Effect of Gate-Body Voltage on Surface Condition

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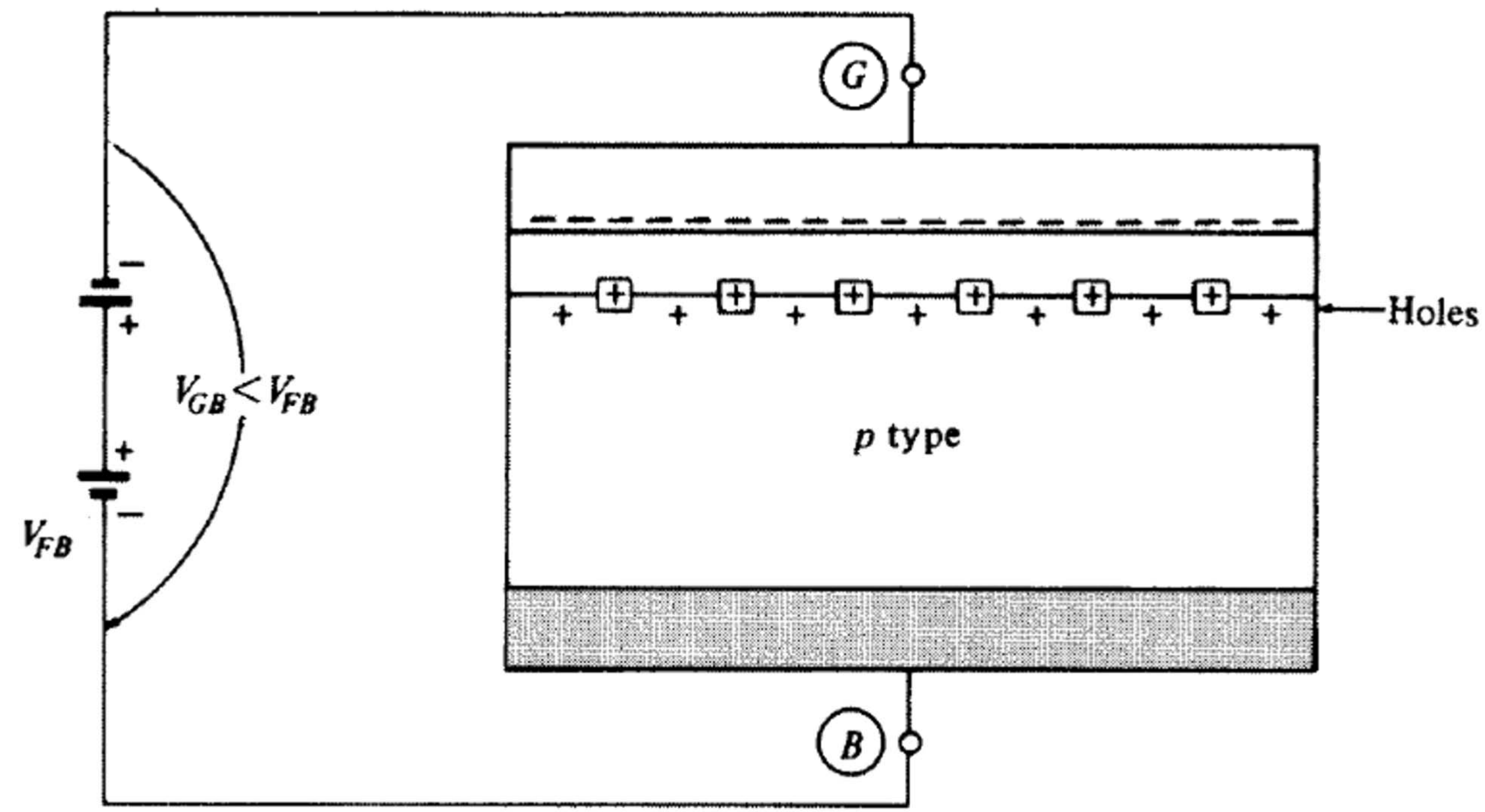
- Effect of V_{GB} on surface condition investigated more specifically Q'_C:
  - $V_{GB} = V_{FB}$
  - $V_{GB} < V_{FB}$
  - $V_{GB} > V_{FB}$
- Flat band Condition:
  - Discussed before
  - If $V_{GB} = V_{FB}$:

$$Q'_C = 0$$
$$\psi_S = 0$$

Effect of Gate-Body Voltage on Surface Condition…

- Accumulation
  - V_{GB}<V_{FB}=-1.043 V
  - Negative change in Q_G
  - Positive change in Q_C
  - Negative change in ψ_S *and* ψ_{ox}
  - In this condition:

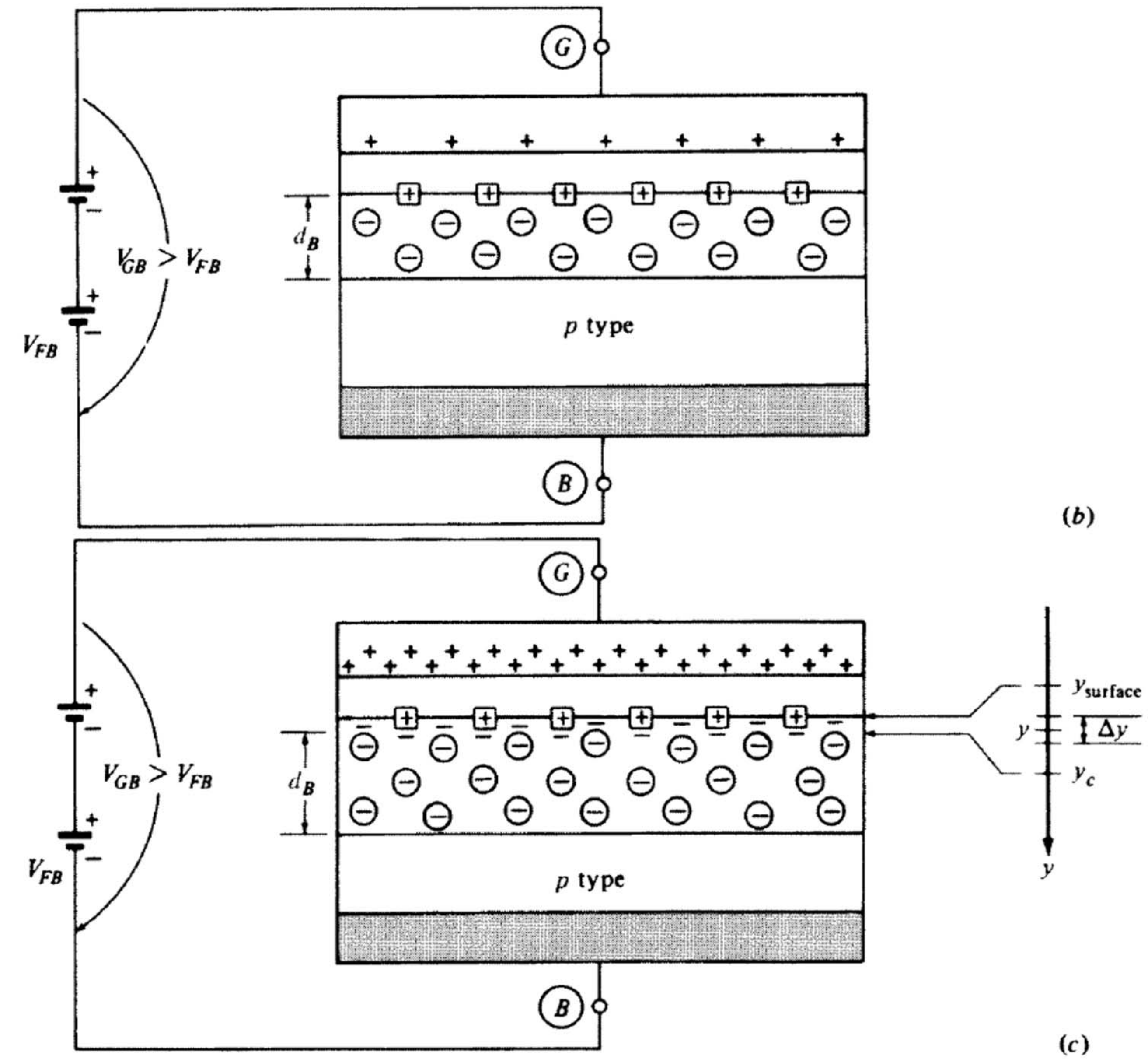
$$Q'_C > 0$$
$$\psi_S < 0$$



Effect of Gate-Body Voltage on Surface Condition…

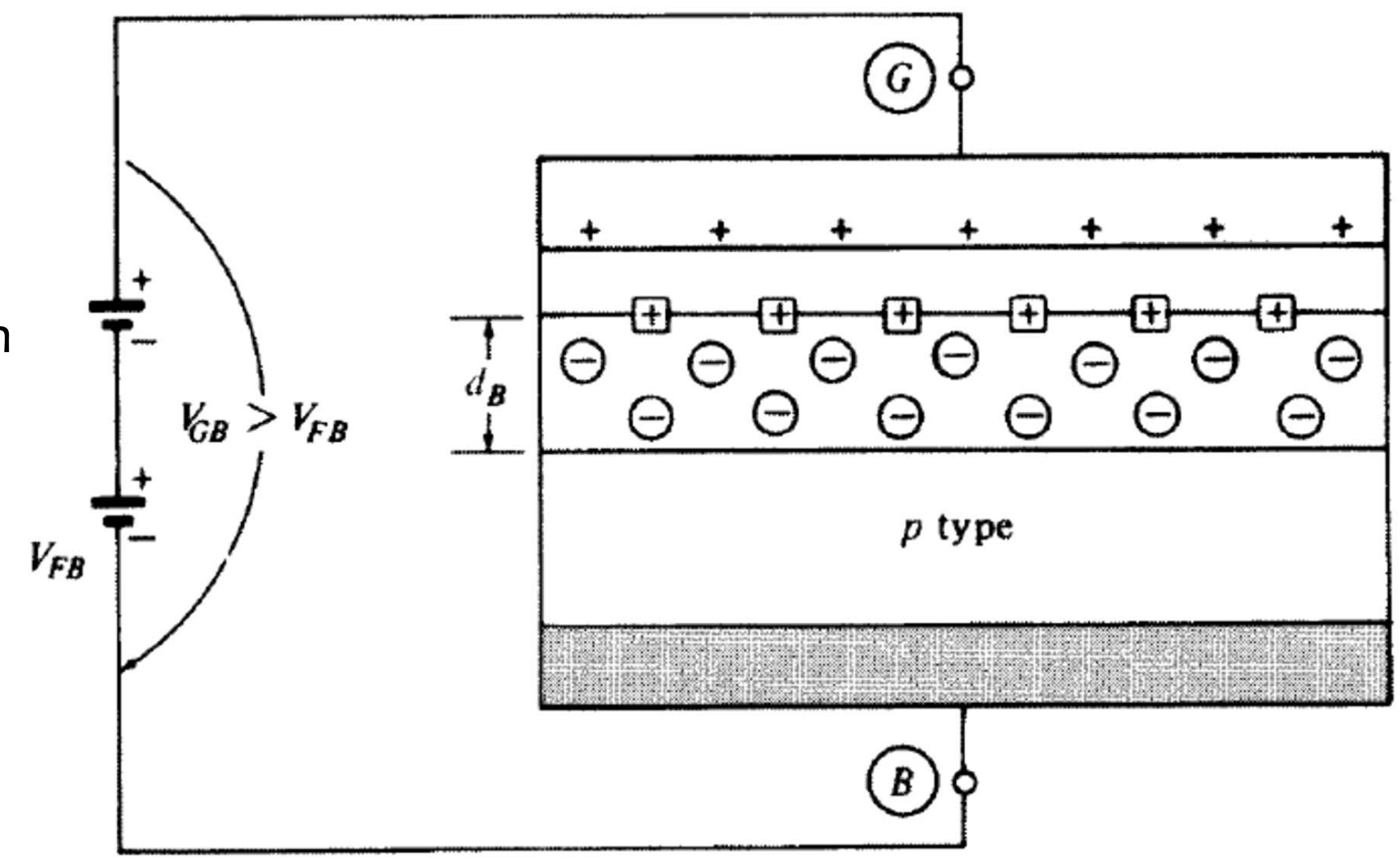
- Depletion and Inversion
  - $V_{GB} > V_{FB} = -1.043$ V
  - Positive change in Q_G
  - Negative change in Q_C
  - Positive change in ψ_S *and* ψ_{ox}
  - In this condition:

$$Q'_C < 0$$
$$\psi_S > 0$$



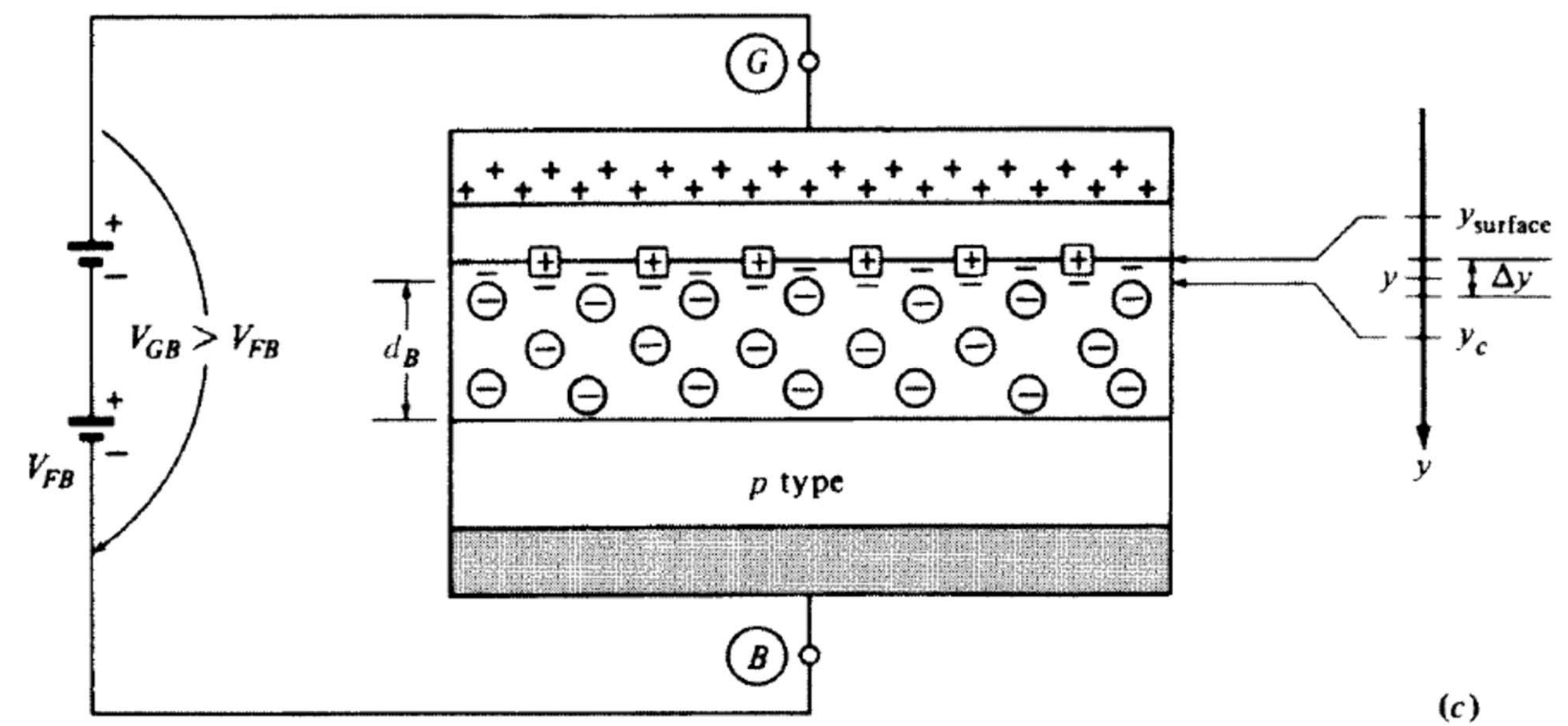
Effect of Gate-Body Voltage on Surface Condition…

- Depletion
  - If V_{GB} is much higher than V_{FB} Positive potential near the surface build up
  - This positive charge push the hole from surface, leaving it *depleted.*
  - With increase of V_{GB} hole density will keep decreasing well below the doping concentration value N_A.
  - The charge Q_c is due to the uncovered acceptor atoms, each of which contributes a charge –q.



Effect of Gate-Body Voltage on Surface Condition…

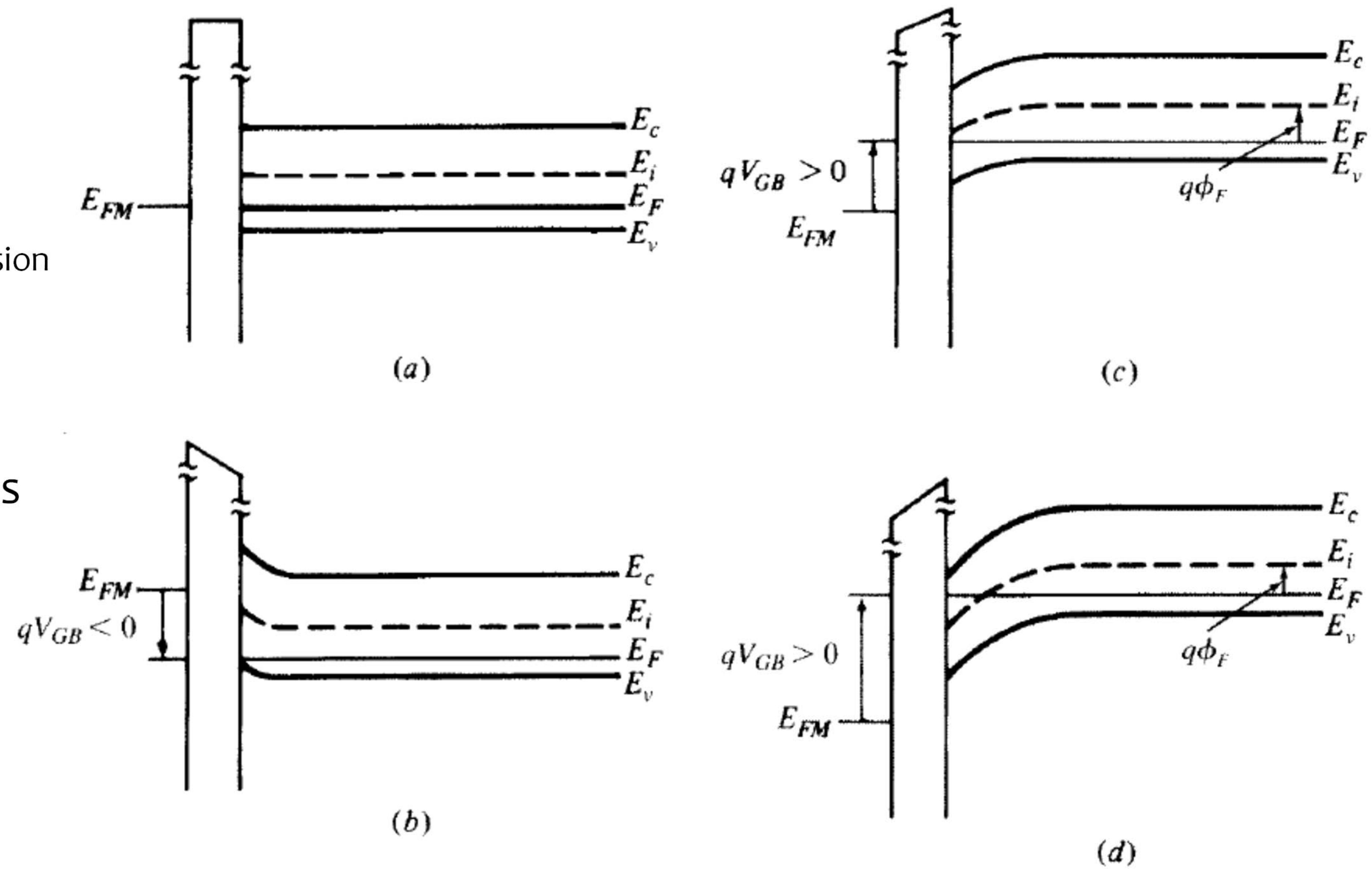
- Inversion
  - If VGB increased further more ions are uncovered and finally the electric force gain enough energy to attract electrons to the surface.
  - What is the source of electrons? Electron hole generation in depletion region (slow process) caused by thermal vibration.
  - For high V_{GB} electron concentration become greater than hole concentration (Inversion)



Effect of Gate-Body Voltage on Surface Condition…

- Band bending
  - If Φ_{MS} and Q_o be zero
    - (b) accumulation
    - (c) Depletion
    - (d) Inversion, who can we know inversion happen?

- potential varies in the opposite direction from the energy bands



Effect of Gate-Body Voltage on Surface Condition…

- Carrier Concentration

$$\frac{n_1}{n_2} = \exp\left(\frac{\psi_{12}}{\phi_T}\right) \Rightarrow \frac{n_{surface}}{n_0} = \exp\left(\frac{\psi_s}{\phi_T}\right)$$

- Where n_o is the carrier concentration in p-type material far from the surface!

$$n_0 = n_i e^{(E_f - E_i)/kT}, \phi_f = \frac{E_i - E_f}{q}$$

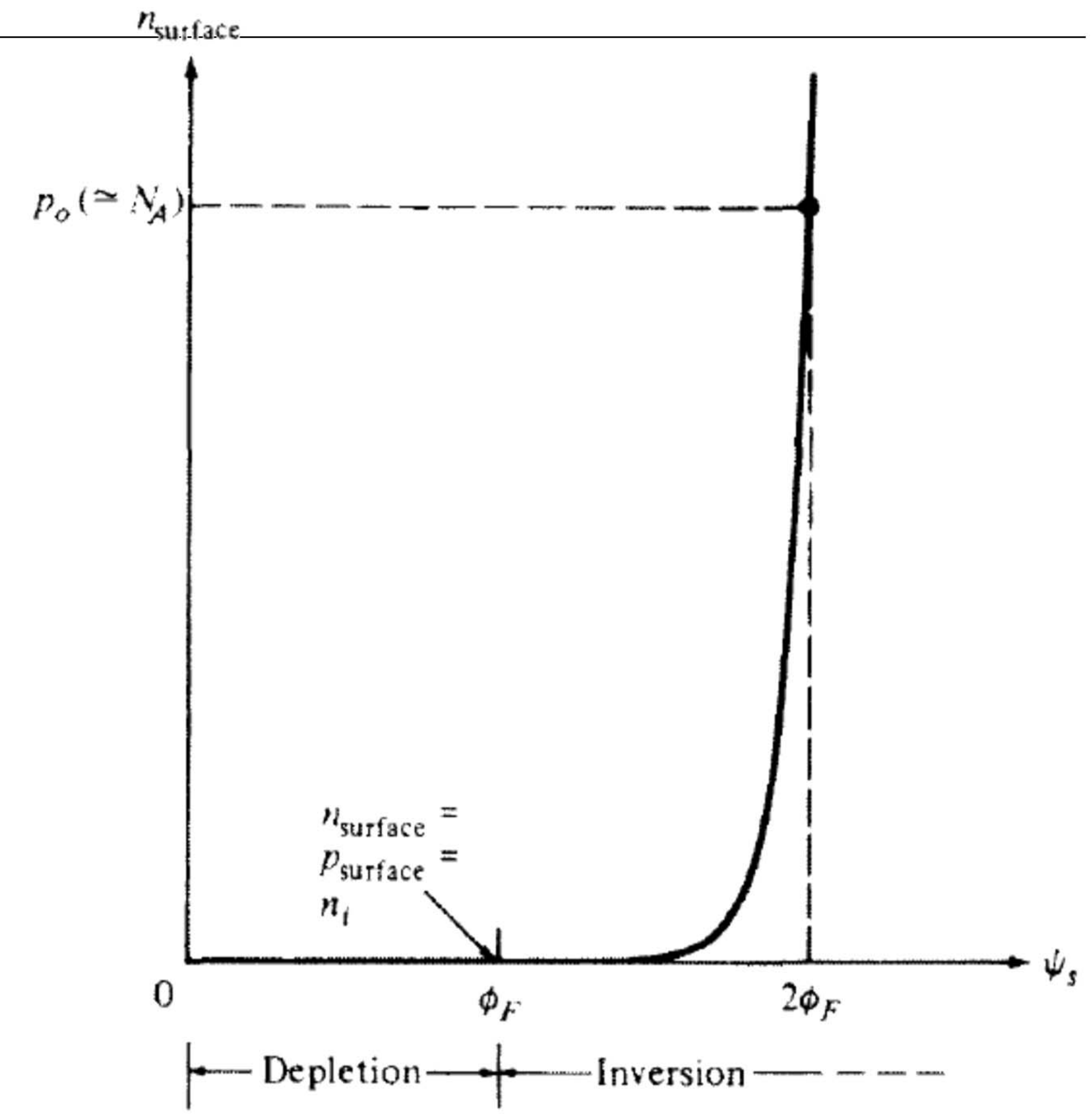
$$n_{surface} = n_i \exp\left(\frac{\psi_s - \phi_f}{\phi_T}\right)$$

$$N_A = p_0 = n_i e^{-(E_f - E_i)/kT} \Rightarrow n_i = p_0 e^{-\phi_f/kT}$$

$$n_{surface} = N_A \exp\left(\frac{\psi_s - 2\phi_f}{\phi_T}\right)$$

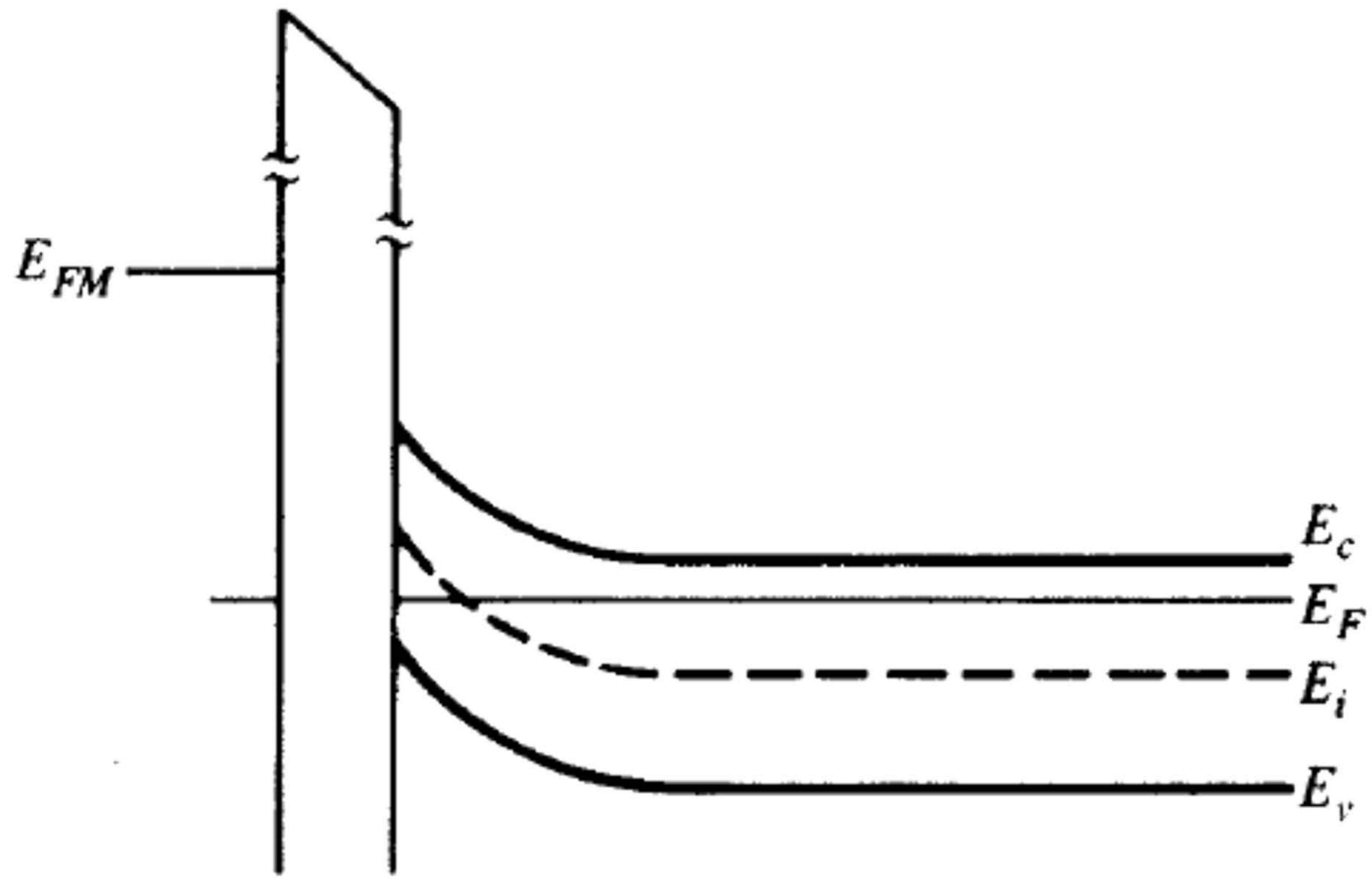
Effect of Gate-Body Voltage on Surface Condition…

- At $\psi_S=\Phi_F$, $n_{surface}=n_i=p_{surface}$!
- The total band bending in this case is q Φ_F, i.e., E_i bends just enough to touch E_F.
- This is defined as the boundary between the depletion and inversion regions.
- At $\psi_S=2\Phi_F$, $n_{surface}=N_A=p_o$!



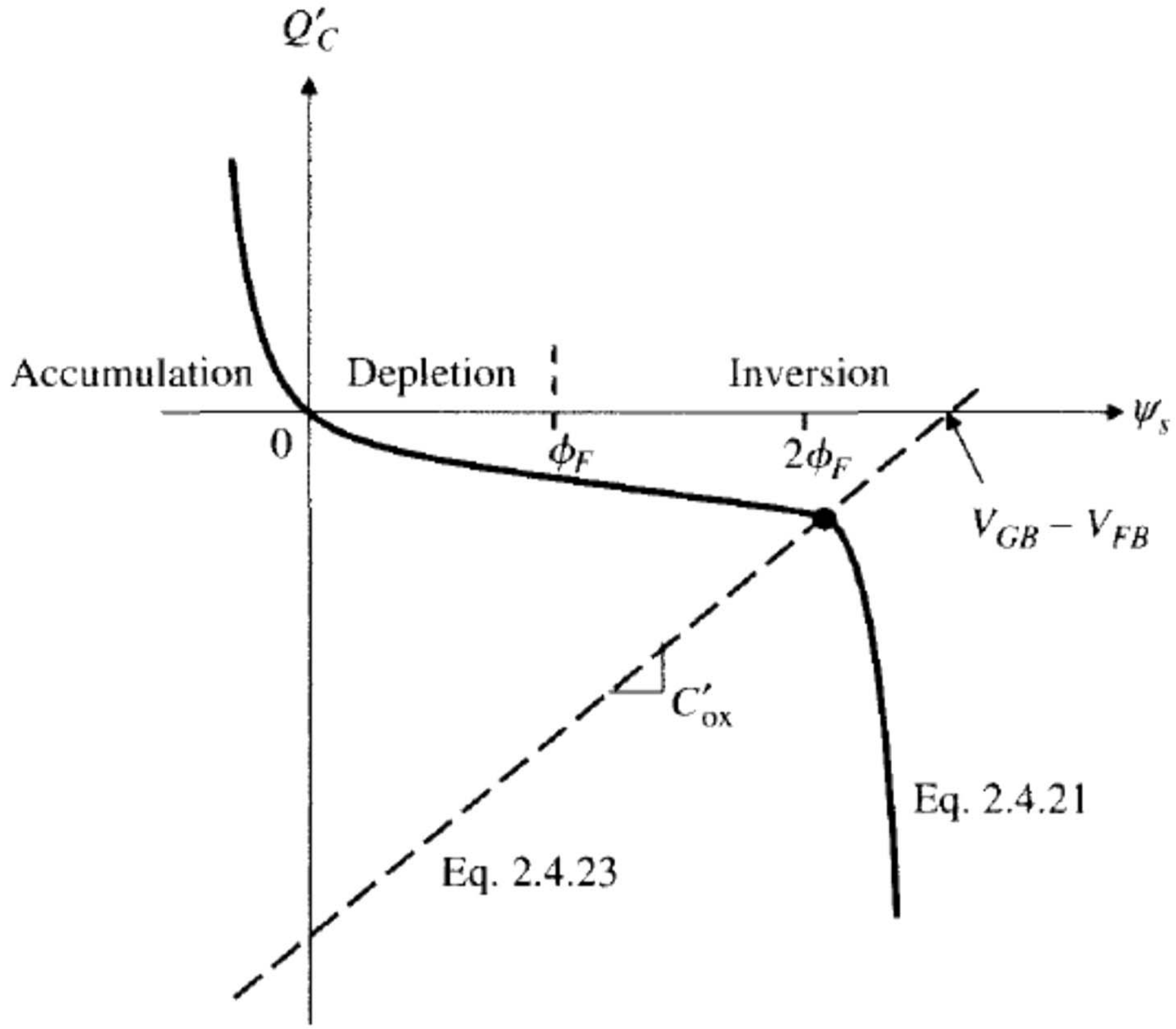
Effect of Gate-Body Voltage on Surface Condition…

- For n-type material
  - The hole inversion layer made when V_{GB} is sufficiently negative!
  - The immobile charge in the depletion region will consist of positively charged ionized donor atoms.
  - Electron pill up for positive V_{GB}



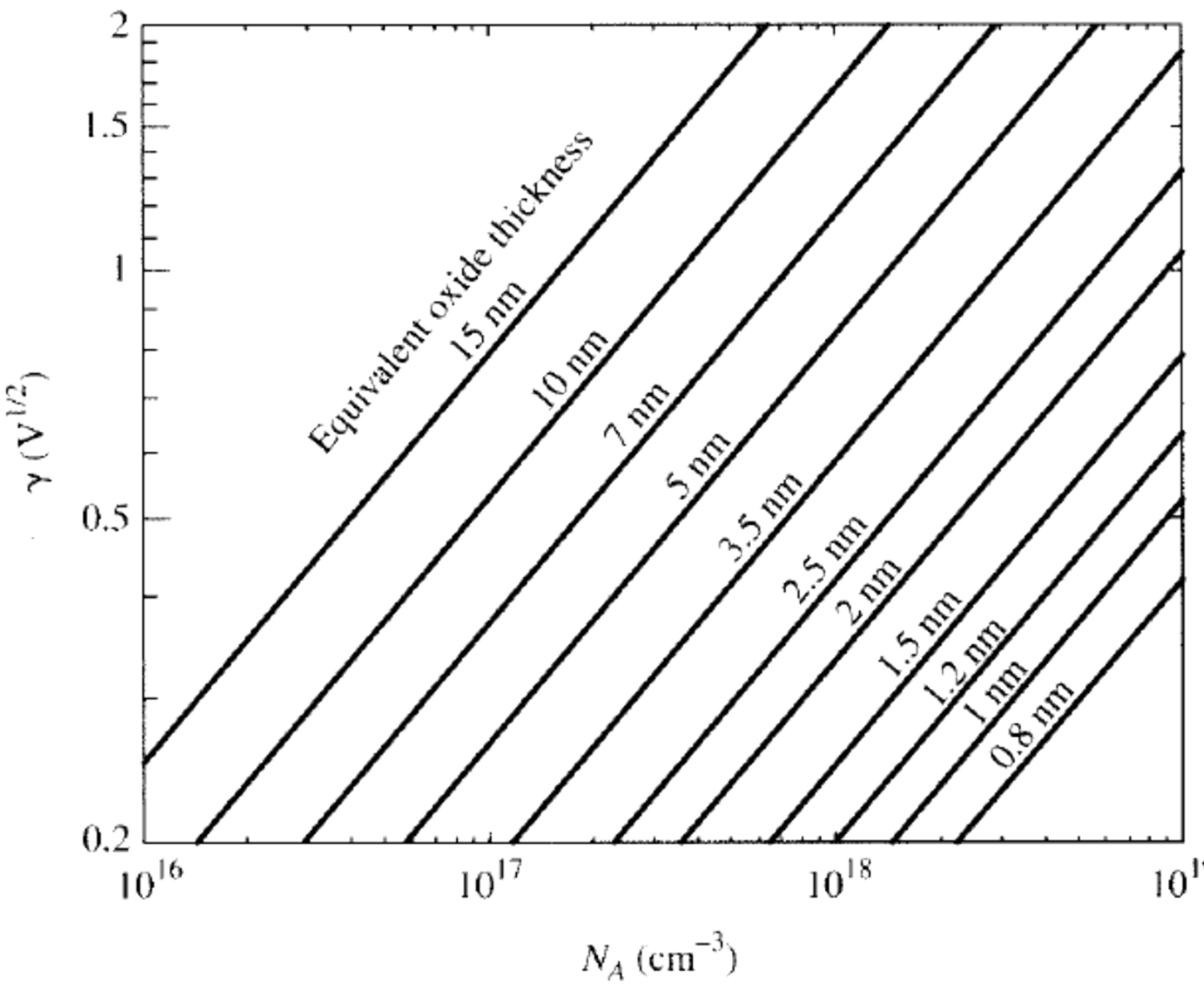
Effect of Gate-Body Voltage on Surface Condition…

- General consideration
- $\psi_S < 0$, hole accumulation
- $0 < \psi_S < \Phi_F$, depletion, N_A or N_D contribute in depletion region
- $\psi_S > \Phi_F$, Inversion. $\psi_S > 2\Phi_F$ electron concentration is dominant



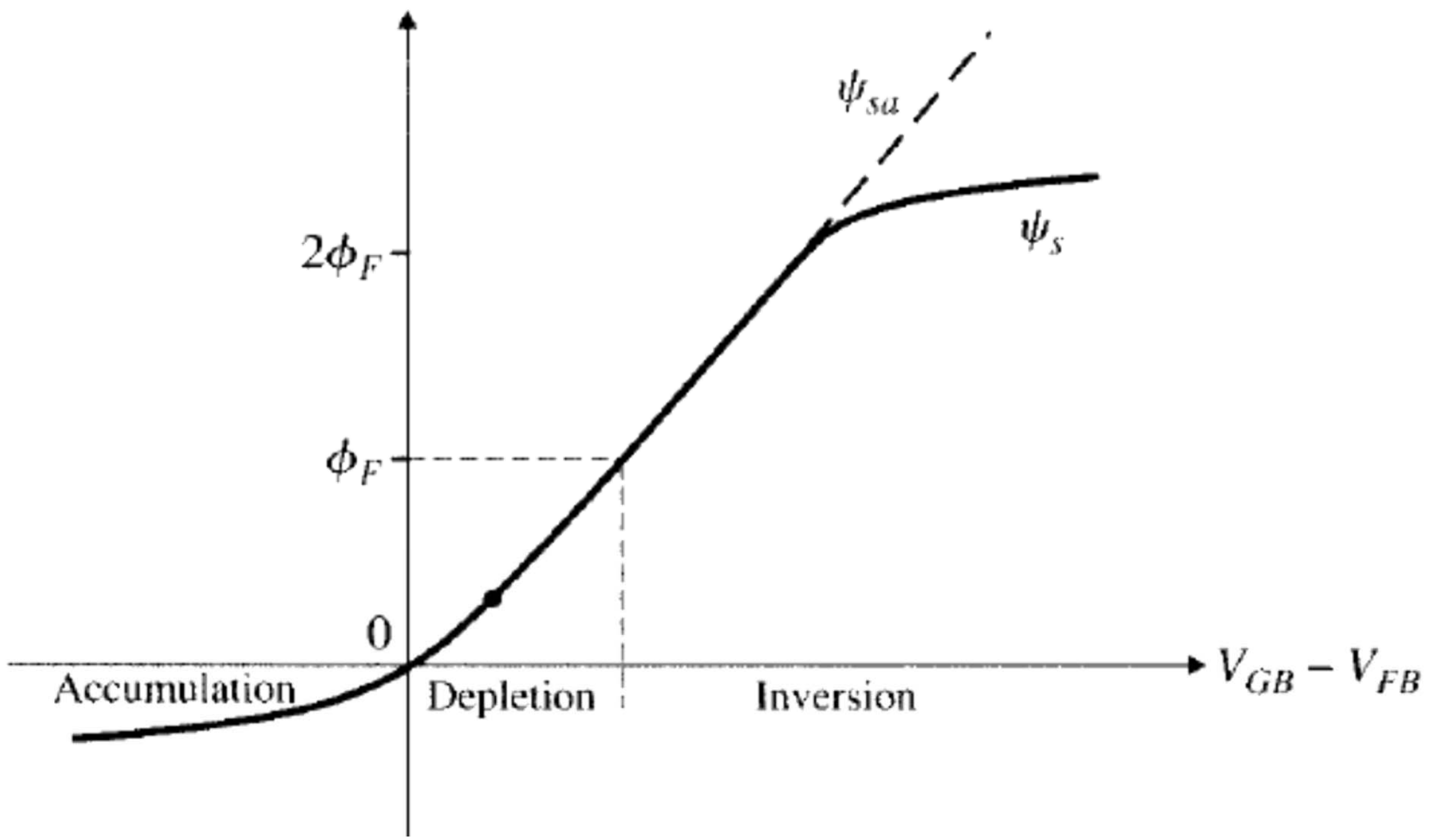
Effect of Gate-Body Voltage on Surface Condition…

- Body effect coefficient



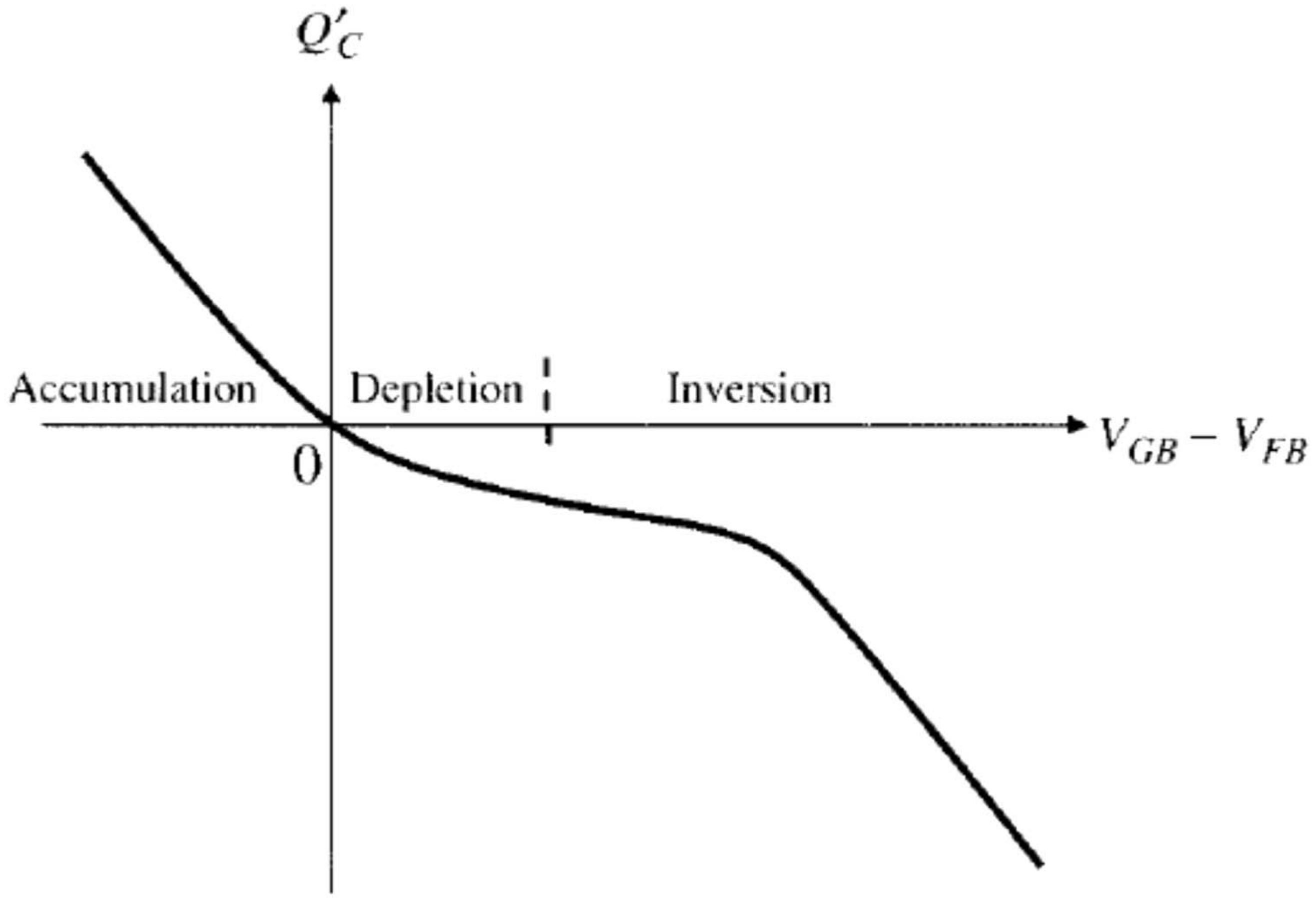
Effect of Gate-Body Voltage on Surface Condition…

- Surface potential versus V_{GB}-V_{FB}



Effect of Gate-Body Voltage on Surface Condition…

- Total semiconductor charge versus V_{GB}-V_{FB}



Accumulation and Depletion

- Accumulation and Depletion
  - In accumulation and depletion, the contribution of electrons can be neglected. Furthermore we know in this case N_D=0.
  - We can neglect some terms in following regions:
    - Deep accumulation: $\psi_s < \phi_T, \psi_s < 0$
    - Deep depletion: $\psi_s > 3\phi_T$
      - In this case one can neglect the effect of mobile electron and hole in equation.
      - Although this assumption work fine for both deletion and week inversion ($\psi_s < 2\phi_F$) as seen in this figure but it collapse for strong inversion regime. In other region electron concentration plat essential role in calculation and should not be neglected!