

Quick Start Micro Training LLC Semiconductor Devices II: MOS

Quick Start Micro Training LLC Quick Start
Semiconductor Devices II: MOS

SAMPLE SLIDES

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Outline of Course

1. Introduction

MOS CAPACITOR

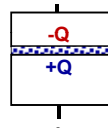
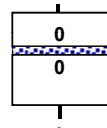
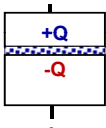
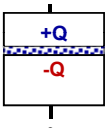
MOS TRANSISTOR

2. I: Field Effect
3. II: CV Curves
4. III: Band Diagrams
5. IV: Threshold Voltage

6. I: Overview
7. II: More Details
8. III: Band Diagrams
9. IV: Subthreshold Currents
10. V: Nonvolatile Floating Gate
11. Digging Deeper

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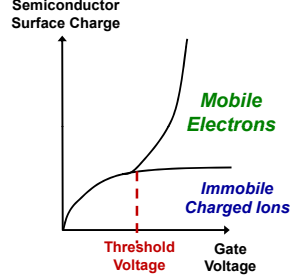
Operating Regions of MOS Capacitor

| Accumulation | Flat Band | Depletion | Inversion |
|---|---|---|---|
| $V_{GATE} < V_{FB}$ | $V_{GATE} = V_{FB}$ | $V_{GATE} > V_{FB}$ $V_{GATE} < V_{TH}$ | $V_{GATE} > V_{TH}$ |
|  |  |  |  |
| 0 | 0 | 0 | 0 |

- Flat band voltage, V_{FB} , and Threshold Voltage, V_{TH} , depend on gate material, semiconductor and doping.
- V_{TH} also depends on oxide thickness

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The Mobile Charges That Can Carry A Current Are Only Created Above Threshold

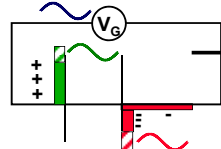


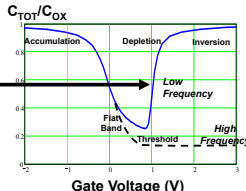
- Need **MOBILE** charges to have a current
- Up to threshold voltage charges are **IMMOBILE** ions
- Above threshold virtually all of the additional charges are mobile electrons

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Differential C Above Threshold ($V_G > V_{TH}$) Low Frequency (< 100 Hz)

Low Frequency (< 100 Hz)

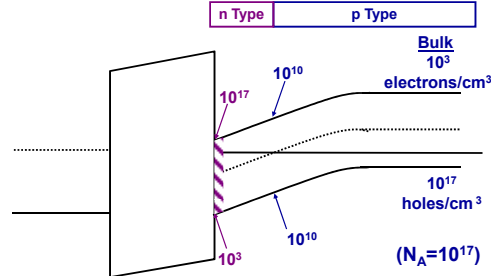




- Semiconductor charges that change due to V_G changes are minority carrier electrons in surface inversion layer
 - Generation/recombination can follow gate voltage changes
- Depletion layer essentially does not change
- Capacitance ~ oxide capacitance

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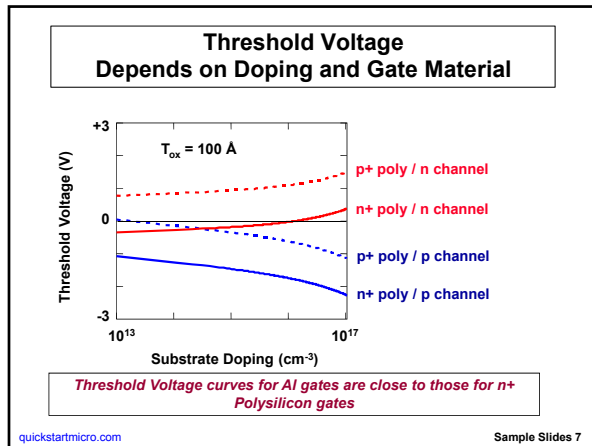
The Region of Very High Electron Density Is A Very Narrow Surface "Channel"



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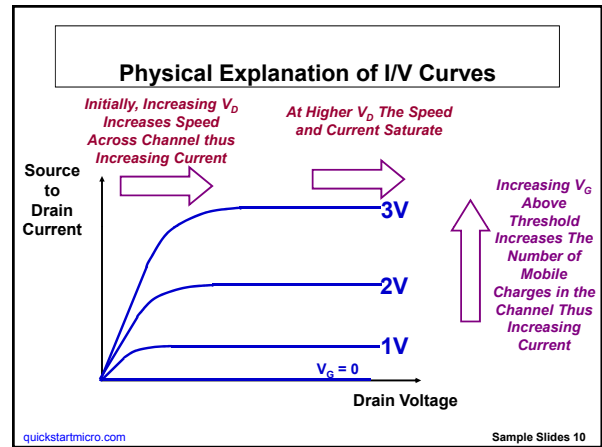
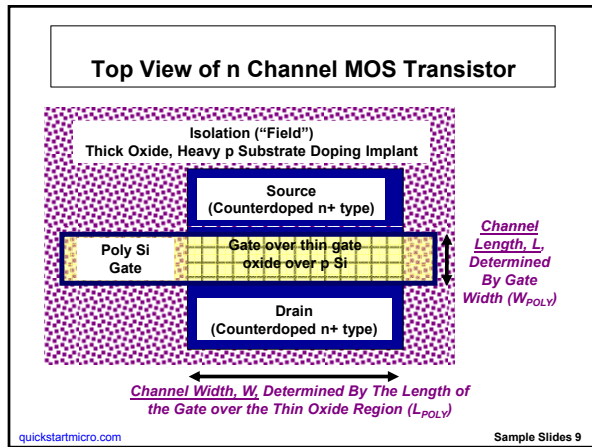
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Interface State Produced By Missing Electron In Atom At Silicon Surface

- Interface states result from dangling Silicon bonds at silicon/oxide interface
 - H anneal used during processing to reduce number of dangling bonds
- Charge depends on gate voltage
 - Charge can be -1, 0 or +1 ("amphoteric")
 - For pMOS in inversion the net charge is + ("acceptor like" states)
 - For nMOS in inversion the net charge is - ("donor like" states)

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Estimating Currents: High V_D ($>V_{DSAT}$) - Saturation Region

- Above threshold, behaves like a simple capacitor
 - $Q_{CH} \sim WC_{OX} (V_G - V_{TH})/2$
- Average field across the channel
 - $E_{CH} \sim V_{DSAT}/L \sim (V_G - V_{TH})/L$
- Velocity
 - $v_{CH} \sim \mu E_{CH} \sim \mu(V_G - V_{TH})/L$
- Current
 - $I_{DSAT} \sim v_{CH} Q_{CH} \sim (\mu C_{OX} W/2L)(V_G - V_{TH})^2$
- Current "saturates" for $V_D > V_{DSAT}$
 - Increases as square of $(V_G - V_{TH})$

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There's a Problem With The MOS Capacitor: It's Too Slow (<100 Hz)

- Generation/recombination too slow to follow V_G changes in inversion
 - Cannot form and remove inversion layer fast enough
- Leads to difference between high and low freq. CV

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