Section 28
MOS Electrostatics & MOScap

28.3 Qualitative Q-V characteristics of MOS capacitor

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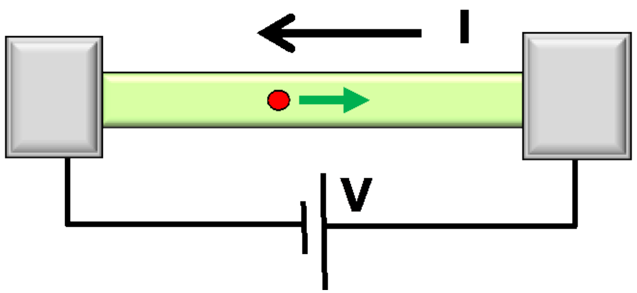
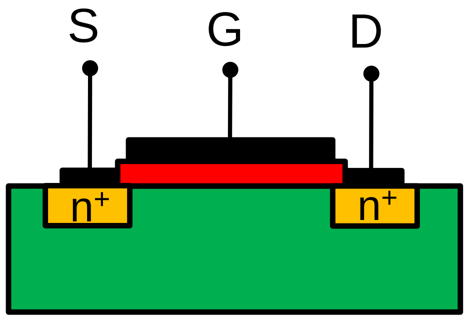


$I = G \times V$

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

charge density velocity area



- 1 • 28.1 Background
- 2 • 28.2 Band diagram in equilibrium and with bias => MOScap
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- 4 • 28.4 MOScap Induced charges in depletion and inversion
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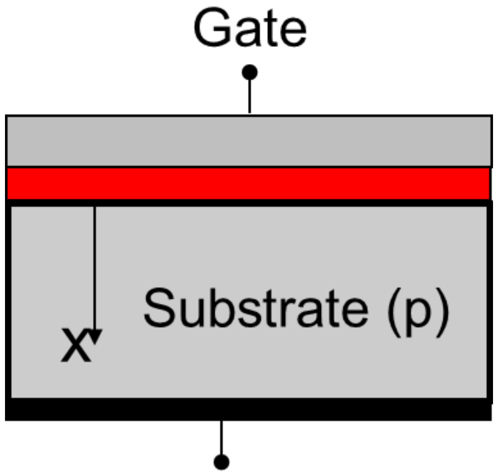
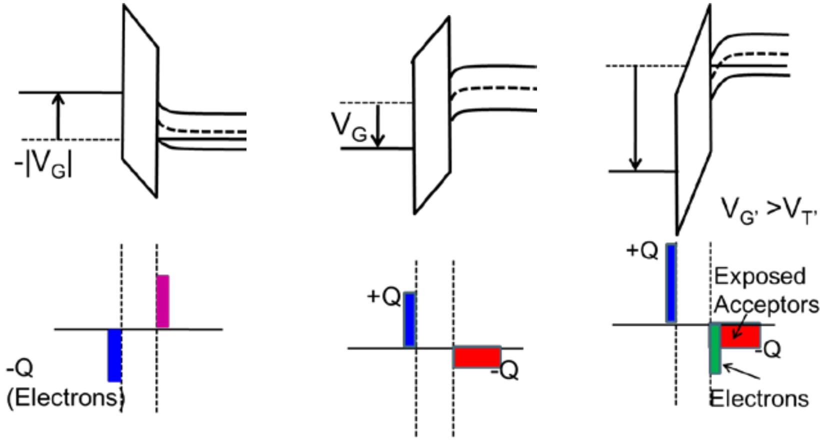
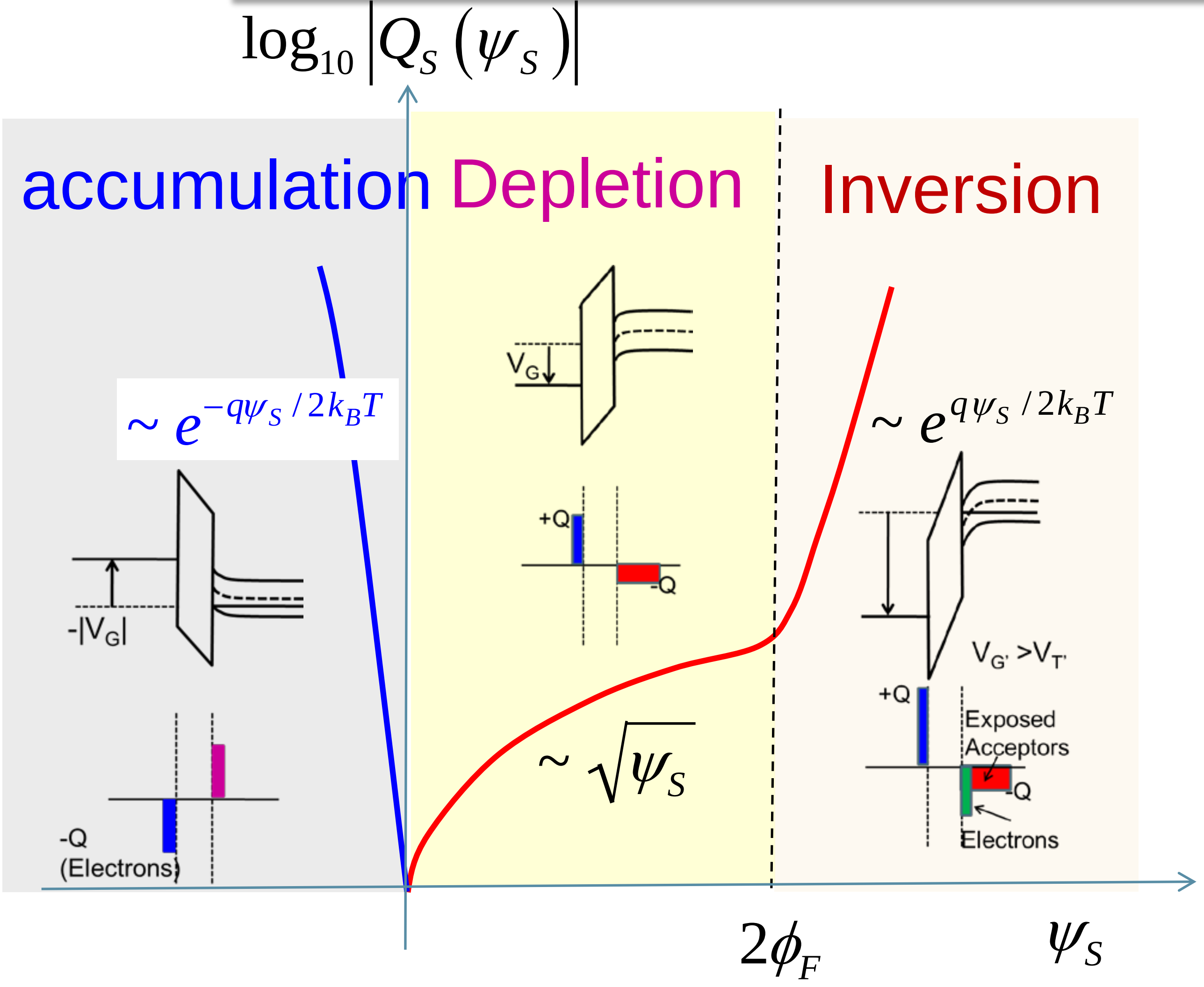


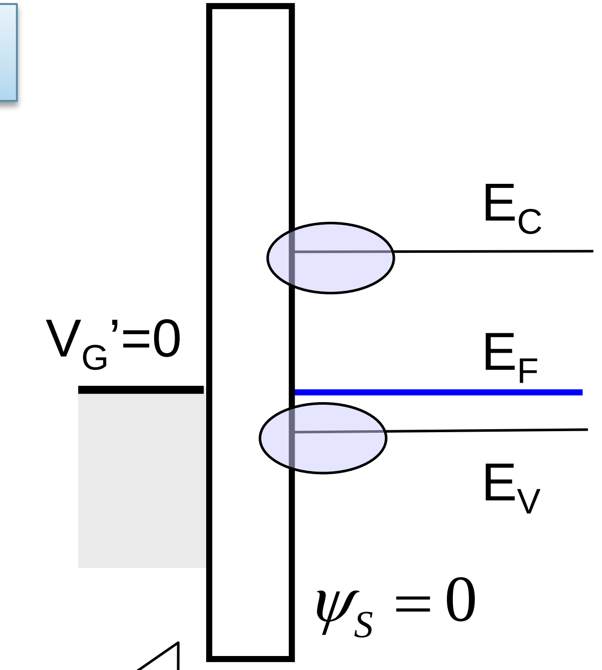


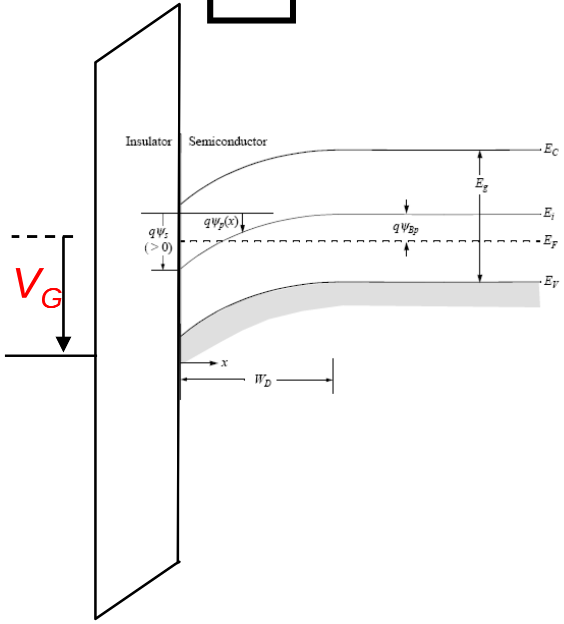
REF: Chapters 15-18 from SDF

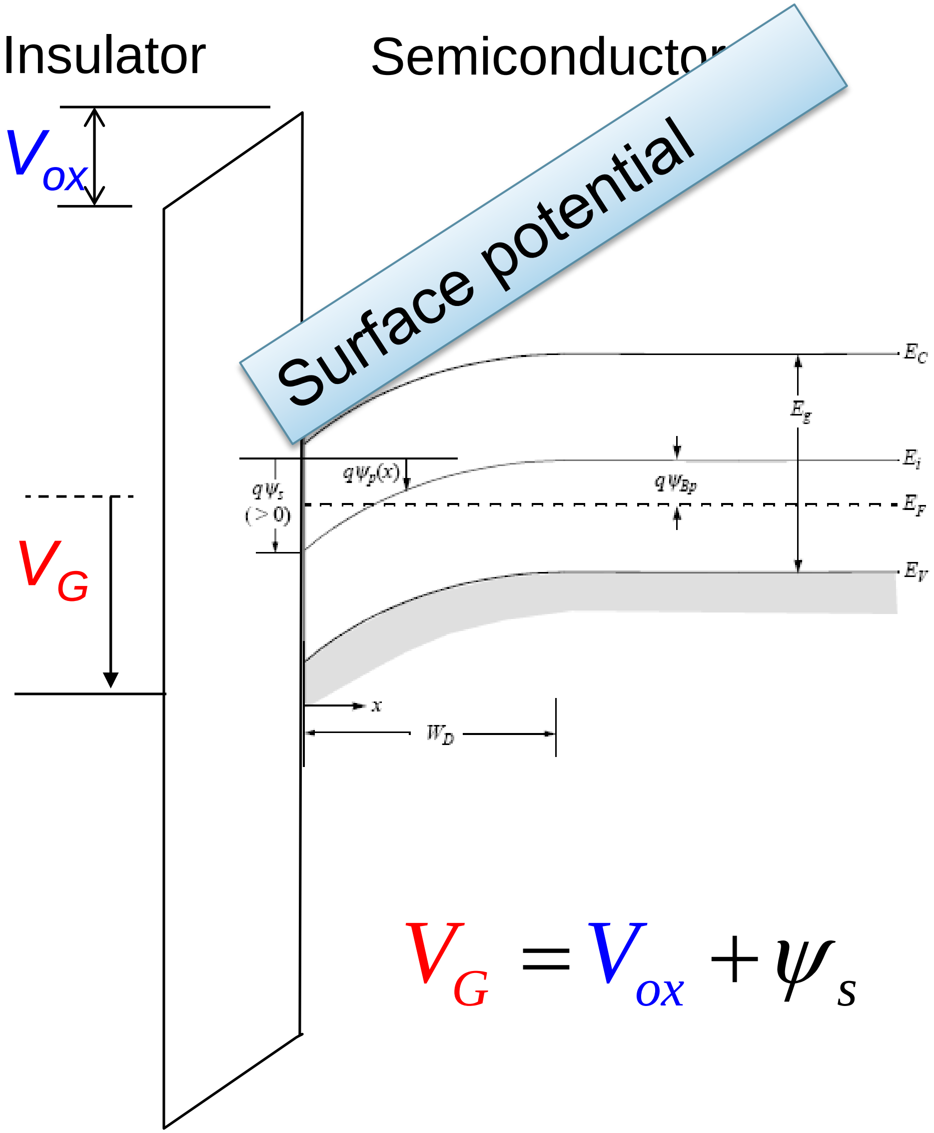
Charges and Surface Potential

Charge in the semiconductor









$$V_G = V_{ox} + \psi_s$$

No current, so only have to solve Poisson

$$\nabla \bullet \vec{D} = \rho$$

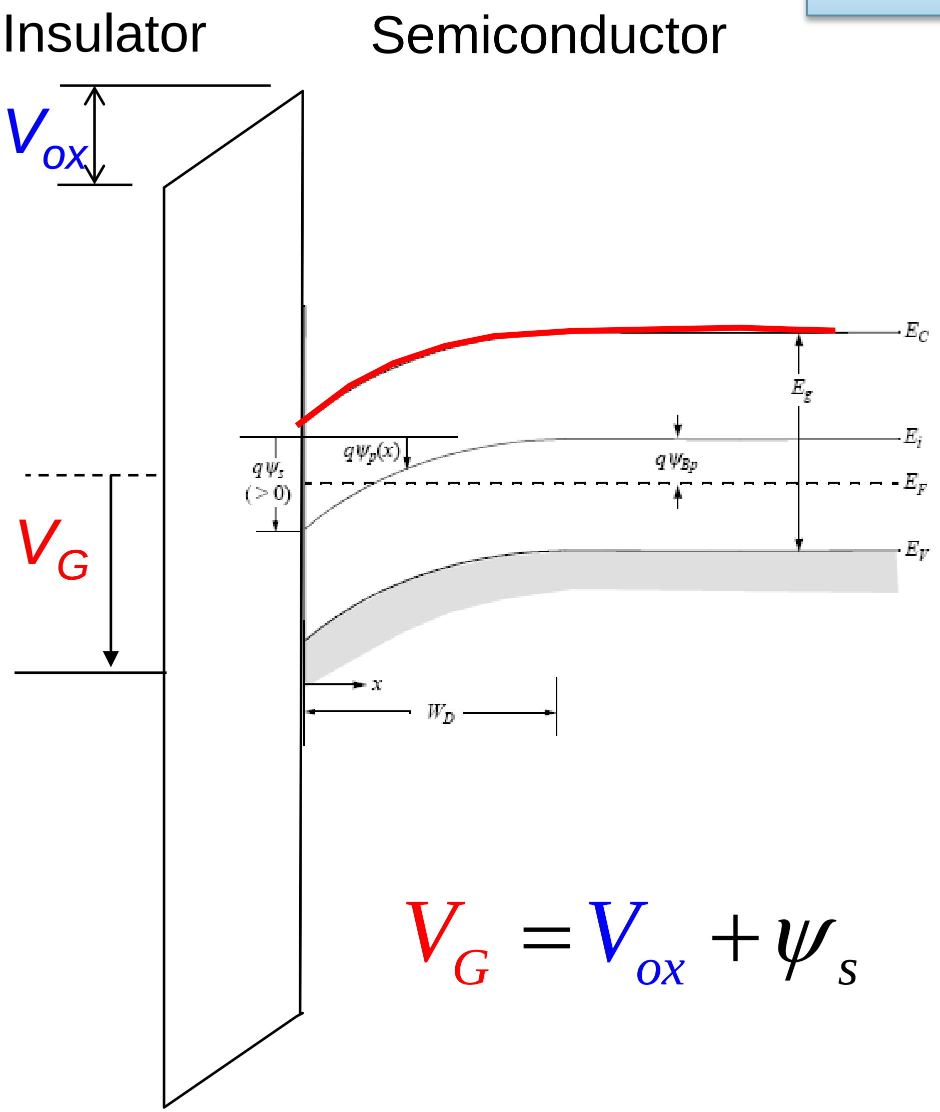
$$\nabla \bullet \left(\vec{J}_n / -q\right) = (G - R)$$

$$\nabla \bullet \left(\vec{J}_p / q\right) = (G - R)$$

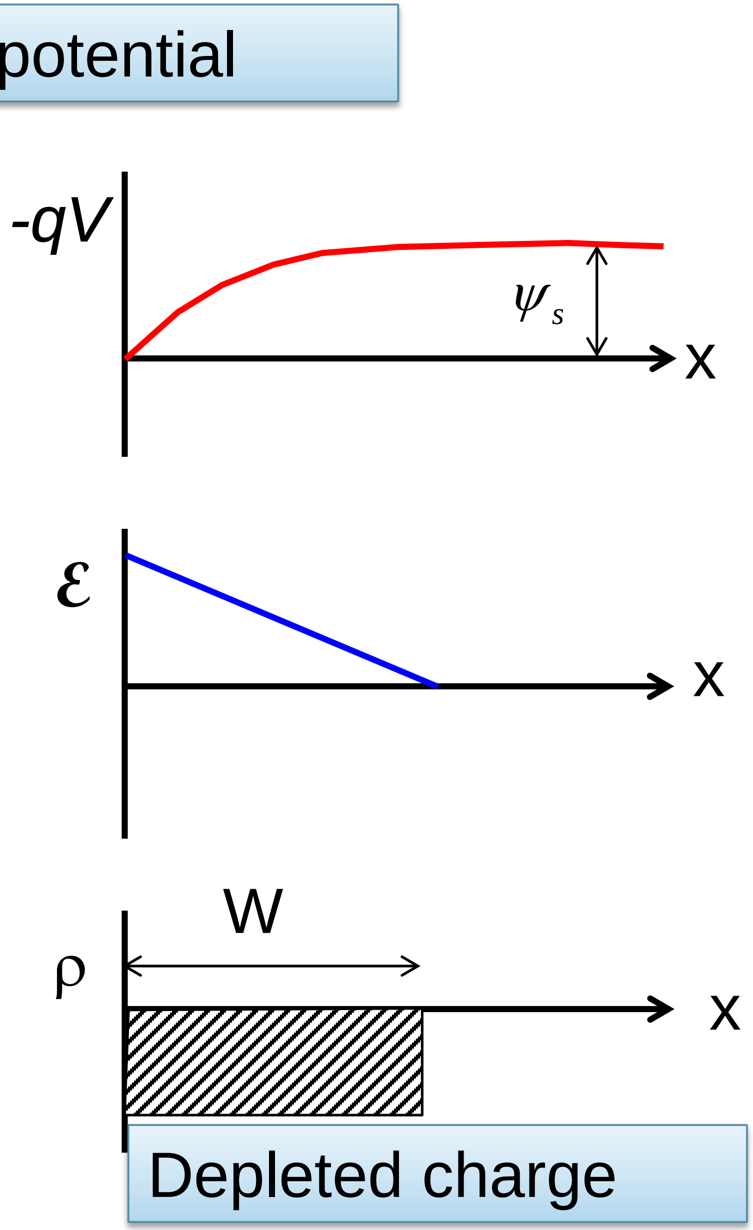
Poisson equation

$$\frac{d^2\psi}{dx^2} = \frac{-q}{\kappa_{Si}\varepsilon_0}\left[p_0(x) - n_0(x) + N_D^+ - N_A^-\right]$$

(Depletion) Potential, Field, Charges



$$V_G = V_{ox} + \psi_s$$

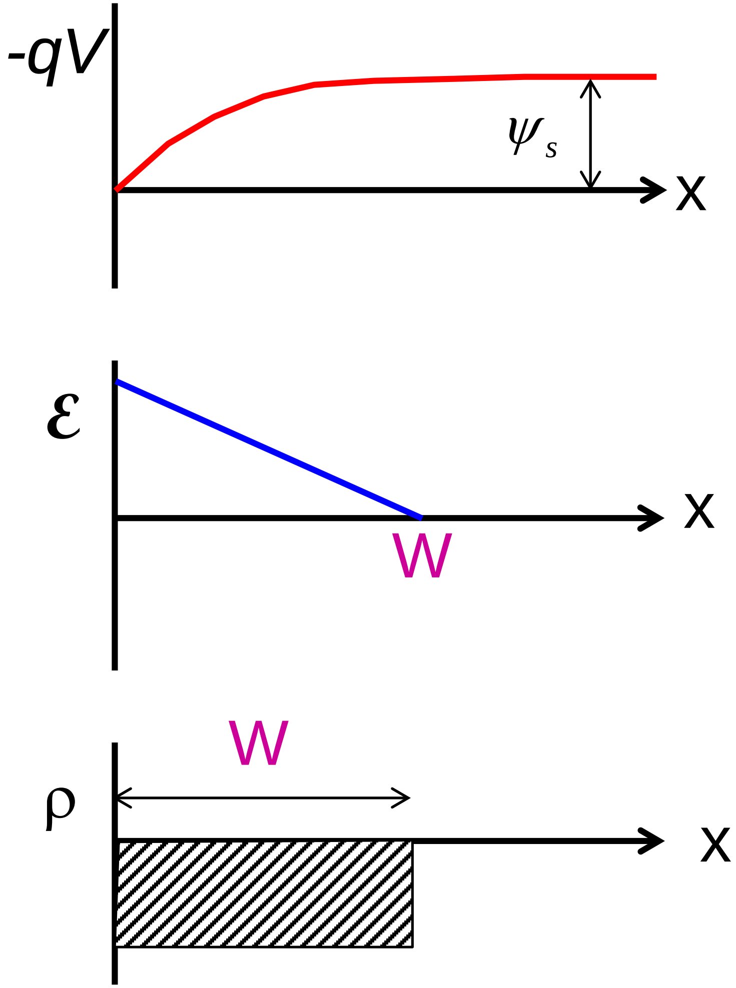


(3) $$W = \sqrt{\frac{2\kappa_s \varepsilon_0 \psi_s}{qN_A}}$$

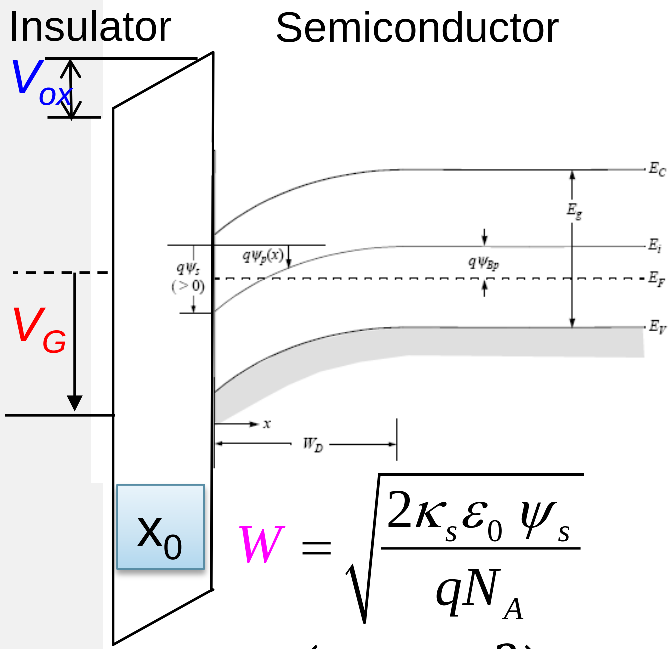
(2) $$\psi_s = \frac{1}{2}\left(\frac{qN_A W}{\kappa_s \varepsilon_0}\right) W \qquad \psi_s = \left(\frac{qN_A W^2}{2\kappa_s \varepsilon_0}\right)$$

(1) $$\mathcal{E}(0^+) = -\frac{qN_A W}{\kappa_s \varepsilon_0}$$

(4) $$V_G = V_{ox} + \psi_s$$



Gate Voltage /Surface Potential in Depletion Region



x_0

$$W = \sqrt{\frac{2\kappa_s\varepsilon_0\,\psi_s}{qN_A}}$$

$$\psi_s = \left(\frac{qN_A W^2}{2\kappa_s\varepsilon_0}\right)$$

$$V_G = V_{ox} + \psi_s$$

$$V_G = \mathcal{E}_{ox}(0^-)x_0 + \left(\frac{qN_A W^2}{2\kappa_s\varepsilon_0}\right)$$

$$= \left[\frac{qN_A W}{\kappa_{ox}\varepsilon_0}\right] x_0 + \left(\frac{qN_A W^2}{2\kappa_s\varepsilon_0}\right)$$

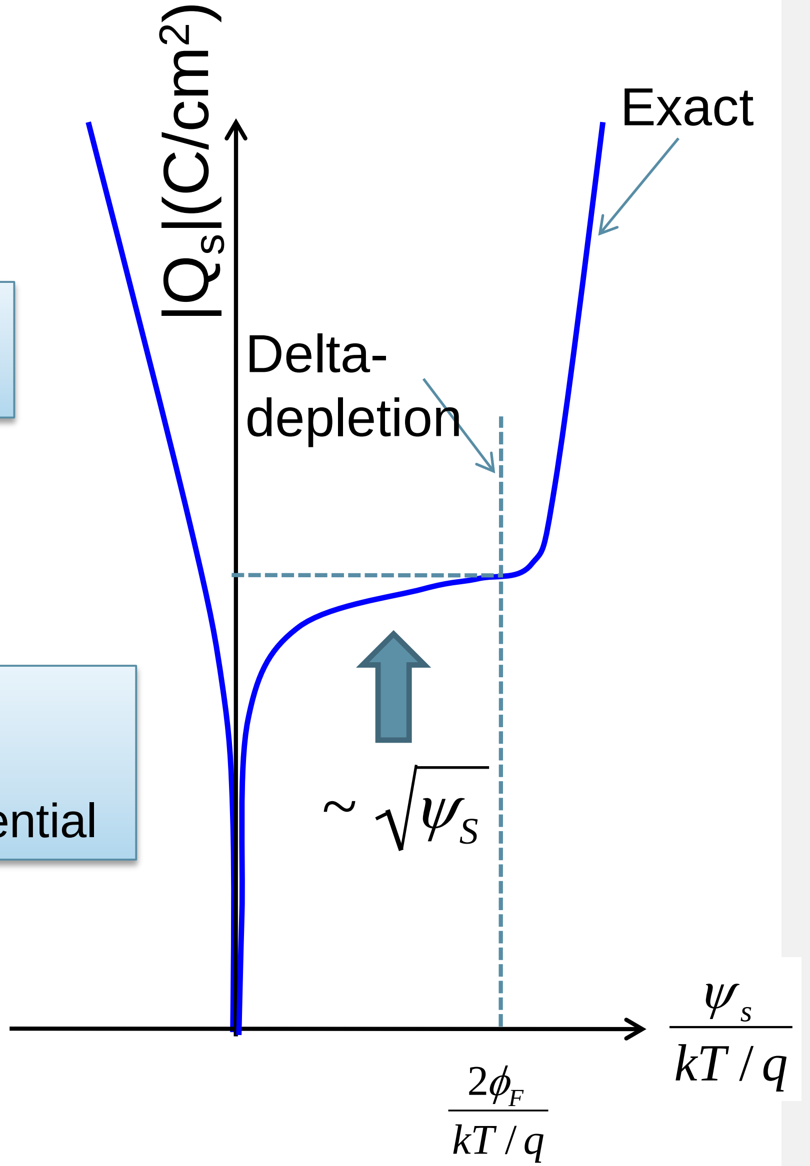
Plug in W

$$= \frac{qN_A x_0}{\kappa_{ox}\varepsilon_0}\sqrt{\frac{2\kappa_{ox}\varepsilon_0}{qN_A}}\sqrt{\psi_s} + \psi_s$$

$$\equiv \mathcal{B}\sqrt{\psi_s} + \psi_s$$

CAN solve for surface potential

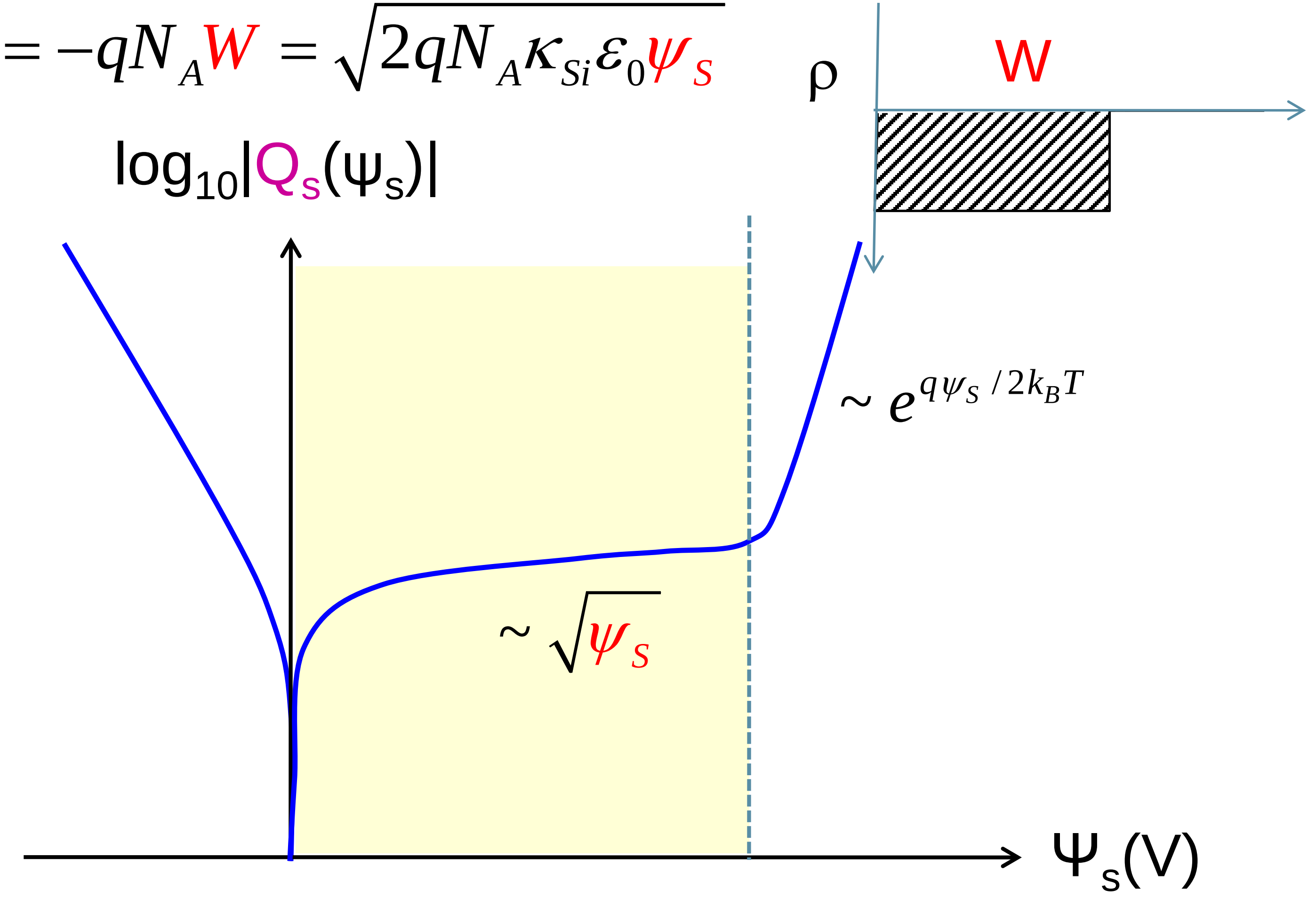
V_G known, determine ψ_S



x_0 oxide thickness

Gate Voltage and Depletion Charge

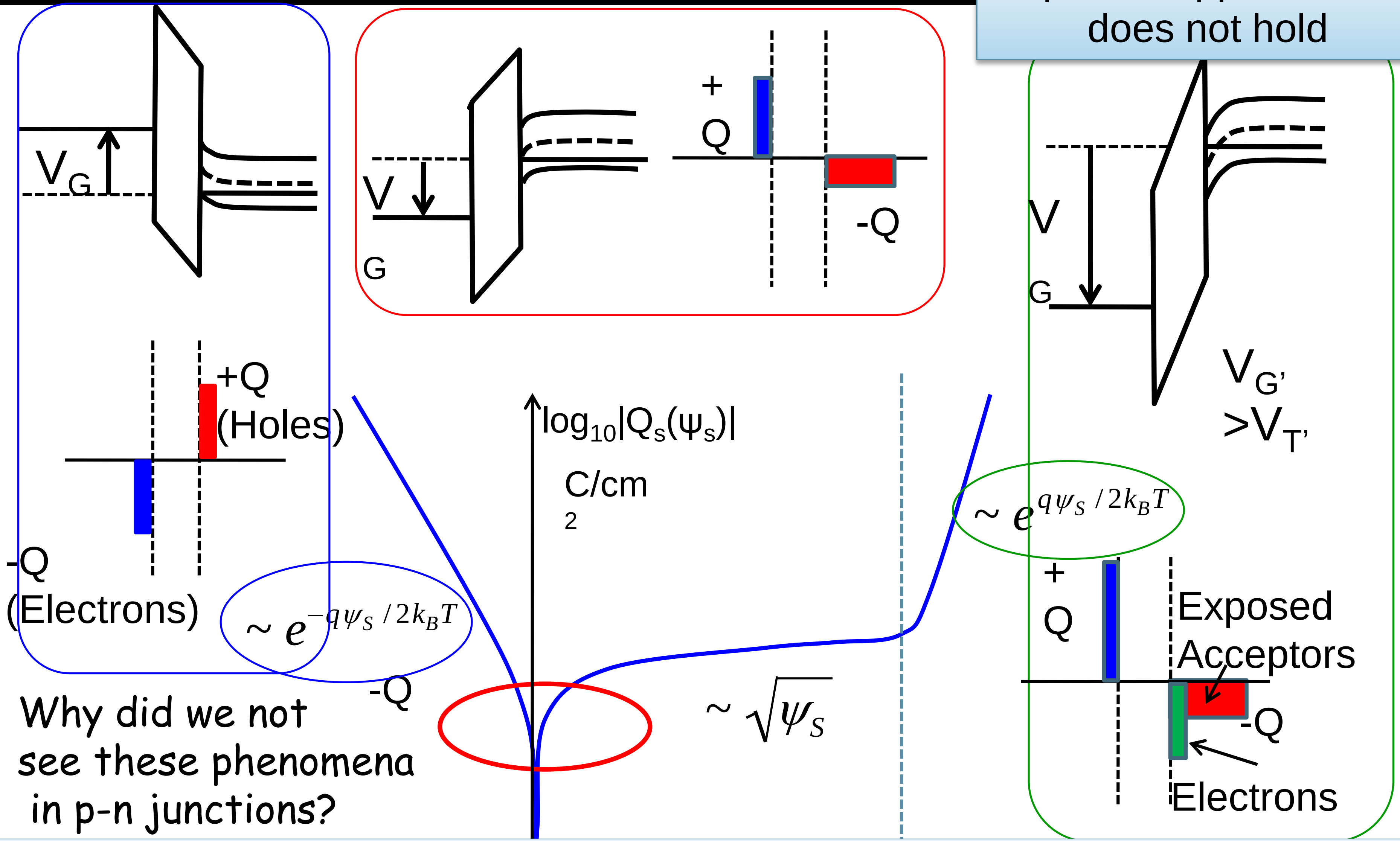
$$Q_S(\psi_S) = -qN_A W = \sqrt{2qN_A\kappa_{Si}\varepsilon_0\psi_S}$$



Recall the depletion charge in the PN Junction

Surface Potential and Induced Charge

Depletion approximation does not hold



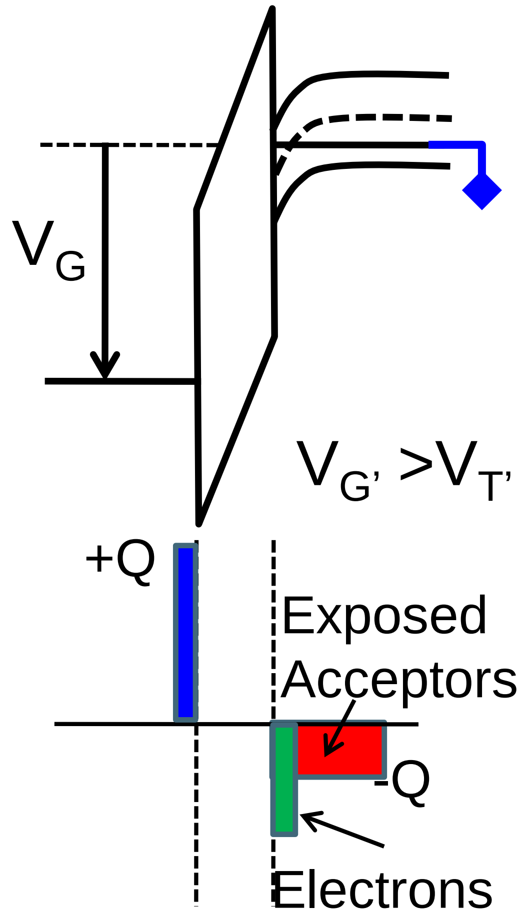
Why did we not see these phenomena in p-n junctions?

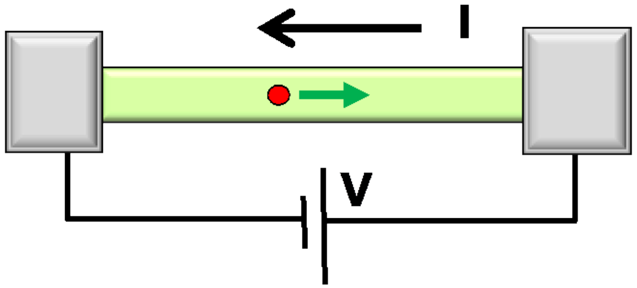
The oxide blocks the current from metal to semiconductor.
No current but charge can accumulate on both side of oxide
→ different from a PN junction

Intermediate Summary

MOSFET is the dominant electronic device now, not because it is superior to BJTs in terms of performance, but because it consumes far less power and allow denser integration.

MOSFET is an inherently 2D device. We separate out the vertical and horizontal components to qualitatively explore the mechanics of its operation.





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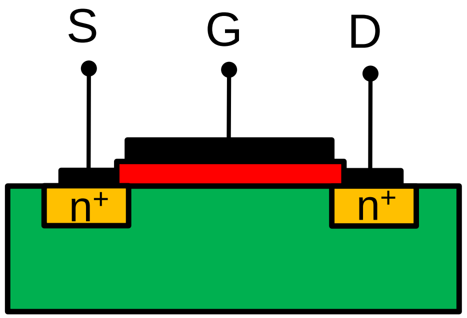

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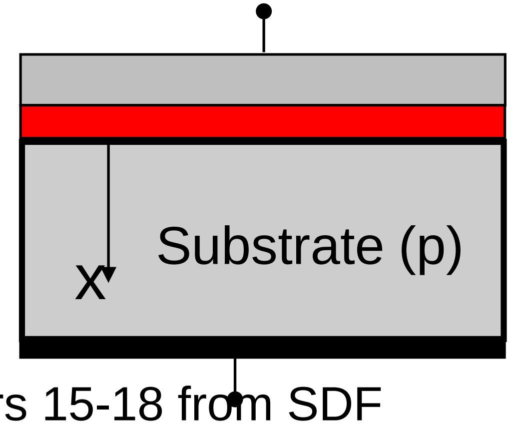

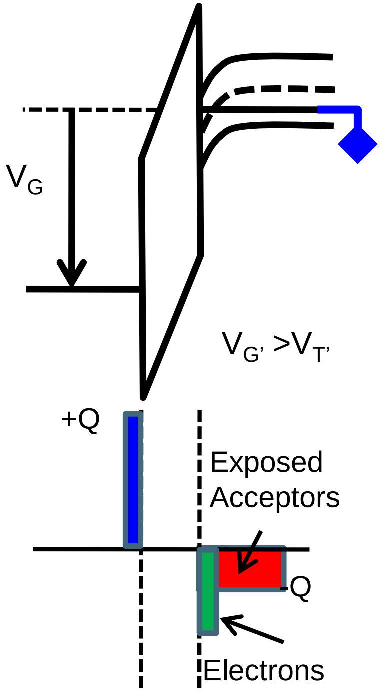

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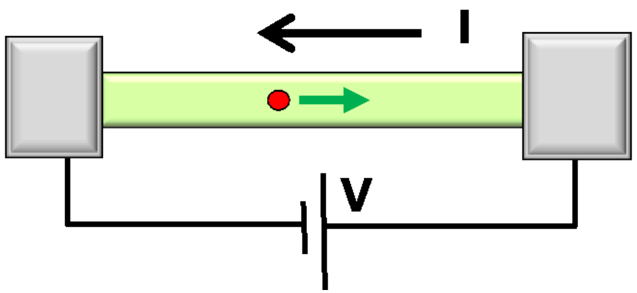

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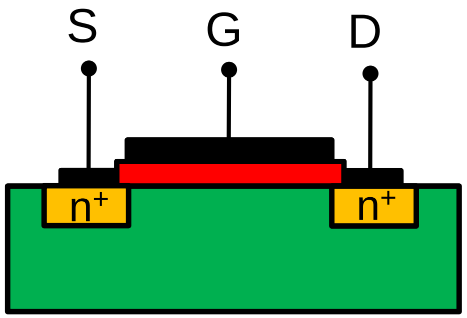

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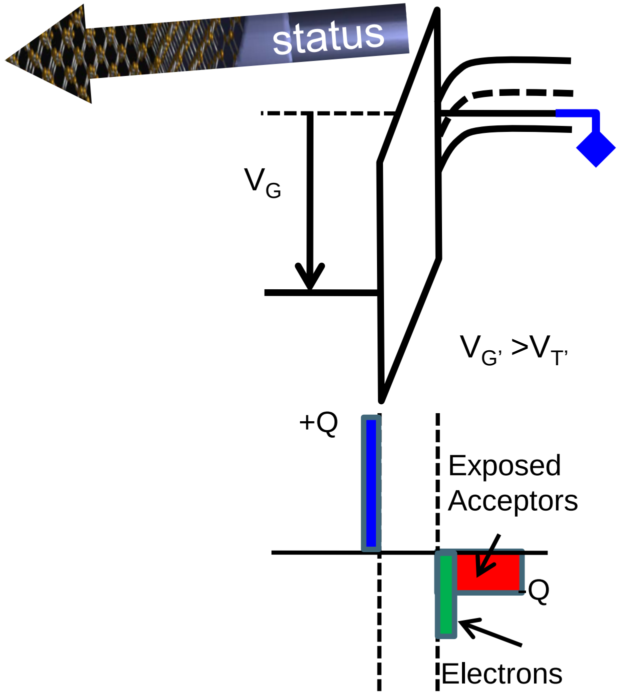

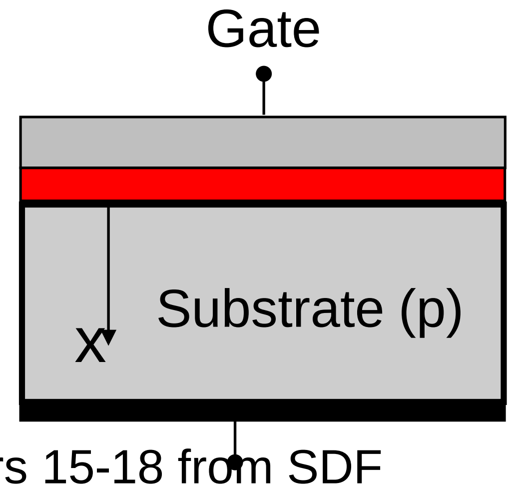

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