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EE C247B - ME C218 Introduction to MEMS Design Spring 2019

Prof. Clark T.-C. Nguyen

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

Lecture Module 4: Lithography, Etching, & Doping

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Etching

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Etching Basics

- Removal of material over designated areas of the wafer
- Two important metrics:
 - Anisotropy
 - Selectivity

1. **Anisotropy** -

a) **Isotropic Etching (most wet etches)**

If 100% isotropic: $d_f = d + 2h$
 Define: $B = d_f - d$
 If $B = 2h \Rightarrow$ isotropic

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Etching Basics (cont.)

b) **Partially Isotropic: $B < 2h$**
 (most dry etches, e.g., plasma etching)

Degree of Anisotropy: (definition)

$$A_f = 1 - \frac{B}{2h} = 0 \quad \text{if 100\% isotropic}$$

$0 < A_f \leq 1 \leftarrow$ anisotropic

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Etching Basics (cont.)

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2. **Selectivity** -

Only poly-Si etched (no etching of PR or SiO₂)

Perfect selectivity

Actual Etch

PR partially etched

SiO₂ partially etched after some overetch of the polysilicon

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Etching Basics (cont.)

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Why overetch?

$\sqrt{2}d = 1.4d = 0.56 \mu\text{m}$ → Thicker spots due to topography!

10nm Gate oxide

45°

1 μm

0.4 $\mu\text{m} = d$

Poly-Si → conformal if deposited by LPCVD

"Stringer" → need to overetch to remove!

Thus, must overetch at least 40%:
40% overetch → $(0.4)(0.4) = 0.16 \mu\text{m}$ poly = ??? oxide

This is a problem caused by topography!

Depends on the selectivity of poly-Si over the oxide

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Etching Basics (cont.)

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Define selectivity of A over B:

$$S_{ab} = \frac{E.R._a}{E.R._b}$$

← Etch rate of A
← Etch rate of B
Selectivity of A over B

e.g., wet poly etch ($\text{HNO}_3 + \text{NH}_4 + \text{H}_2\text{O}$)

$$S_{\text{poly}/\text{SiO}_2} = \frac{15}{1} \text{ (very good selectivity)}$$

$S_{\text{poly}/\text{PR}}$ = Very high (but PR can still peel off after soaking for > 30 min., so beware)

e.g., polysilicon dry etch:

Regular RIE

$$S_{\text{poly}/\text{SiO}_2} = \frac{5-7}{1} \text{ (but depends on type of etcher)}$$

ECR: 30:1
Bosch: 100:1 (or better)

$S_{\text{poly}/\text{PR}} = \frac{4}{1}$

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Etching Basics (cont.)

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If $S_{\text{poly}/\text{SiO}_2} = \frac{8}{1} \Rightarrow$ 40% overetch removes

$$\frac{0.16}{8} = 20 \text{ nm of oxide!} \Rightarrow$$

This will etch all poly over the thin oxide, etch thru the 10nm of oxide, then start etching into the silicon substrate → needless to say, this is bad!

with better selectivity:

e.g., $S_{\text{poly}/\text{SiO}_2} = \frac{30}{1}$

(Can attain with high density Cl plasma ECR etch!)

40% overetch removes $\frac{0.16}{30} = 5.3 \text{ nm}$ (better)

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Dry Etching

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Dry Etching

- Physical sputtering
- Plasma etching
- Reactive ion etching

All based upon plasma processes.

(+) ions generated by inelastic collisions with energetic e^{-1} 's
Get avalanche effect because more e^{-1} 's come out as each ion is generated.

Develop (-) bias

Plasma (partially ionized gas composed of ions, e^{-1} 's, and highly reactive neutral species)

E-field

wafer

Develops (+) charge to compensate for -

\therefore (+) ions will be accelerated to the wafer

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