Section 28
MOS Electrostatics & MOScap

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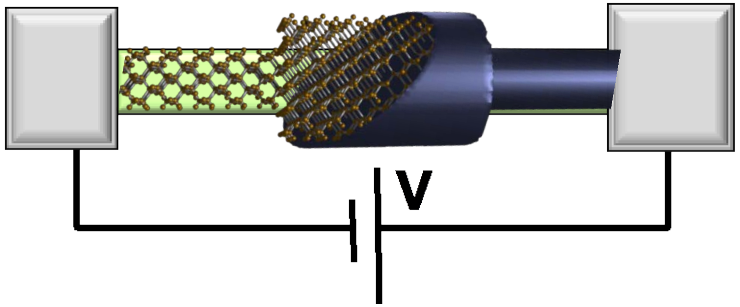
PURDUE UNIVERSITY

School of Electrical and Computer Engineering



$I = G \times V$

$= q \times n \times v \times A$

charge density velocity area

	Equilibrium	DC	Small signal	Large Signal	Circuits
PN Diode					
Schottky Diode					
BJT/ HBT					
MOS					

Differences between MOS FET and Bipolar:
MOS FET have insulator

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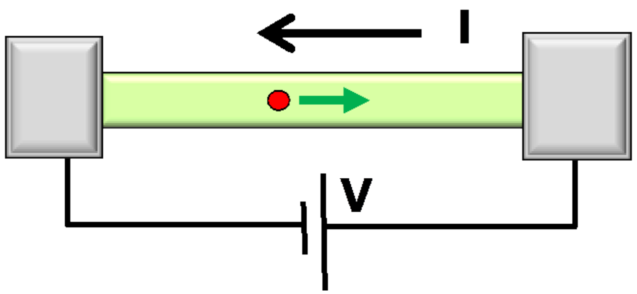

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charge density velocity area

1 • 28.1 Background

2 • 28.2 Band diagram in equilibrium and with bias => MOScap

3 • 28.3 Qualitative Q-V characteristics of MOS capacitor

4 • 28.4 MOScap Induced charges in depletion and inversion

5 • 28.5 MOScap Exact solution of electrostatic problem

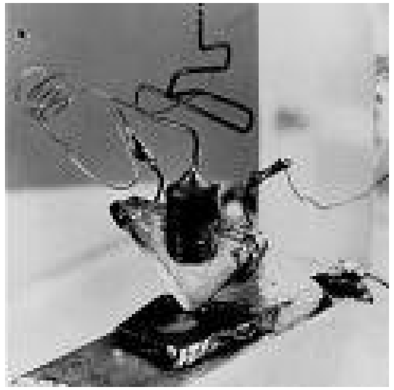
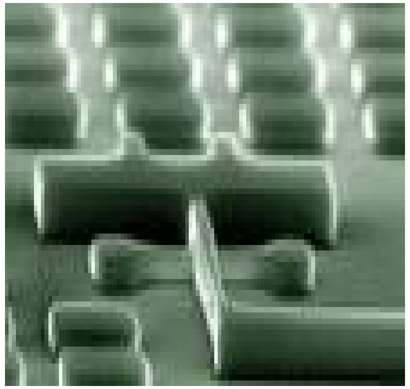
MOS ; metal oxide semiconductor

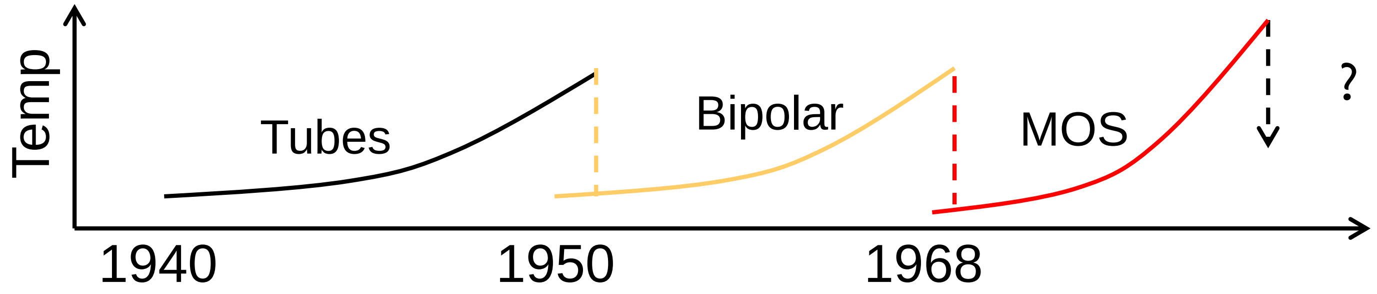
Can be capacitors or transistor

>90% of the markets

REF: Chapters 15-18 from SDF

Temperature Management as one of the Grand Challenges in Electronics

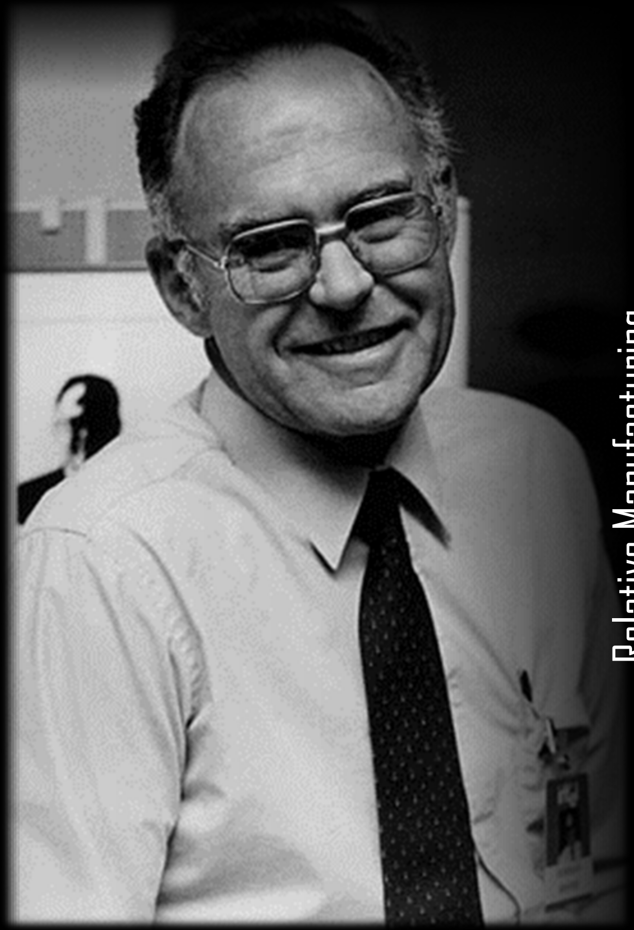
Vacuum Tubes	Bipolar	MOSFET	Now ??
			NCFET TFET ….
1906-1950s	1947-1980s	1960-until now	Bio Sensors Displays ….

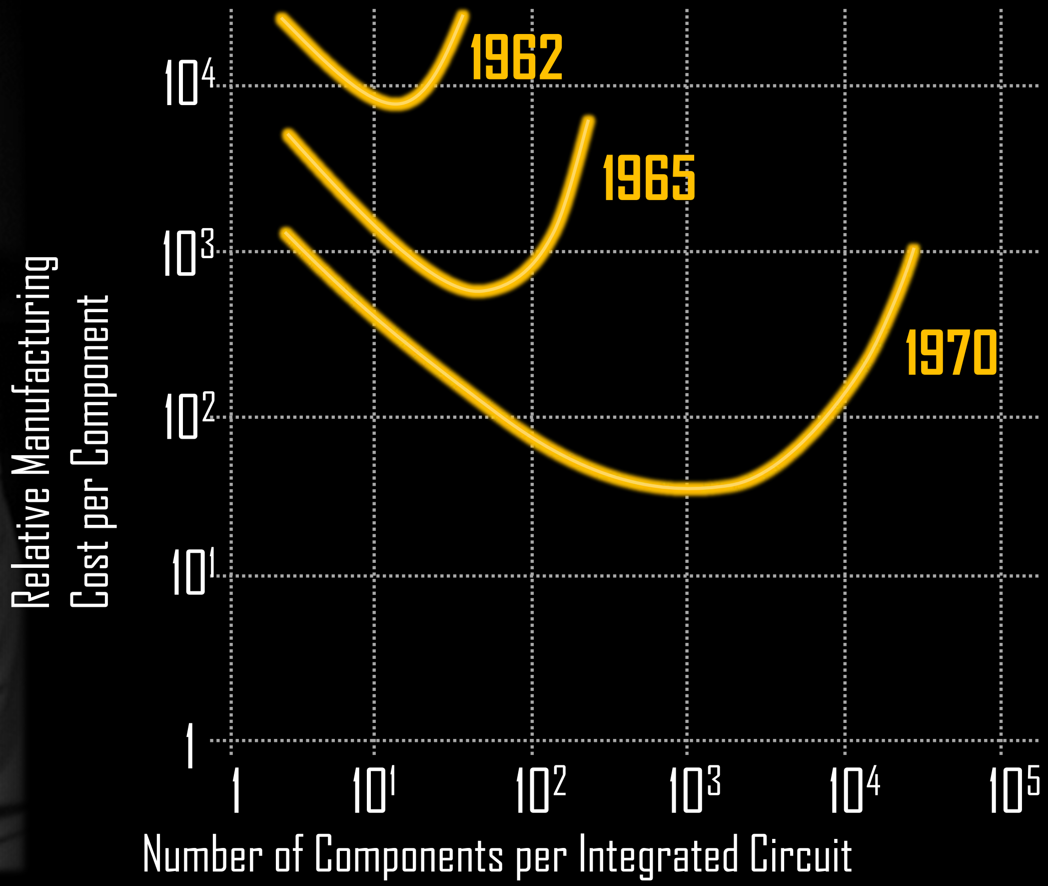


Bipolar has larger leakage current

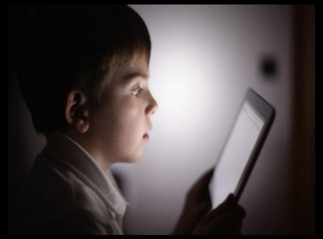
Temperature & Size determine integration level

1965 – Gordon Moore predicts the future of integrated circuits





http://www.intel.com/technology/mooreslaw



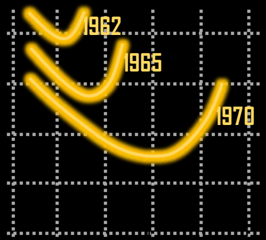
10^9

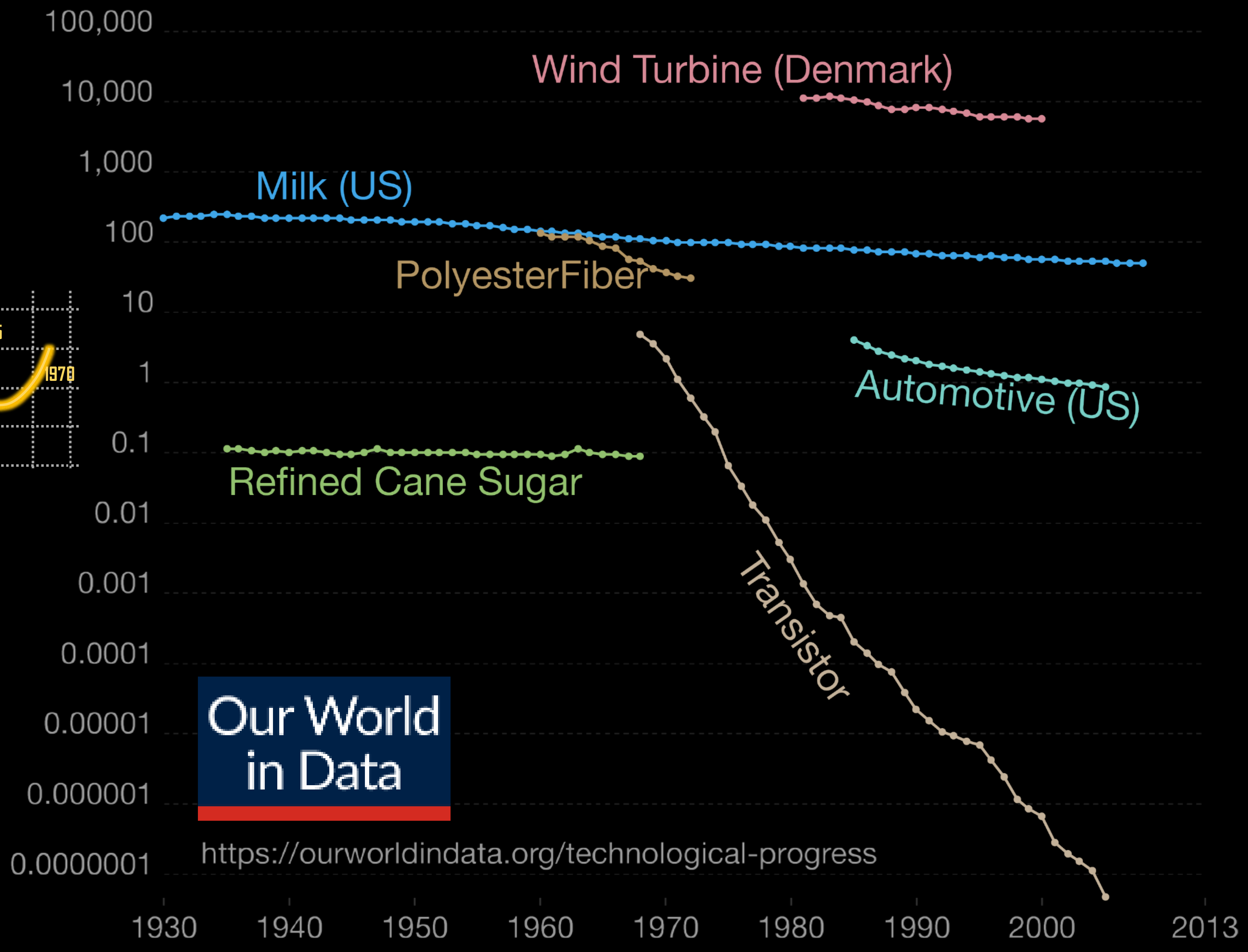
$4x10^4$ smaller

$1x10^6$ larger

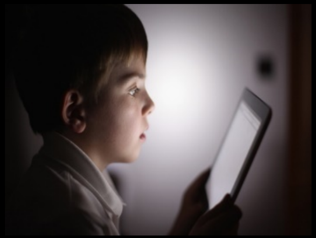
Changed Human History

Costs of 66 different technologies over time, 1930 to 2013





Source: J. Doyne Farmer and François Lafond (2016)



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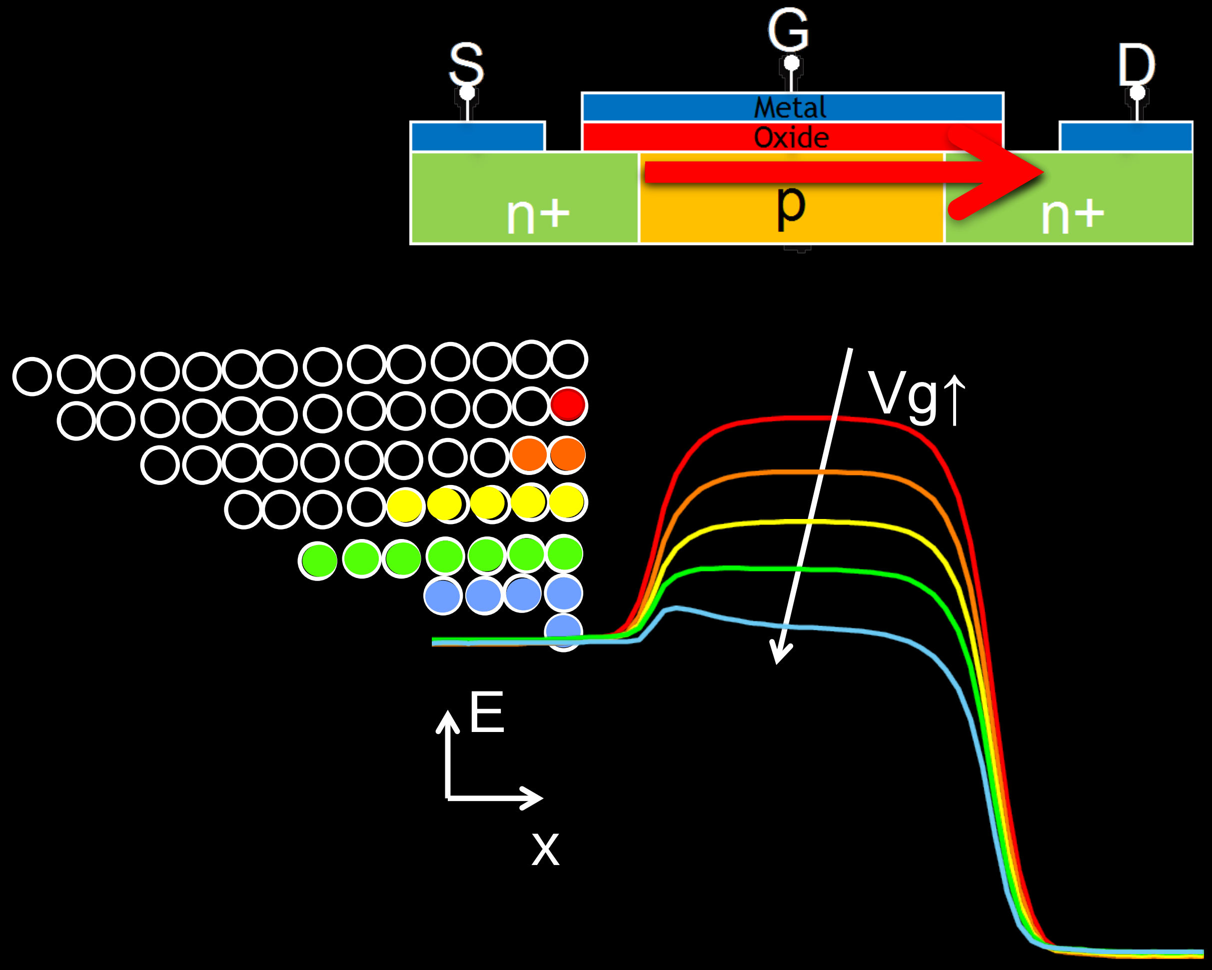
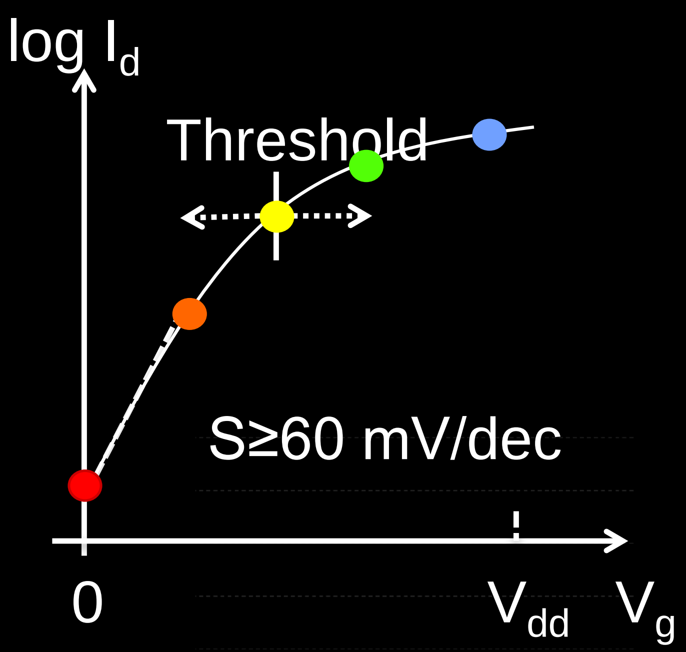
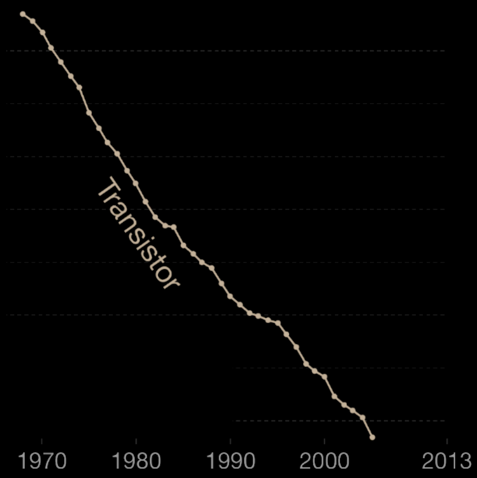
Changed Human History

Fundamental Transistor Operation

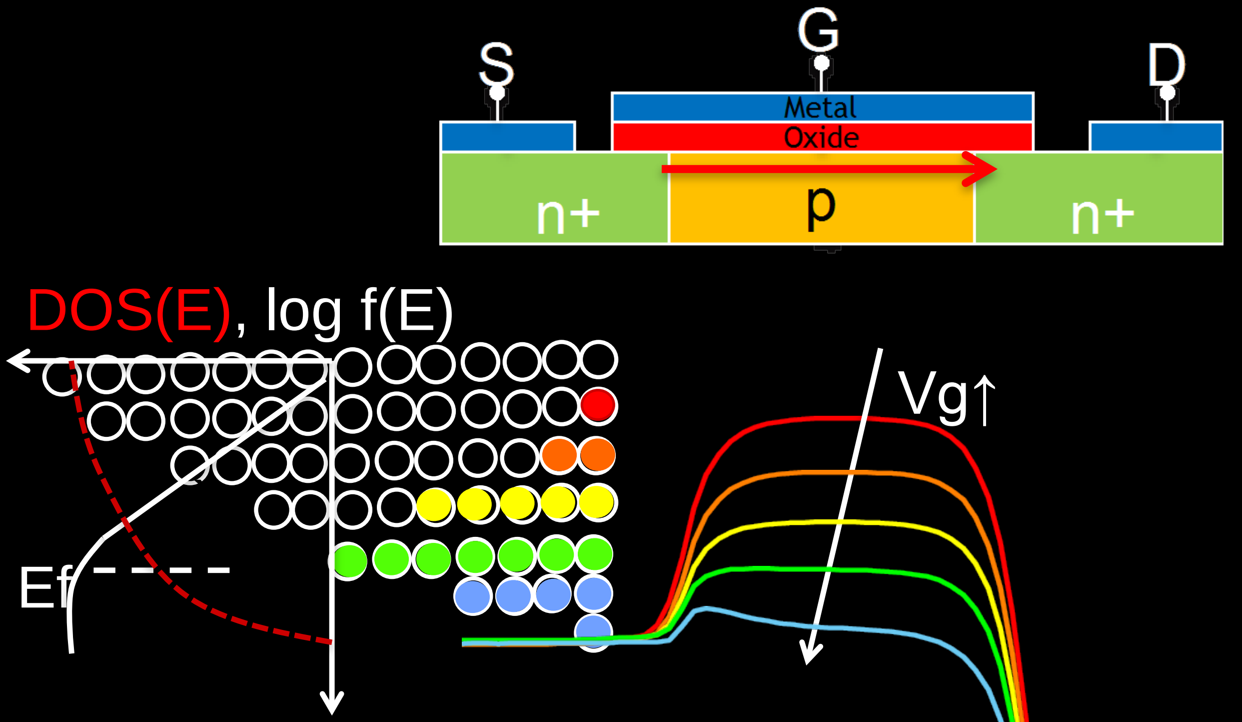


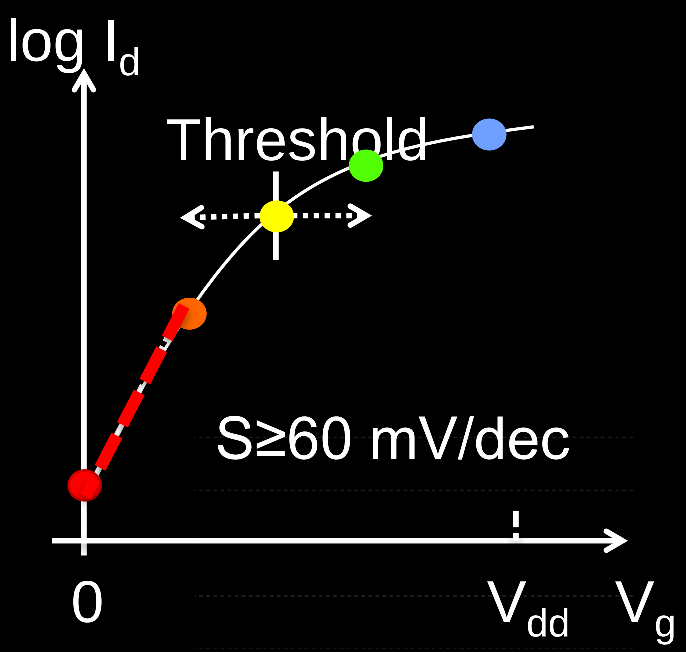


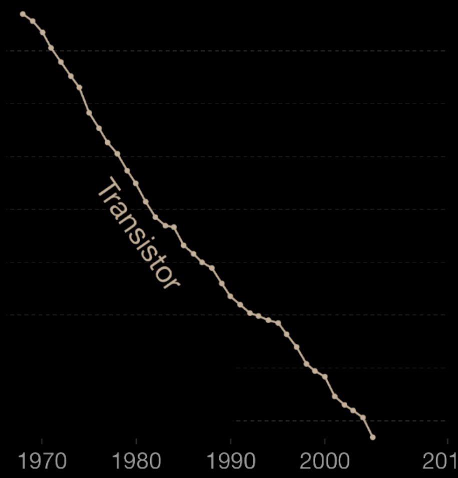


- Explain the working principles of these devices
- Explain the physical processes in these devices

A Picture speaks a 1000 words - but:
These pictures should inspire a 1000 questions!

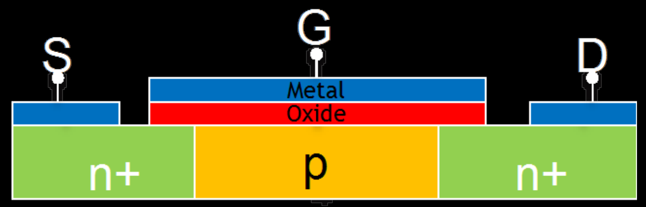


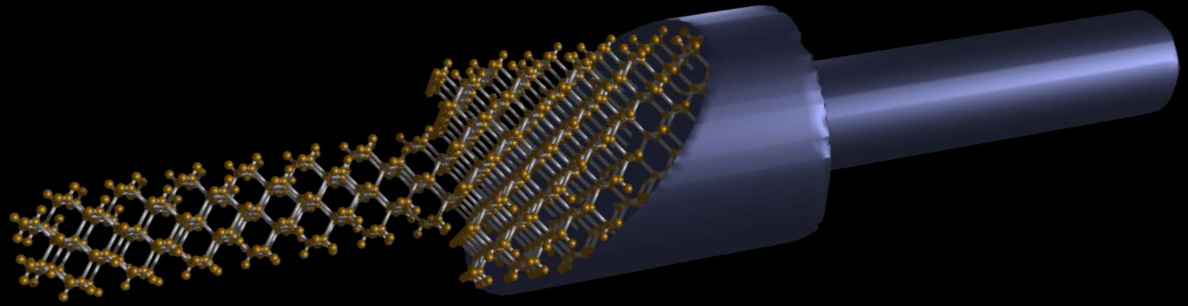


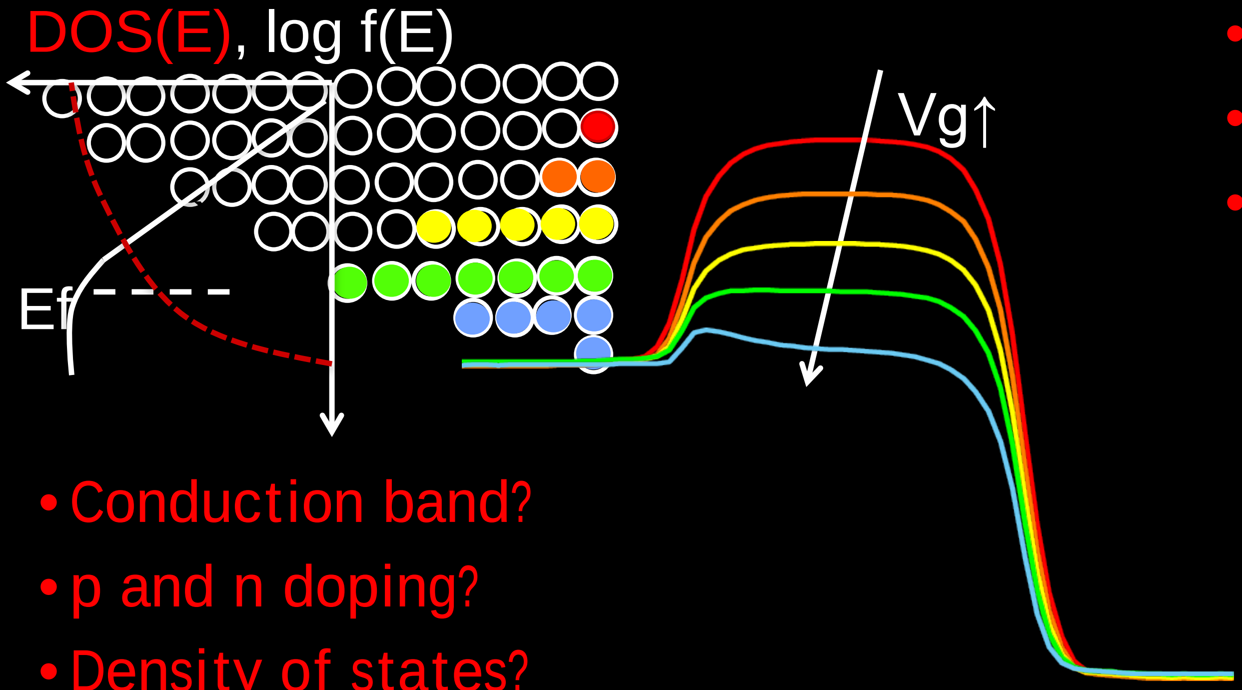


- Conduction band?
- p and n doping?
- Density of states?
- Fermi distribution?
- 60mV/dec?

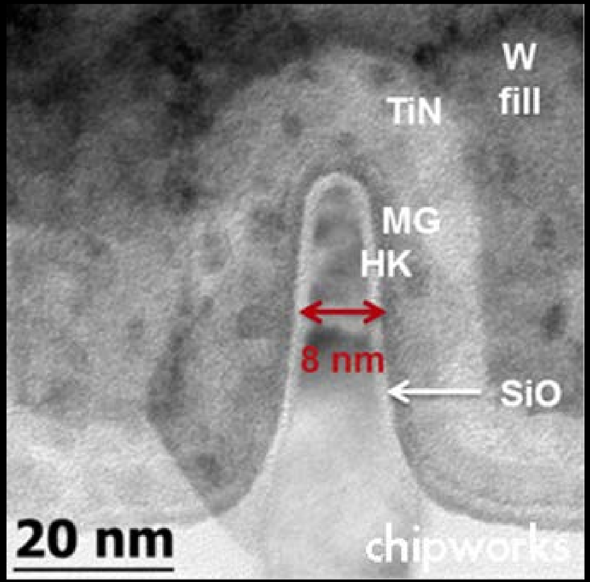
Modern Devices are not planar - but 3D
These pictures should inspire a 1000 questions!







- Material choices
- Crystal structures
- Structure / Geometry



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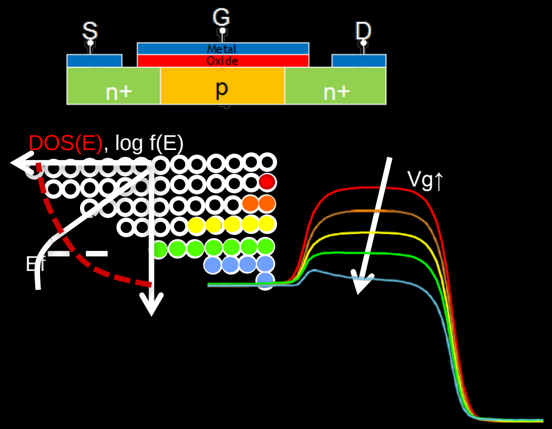
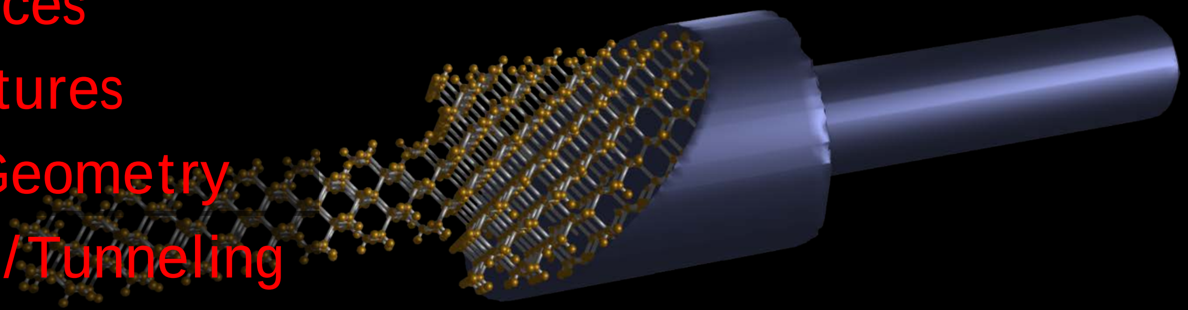
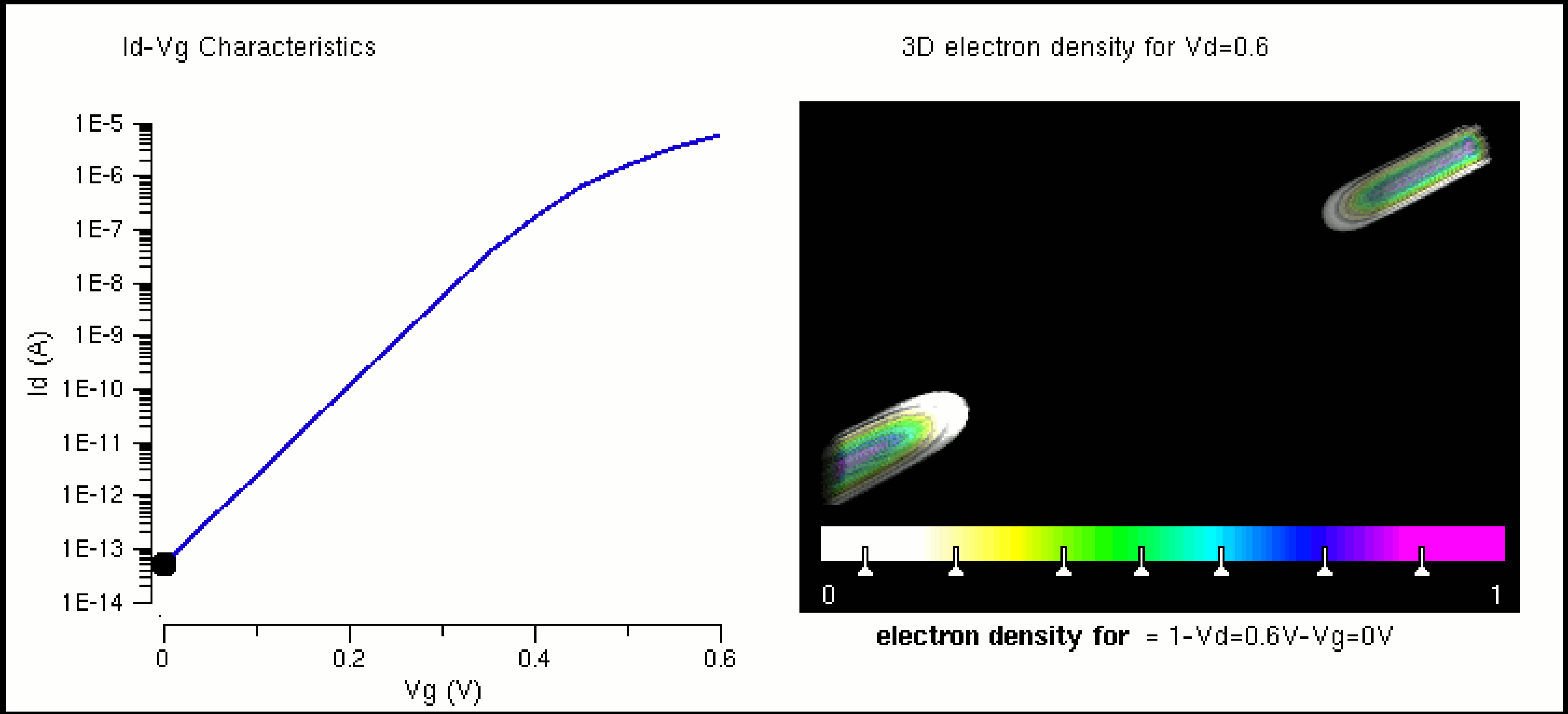
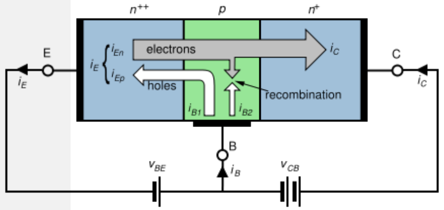


- Material choices
- Crystal structures
- Structure / Geometry
- Confinement / Tunneling
- Strain

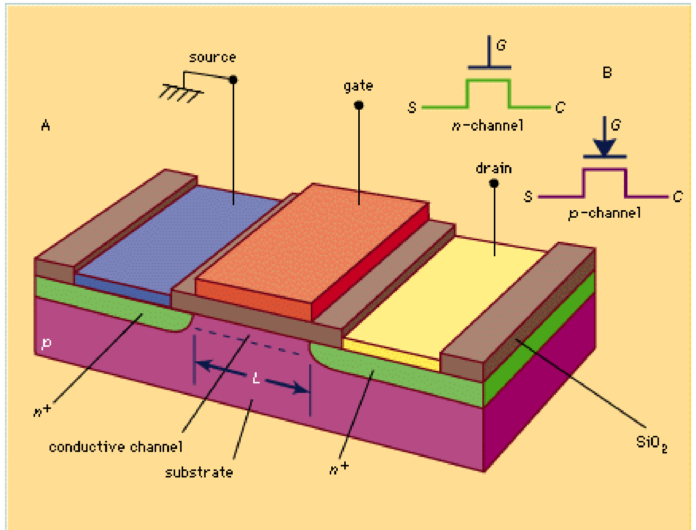


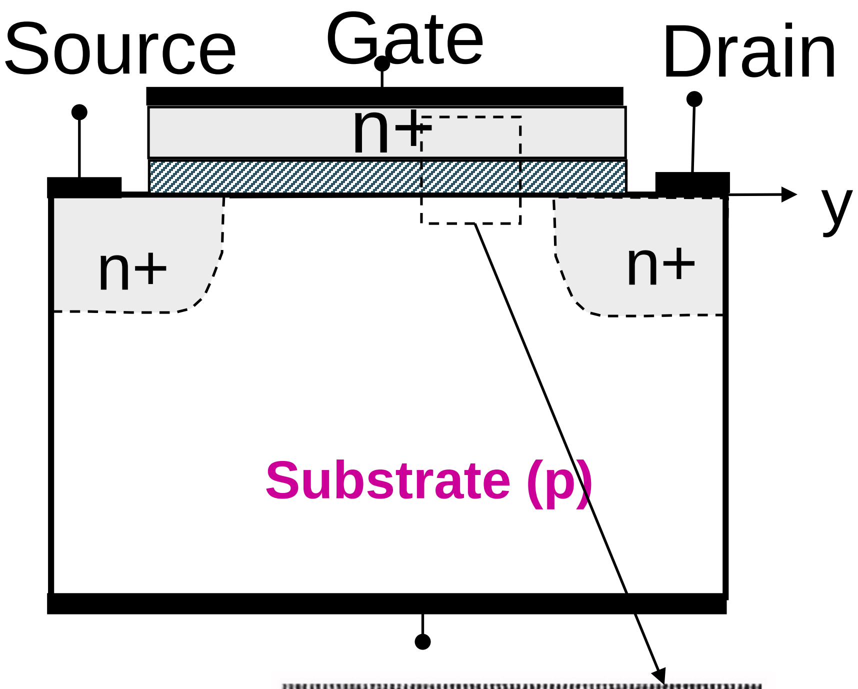


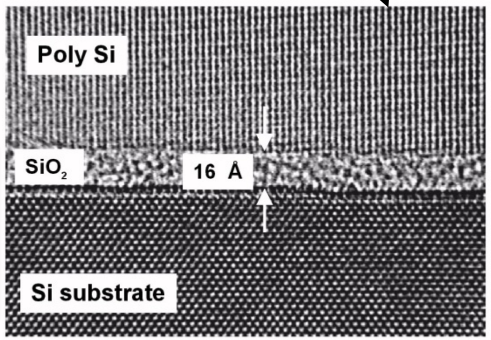
Basic Configuration of a MOSFET



S and D are far away→ could not work like a BJT



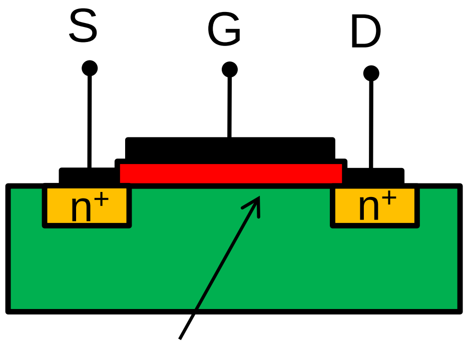




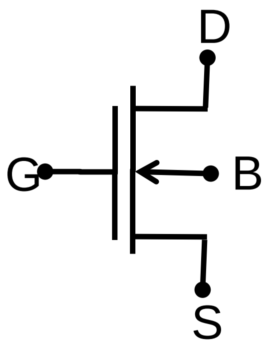
Almost like a lateral bipolar transistor!

Insulators: Amorphous material →

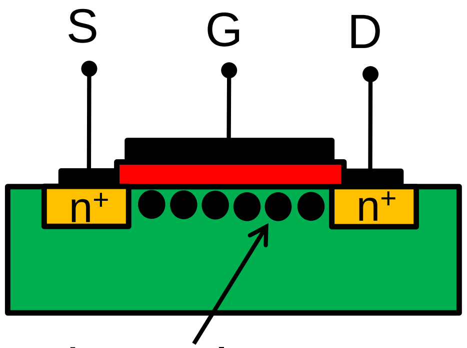
Symbols



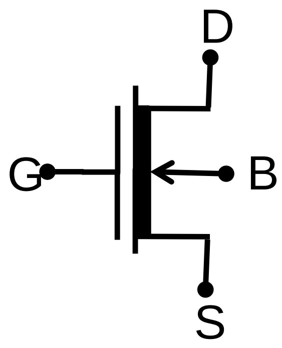
No channel
when $V_G = 0$



Enhancement Type
Requires a Gate-Source voltage, (V_{GS}) to switch the device "ON".
Equivalent to a "Normally Open" switch.

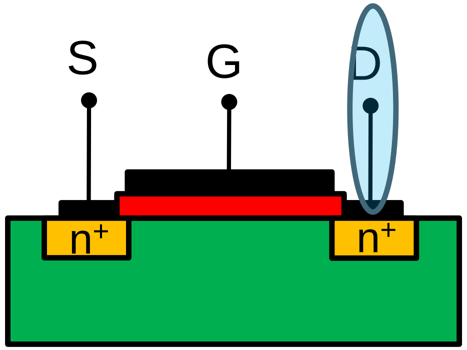


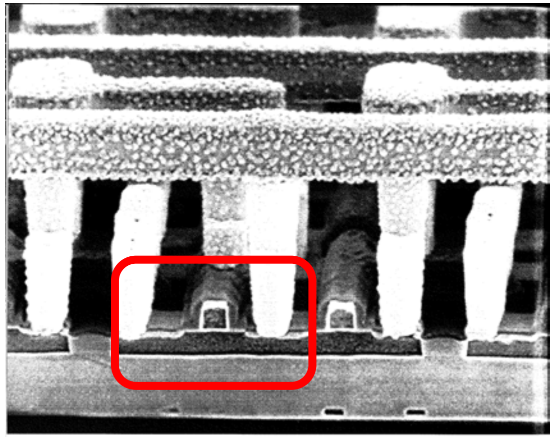
Channel
when $V_G = 0$



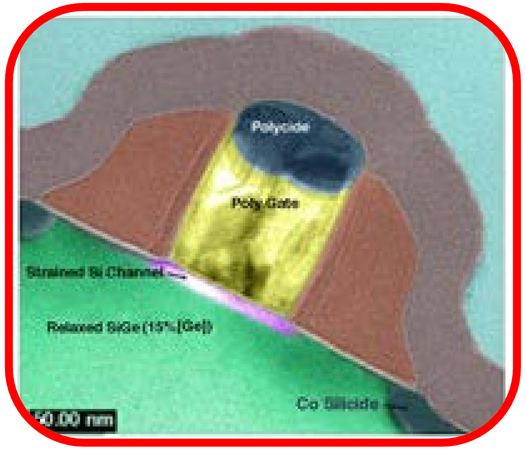
Depletion Type
Requires a Gate-Source voltage, (V_{GS}) to switch the device "OFF".
Equivalent to a "Normally Closed" switch.

Background

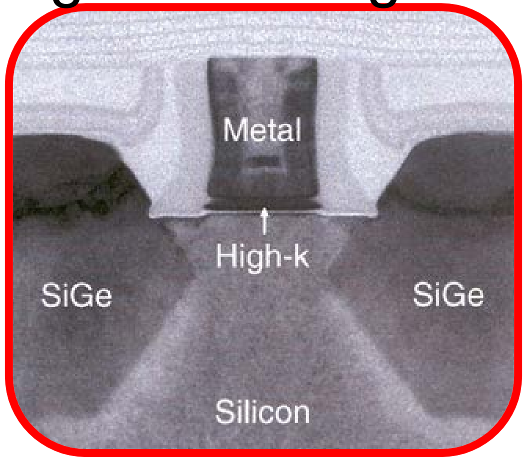




Strained MOSFET



High-k/metal gate MOSFET



Sources:
IBM J. Res. Dev.
Google Images
Intel website

MOSFET begins to look a lot like double heterojunction HBT

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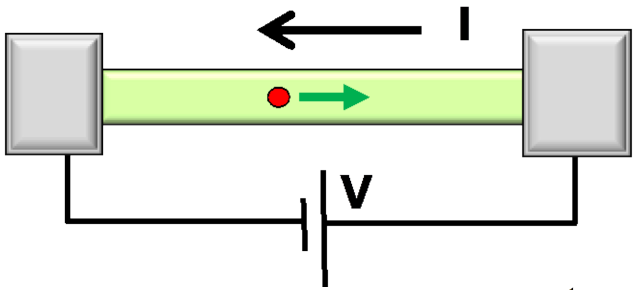
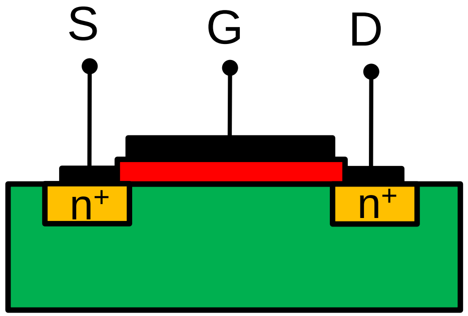


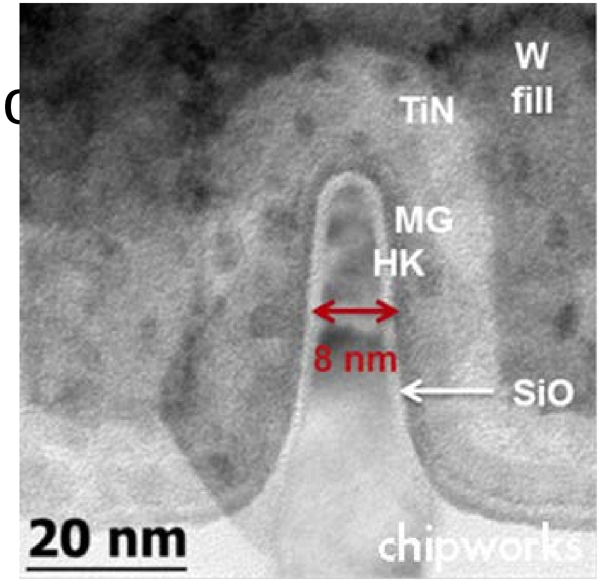
$$I = G \times V$$
$$= q \times n \times v \times A$$

charge density velocity area



status

- 28.1 Background
- 28.2 Band diagram in equilibrium and with bias => MOScap
- 28.3 Qualitative Q-V characteristics of MOS capacitor
- 28.4 MOScap Induced charges in depletion and inversi
- 28.5 MOScap Exact solution of electrostatic problem



REF: Chapters 15-18 from SDF

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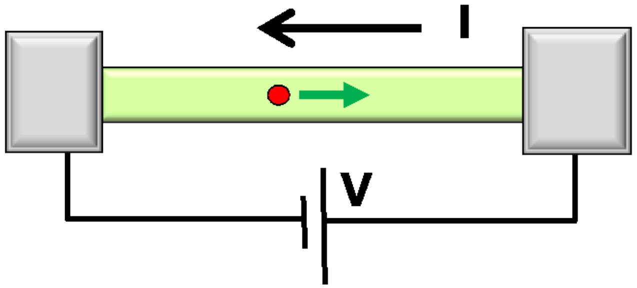

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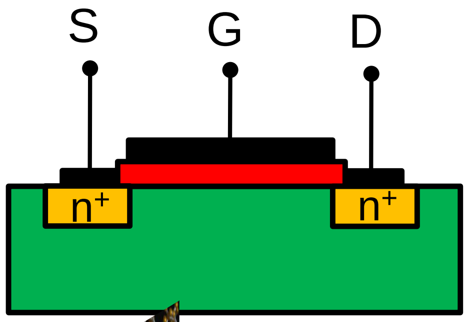

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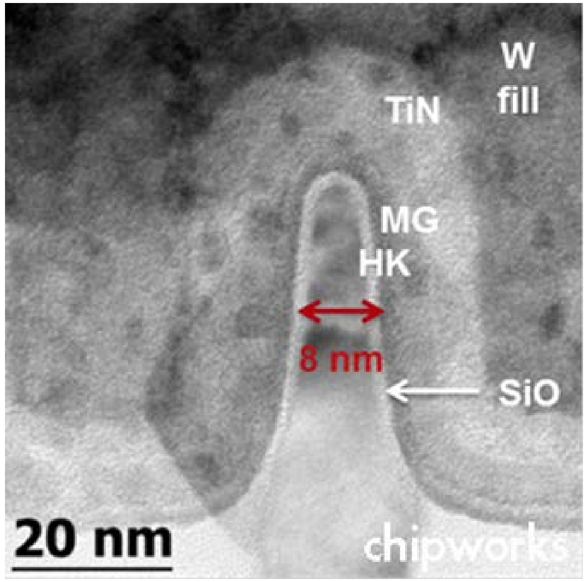

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