Lecture 8: Lithography II

- **Announcements:**
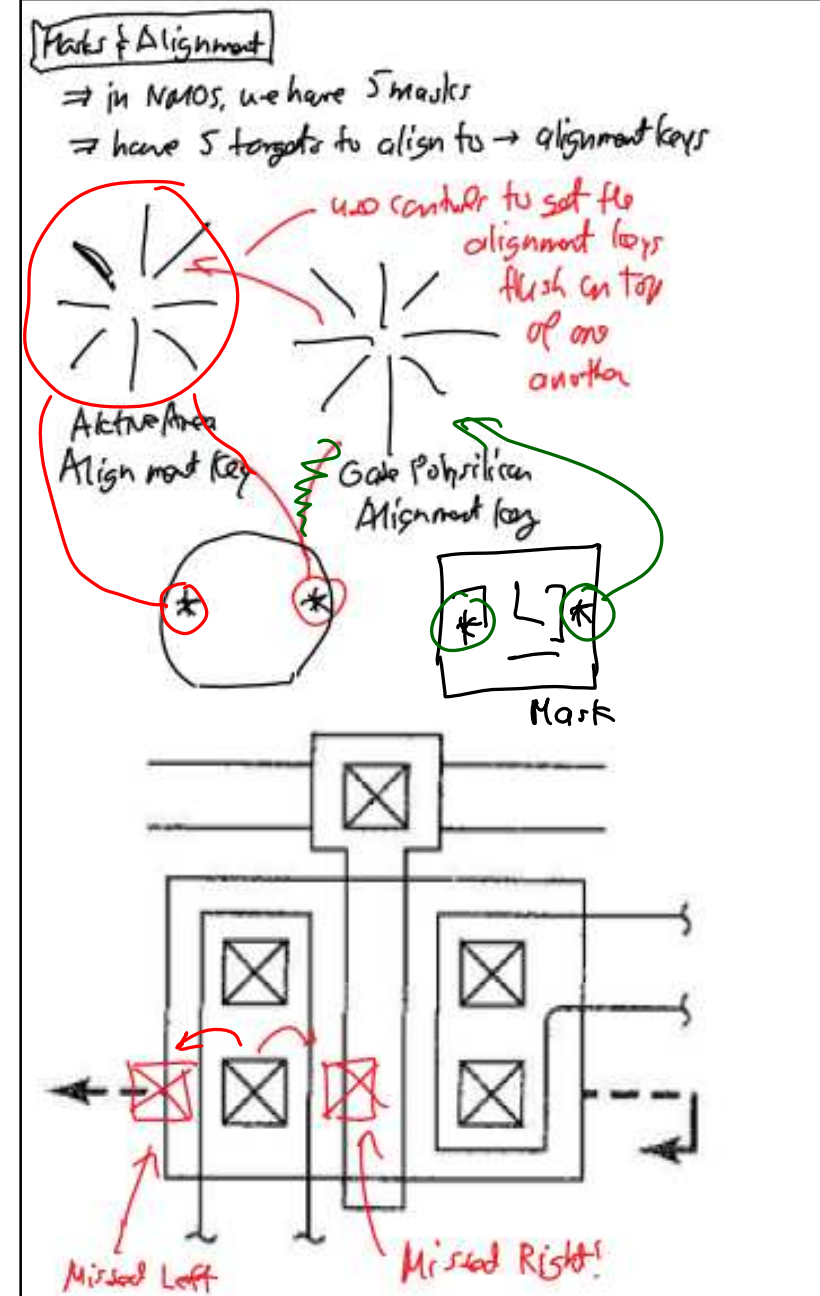 - ↳ HW#3 due tomorrow
  - ↳ HW#4 online soon
  - ↳ Graded HW#2 coming back
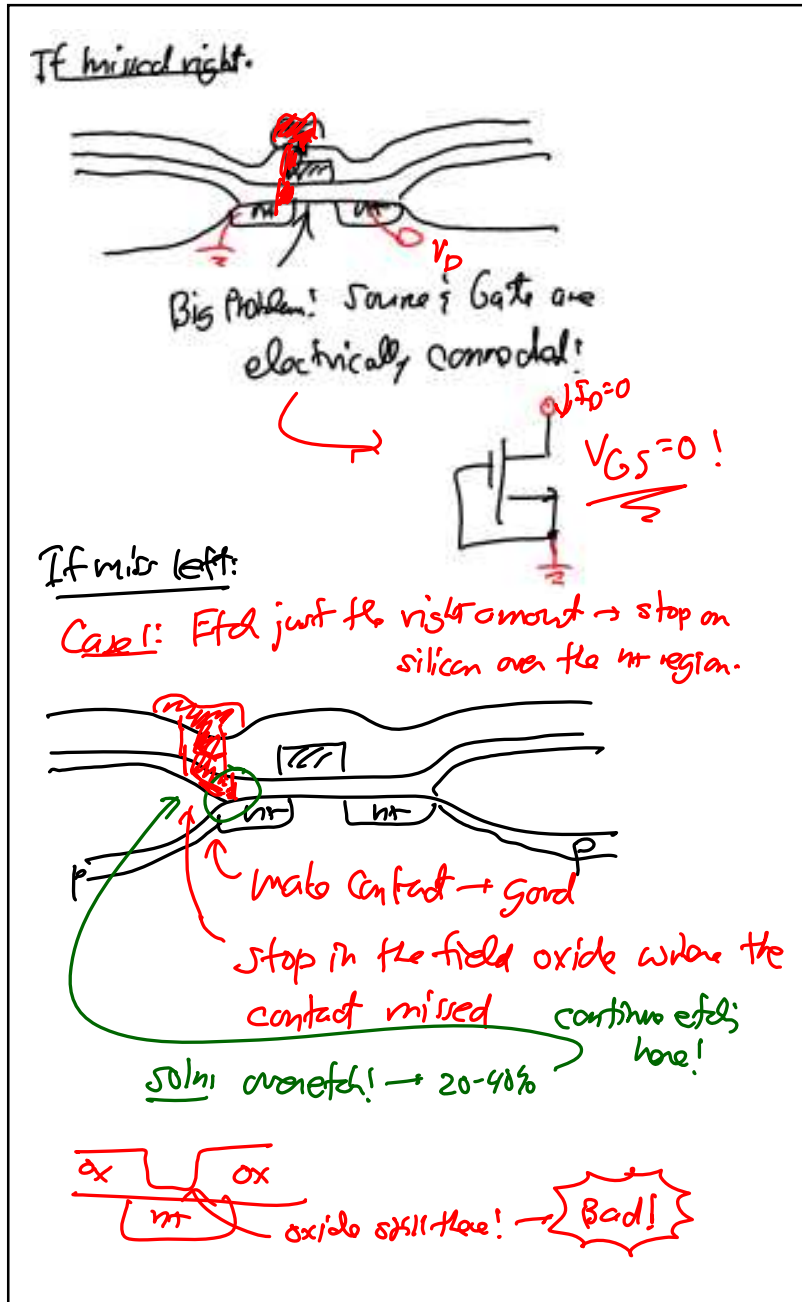- ------------------------------------
- **Lecture Topics:**
  - ↳ **Masks & alignment**
  - ↳ **Lambda design rules**
  - ↳ Four main components of lithography
    - —Radiation source
    - —Mask
    - —Photoresist
    - —Exposure system
  - ↳ **Resolution**
  - ↳ **Linewidth control**
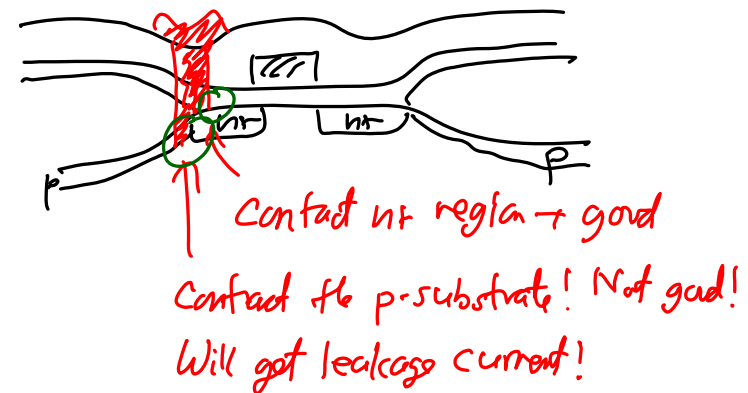 - ↳ **Alignment accuracy**
- ------------------------------------
- **Last Time:**
- Went through Module 1 on Lithography
- Finish this up now …
- … then get back to Masks & Alignment, which we were doing before my computer problems

If missed right.

Big Problem! Source & Gate are electrically connected!

$V_{DS} = 0$

$V_{GS} = 0$!

If miss left:

Case I: Etch just the right amount → stop on silicon over the n+ region.

make Contact → Good

stop in the field oxide where the contact missed

continue etch here!

Soln: overetch! → 20-40%

oxide still there! → Bad!

Case 2: Overetch to make sure the contact goes all the way to the n+ region → this is usually what one would do

Contact n+ region → good

Contact the p-substrate! Not good!
Will get leakage current!

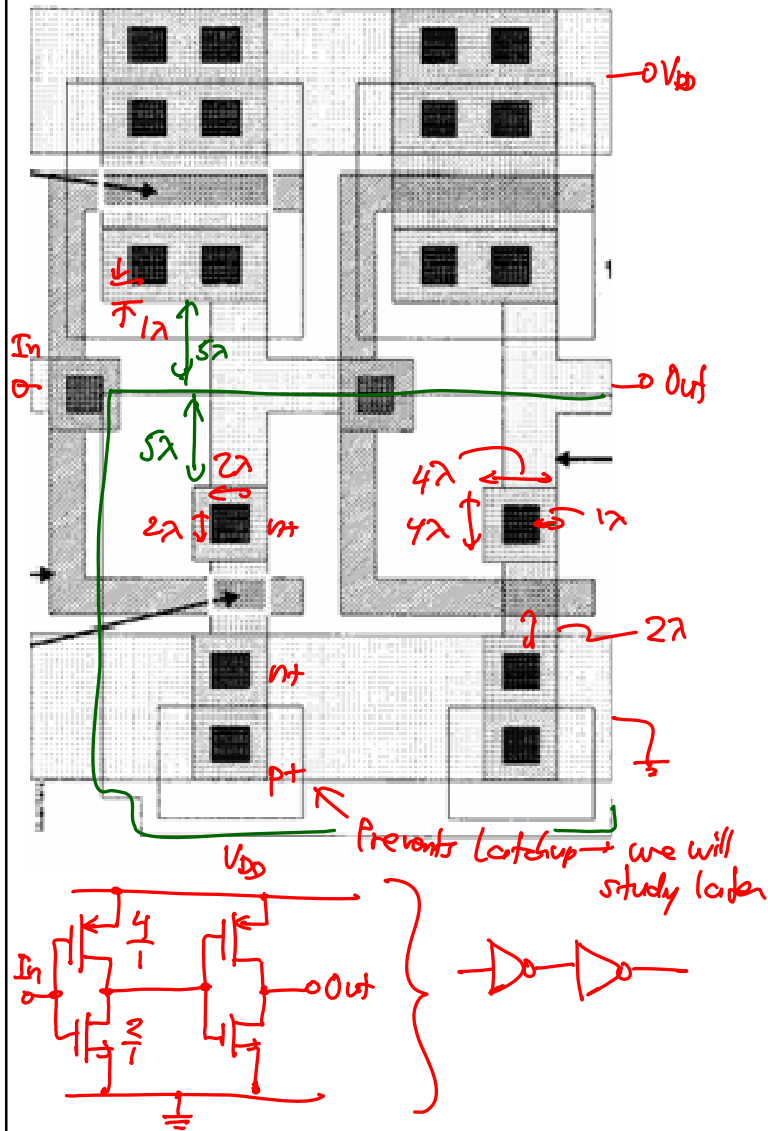To reduce the probability that the above happen, we use design rules!

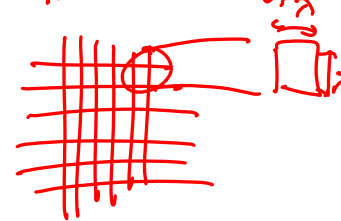Definition. Design Rules
  A set of rules that set a lower limit on:
  ① The dimension of a pattern.
  ② Separation between patterns of the same or different layers.
  ③ Extension of a pattern (of one layer) beyond another pattern (of another layer).

Left Panel

In the 90's, we had λ design rules.
↳ a standard dimension

—○ V_{DD}

In ○

1λ 5λ

In

5λ

○ Out

2λ
2λ n+

4λ
4λ 1λ

2λ

n+

2λ

p+

Prevents Latchup → we will study later

V_{DD}

In

$\frac{4}{1}$

$\frac{2}{1}$

○ Out

Right Panel

Usually, 2λ = technology resolution (e.g., 0.18μm, 14nm)

2λ ″ 2λ ″

↓   ↓

λ = 90nm λ = 7nm

e.g., minimum size gate!

2λ
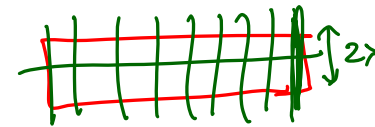
What determines these rules?

D_C → minimum dimension of a Contact

E_{AC} → Minimum extension of Active Area (A) beyond Contact (C)
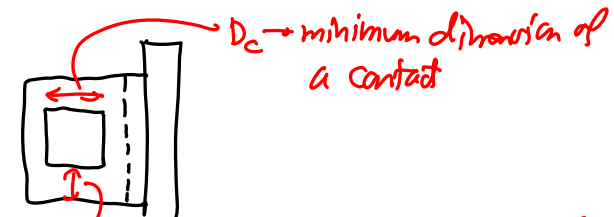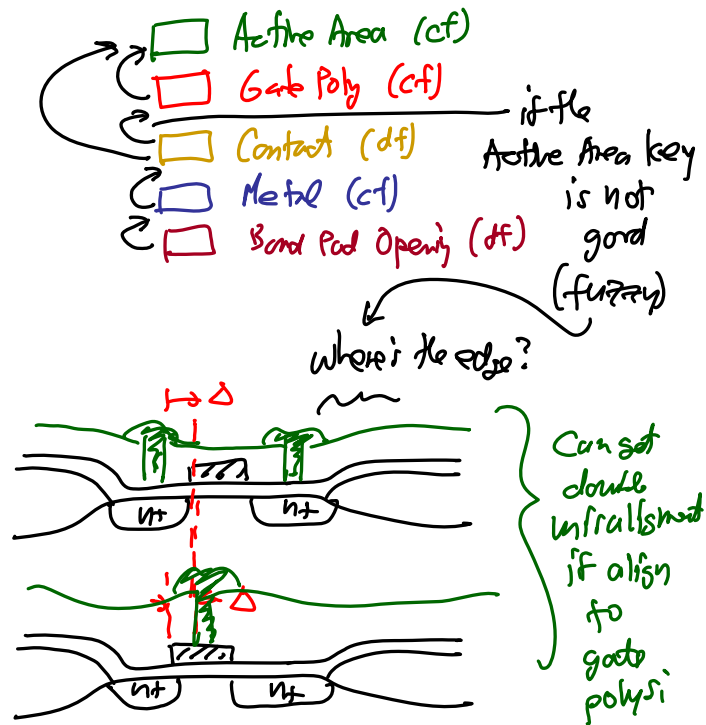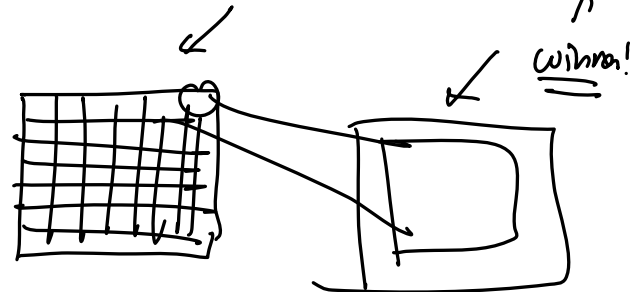
D_C → limited by resolution of photolithography

E_{AC} → { Alignment Error (layer-to-layer) + Undercutting of the Contact Hole (or size variation) + Encroachment on the Active Region (by the field oxide) }

Which aligned key to align to?

- Active Area (cf)
- Gate Poly (cf)
- Contact (df)
- Metal (cf)
- Bond Pad Opening (df)

if the Active Area key is not good (fuzzy)

where's the edge?

Can set double misalignment if align to gate poly!

Exposure Tool Comparison

	Contact	Proximity	Projection
Tool Cost	cheap	more expensive	very expensive
Maintenance Cost	low	low	high
Resolution	excellent	not too good	very good
Throughput	high	high	lower
Mask Cost	high	high	lower

wafer!

Resolution (for projection lithography)

Depth of Focus (DOF)

Point Source

Collimating Lens

Aperture

Focusing Lens

Image Plane

Diffracted Light

Collected Light

d

f

Intensity

1.22 λf/d

min L

Entrance
Aperture

Image
Plane

α

Point
Sources

B

A

d

A'

B'

wavelength
of light

Assume diffraction-limited system:

$$\text{minimum } L \triangleq \text{min. feature size} = \frac{0.6\lambda}{NA}$$

2λ (from before)

Numerical Aperture