoresist layer.
- Photoresist is a liquid film that can be spread out onto a substrate, exposed with a desired pattern, and developed into a selectively placed layer for subsequent processing.
- Photolithography is a binary pattern transfer process:
  there is no gray-scale, no color, and no depth to the image.

OVERVIEW OF THE PHOTOLITHOGRAPHY PROCESS

- Surface preparation
- Coating (spin casting)
- Pre-bake (soft bake)
- Alignment
- Exposure
- Development
- Post-bake (hard bake)
- Processing using the photoresist as a masking film
- Stripping
- Post processing cleaning (ashing)

SURFACE PREPARATION: BAKE AND PRIME

- Adhesion promoters are used to assist resist coating.
- Resist adhesion factors:
  - moisture content on surface – VERY IMPORTANT!
  - wetting characteristics of resist
  - delay in exposure and prebake
  - resist chemistry
  - surface smoothness
  - stress from coating process
  - surface contamination
- Ideally, the wafer surface should be dehydrated of all H_2O
  - Wafers are given a “singe” step to desorb any water surface film
    - 15 minutes in 80-90°C convection oven, OR
    - 1 minute on 90°C hot plate

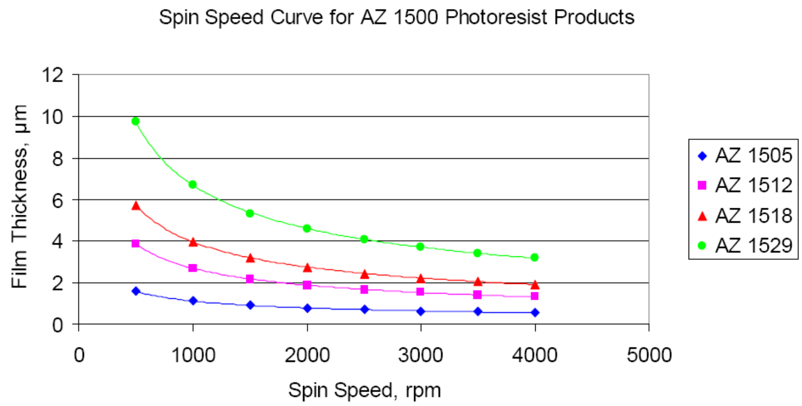
BAKE AND PRIME/WAFER PRIMERS

- For silicon and sapphire:
  - primers form bonds with surface and produce a polar (electrostatic) surface
  - most are based upon siloxane linkages (Si-O-Si)
    - 1,1,1,3,3,3-hexamethyldisilazane (HMDS), $(CH_3)_3SiNHSi(CH_3)_3$

PHOTORESIST SPIN COATING

- Wafer is held on a spinner chuck by vacuum and the resist is spread out to a uniform thickness by spin coating.
- Typically 2000-6000 rpm for 15-30 seconds.
- Resist thickness is set by:
  - primarily resist viscosity
  - secondarily spinner rotational speed
- Resist thickness is given by $t = kp^2/\omega^{1/2}$, where
  - k = spinner constant, typically 80-100
  - p = resist solids content in percent
  - ω = spinner rotational speed in rpm/1000
- Most resist thicknesses are 1-2 μm for commercial Si processes.

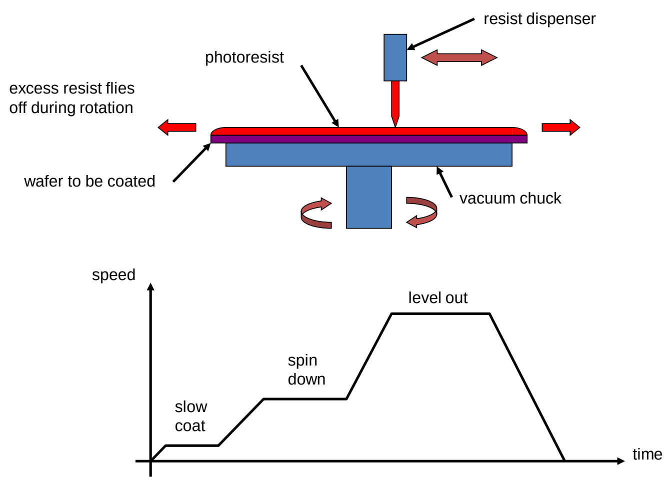
SPIN COATING / AZ-1500 SERIES PHOTORESIST THICKNESS VERSUS SPIN SPEED



Note that choosing the proper photoresist viscosity is the primary means to control the applied thickness. The spin speed only adds fine adjustment within this range.

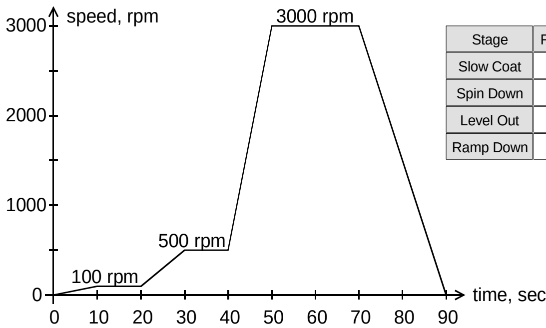
Graph from AZ Electronic Materials data sheet

SPIN COATING / PHOTORESIST SPIN COATING



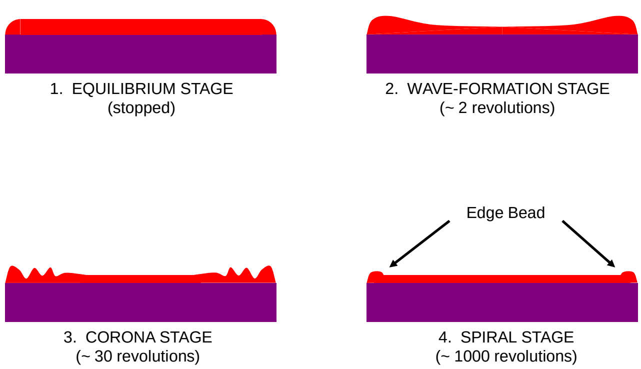
SPIN COATING/PROTOTYPE SPIN COATING RECIPE

- This is a good starting point for most positive photoresists.
- Automatic systems dispense the resist during the slow coat stage.
- The final spin speed (e.g. 3000 rpm) sets the final resist thickness.



Stage	Final Speed	Ramp Time	Hold Time
Slow Coat	100 rpm	10 sec	10 sec
Spin Down	500 rpm	10 sec	10 sec
Level Out	3000 rpm	10 sec	20 sec
Ramp Down	0 rpm	20 sec	0 sec

SPIN COATING/STAGES OF RESIST COATING

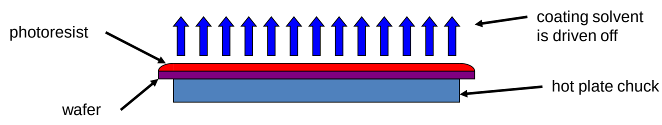


SPIN COATING/SPINNING ARTIFACTS

- Striations
  - ~ 30 nm variations in resist thickness due to nonuniform drying of solvent during spin coating
  - ~ 80-100 μm periodicity, radially out from center of wafer
- Edge bead
  - a residual ridge in the resist at edge of wafer
  - can be up to 20-30 times the nominal thickness of the resist
  - radius on wafer edge greatly reduces the edge bead height
  - non-circular wafers greatly increase the edge bead height
  - edge bead removers are solvents that are spun on after resist coating and which partially dissolve away the edge bead
- Streaks
  - radial patterns caused by hard particles whose diameter are greater than the resist thickness

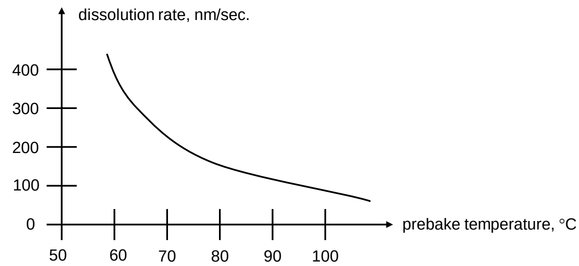
PREBAKE (SOFT BAKE) - 1

- Used to evaporate the coating solvent and to densify the resist after spin coating.
- Typical thermal cycles:
  - 90-100°C for 20 min. in a convection oven
  - 75-85°C for 45 sec. on a hot plate
- Commercially, microwave heating or IR lamps are also used in production lines.
- Hot plating the resist is usually faster, more controllable, and does not trap the solvent like convection oven baking.



PREBAKE (SOFT BAKE) - 2

- A narrow time-temperature window is needed to achieve proper linewidth control.
- The thickness of the resist is usually decreased by 25 % during prebake for both positive and negative resists.
- Less prebake increases the development rate:



PREBAKE (SOFT BAKE) - 3

- Convection (ovens):
  - Solvent at the surface of the resist is evaporated first, which can cause the resist to develop an impermeable skin, trapping the remaining solvent inside.
  - Heating must go slow to avoid solvent burst effects.
- Conduction (hot plates):
  - Need an extremely smooth surface for good thermal contact and heating uniformity.
  - The temperature rise starts at bottom of wafer and works upward, more thoroughly evaporating the coating solvent.
  - It is generally much faster and more suitable for automation.