Lecture 9

- Last time:
  - Compensation
  - Drift current density

- Today:
  - IC resistors
  - Metal-metal capacitors (start)
Campus Memorial: Noon today

Lab M 12-3 cancelled

W 2-5 make-up lab or
  go to other sections

O.H. Today 4-5:30

• Exp. 3 is the first formal lab write-up.
  [Color version of write-up posted. Instructions on what we want from you.]
Mobility vs. Doping

**EE 130**

\[
\begin{align*}
\mu_n &= f(T) \\
\mu_p &= f(T)
\end{align*}
\]

"default" values:

\[
\begin{align*}
\mu_n &= 1000 \text{ cm}^2/\text{V}s \\
\mu_p &= 400 \text{ cm}^2/\text{V}s \\
N_d + N_a &= 10^{17} \text{ cm}^{-3}
\end{align*}
\]
Velocity Saturation

\[ E = 10^4 \text{ V/cm} \rightarrow 10^5 \text{ V/cm} \]

\[ 1 \mu\text{m} = 10^{-4} \text{ cm} \]

\[ 1 \mu\text{m} = 1V/\mu\text{m} \]
Drift Current Density (Holes)

Hole case: drift velocity is in same direction as $E$

\[ V_{dp} = +\mu_p E \]  
\[ E > 0 \quad \text{points in the same direction as } x. \]

The hole drift current density is:

\[ J_p = q \rho \mu_p E \]

COUNT CHARGE $\rho = \# / \text{cm}^3$
Drift Current Density (Electrons)

Electron case: drift velocity is in opposite direction as $E$

The electron drift current density is:

$$J_n^{dr} = (-q) \ n \ \nu_{dn}$$

units: Ccm$^{-2}$ s$^{-1} = $Acm$^{-2}$
Resistivity

**Bulk silicon:** uniform doping concentration, away from surfaces

n-type example: in equilibrium, \( n_o = N_d \).

When we apply an electric field, \( n = N_d \).

\[
J_n = q \mu_n n E = q \mu_n N_d E
\]

\[
\rho_n = \frac{\sigma_n}{n} = \frac{1}{\sigma_n}
\]

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Ohm’s Law

- Current $I$ in terms of $J_n$
- Voltage $V$ in terms of electric field

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Result for $R$

\[ I = \left( \frac{1}{\rho_n} \right) \text{mDot} \cdot \frac{V}{L} \rightarrow \frac{V}{I} = R = \frac{\rho L}{W^2}. \]
Sheet Resistance

- IC resistors have a specified thickness — not under the control of the circuit designer.
- Eliminate $t$ by absorbing it into a new parameter: the sheet resistance.

$$R = \frac{\rho L}{Wt} = \left(\frac{\rho}{t}\right) \left(\frac{L}{W}\right) = R_{sq} \left(\frac{L}{W}\right)$$