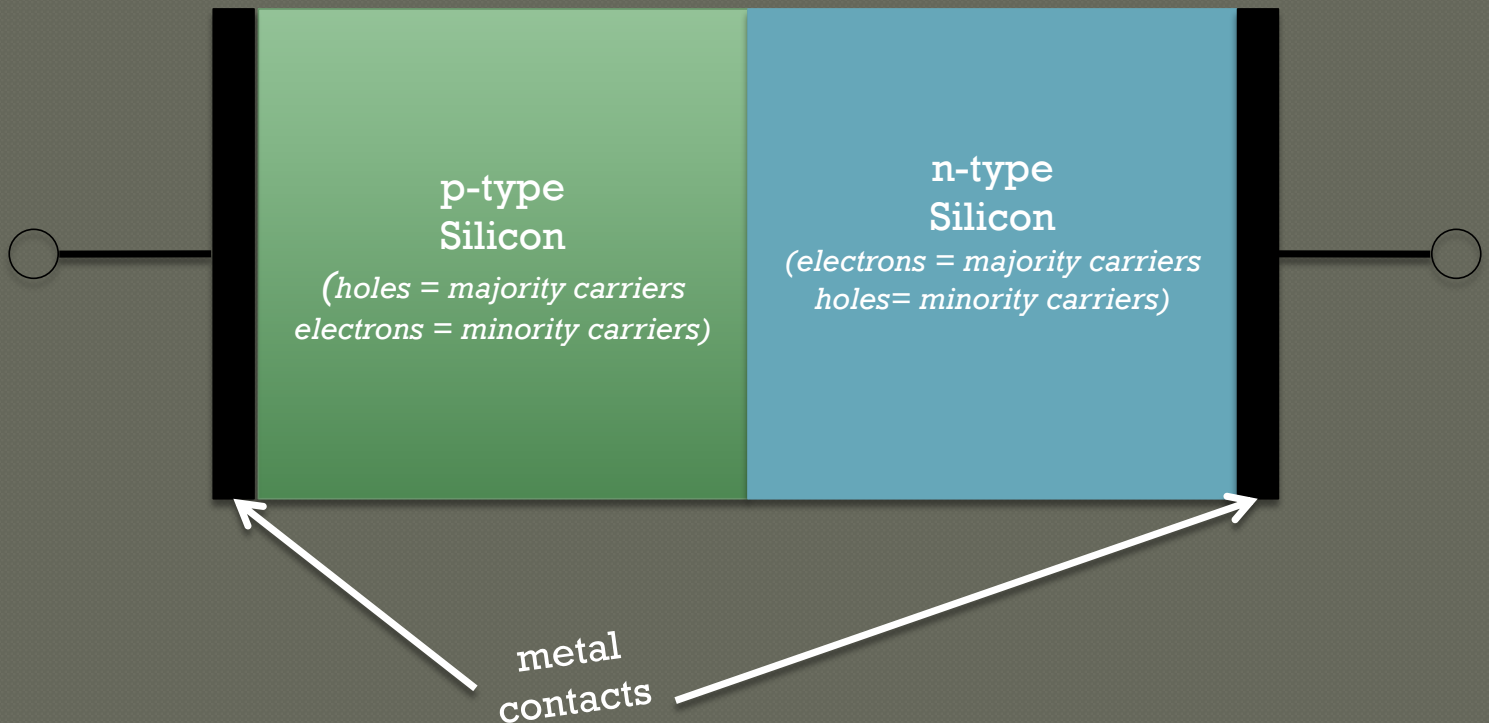


# Silicon PN Junctions

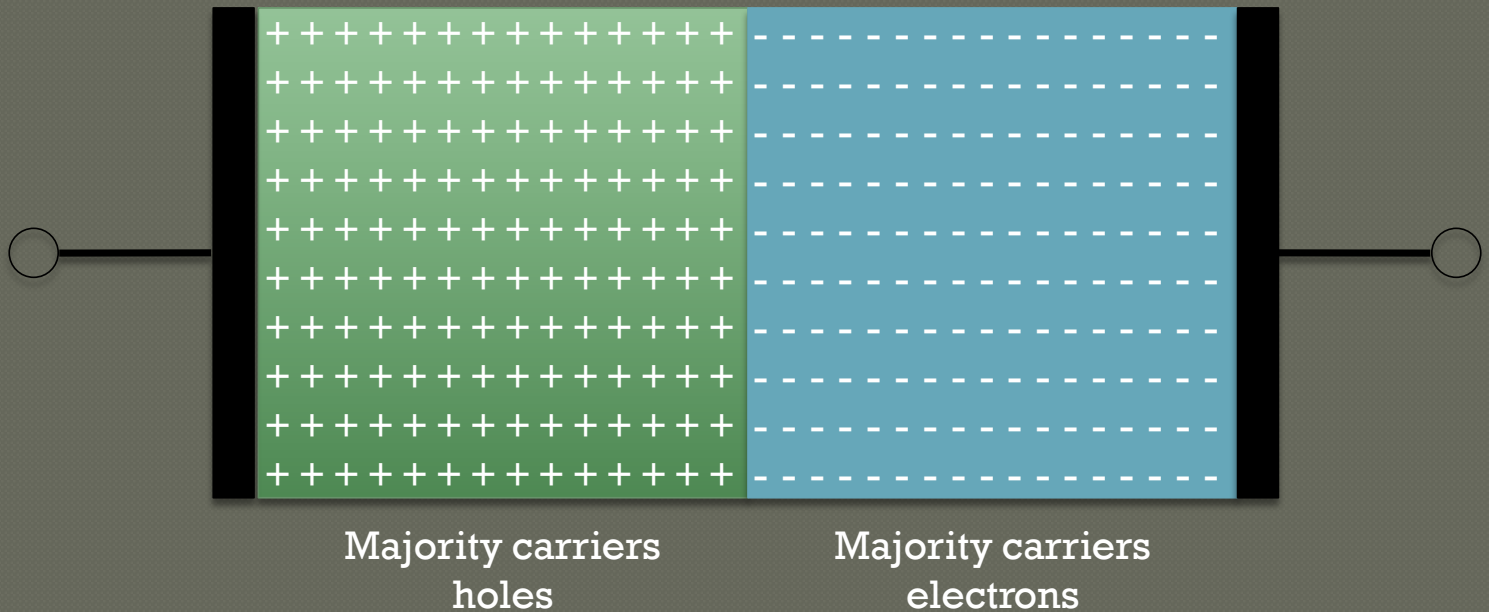
A Basic Summary

# The pn junction



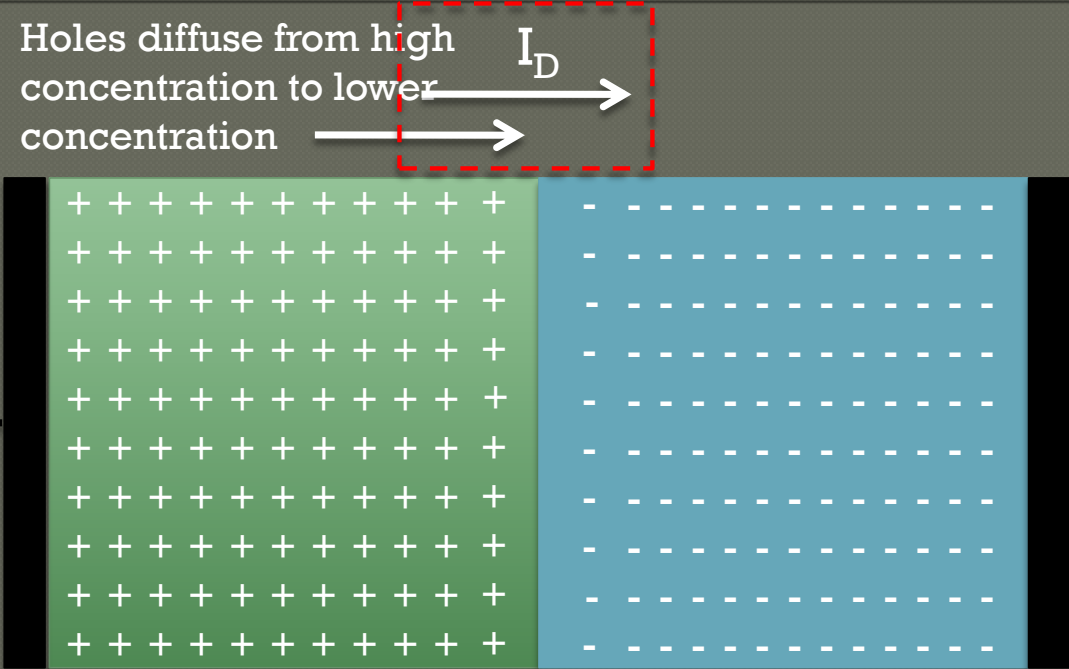
# The pn junction: open-circuited

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# The pn junction: Diffusion Current

Holes diffuse from high concentration to lower concentration  $I_D$



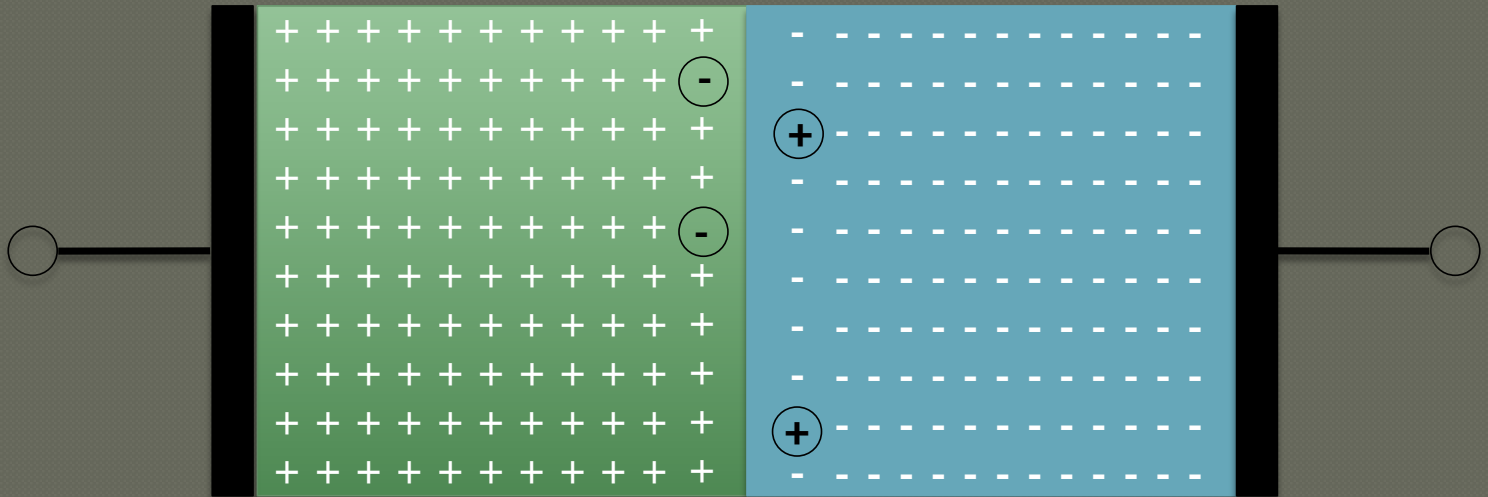
The diagram illustrates a pn junction. On the left is the p-type region, colored green, containing a grid of white '+' symbols representing holes. On the right is the n-type region, colored blue, containing a grid of white '-' symbols representing electrons. A red dashed box highlights the top portion of the junction. Inside this box, an arrow points from the p-region to the n-region, labeled  $I_D$ . Above this arrow, the text 'Holes diffuse from high concentration to lower concentration' is written. Below the diagram, another red dashed box contains text explaining the net result of diffusion currents.

Electrons diffuse from high concentration to lower concentration  $I_n$

The net result is a diffusion current ( $I_D$ ) that flows from the p-type Si to the n-type Si.

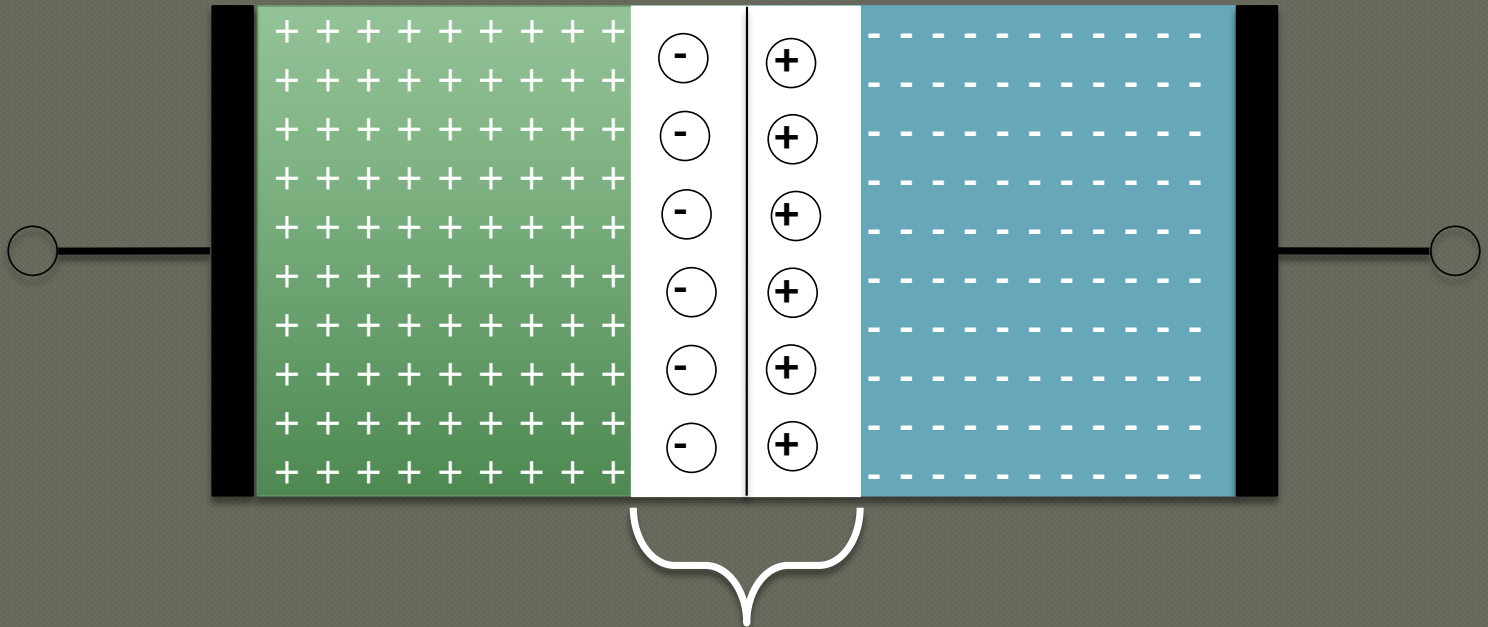
# The pn junction: Depletion Region

- As diffusion occurs, electron-hole pairs are formed. This leaves uncovered or “bound” minority carrier charge near the junction.



# The pn junction: Depletion Region

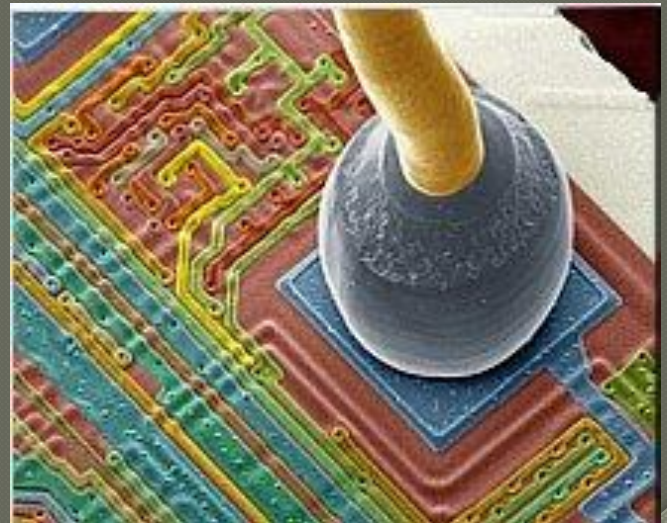
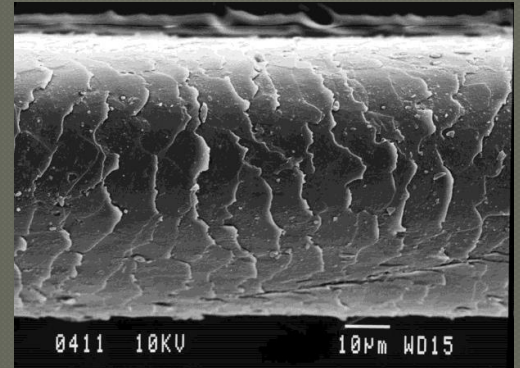
- Eventually, the area on each side of the junction becomes depleted of majority carriers.



Depletion region ( $\sim .1$  to  $.5$  microns)

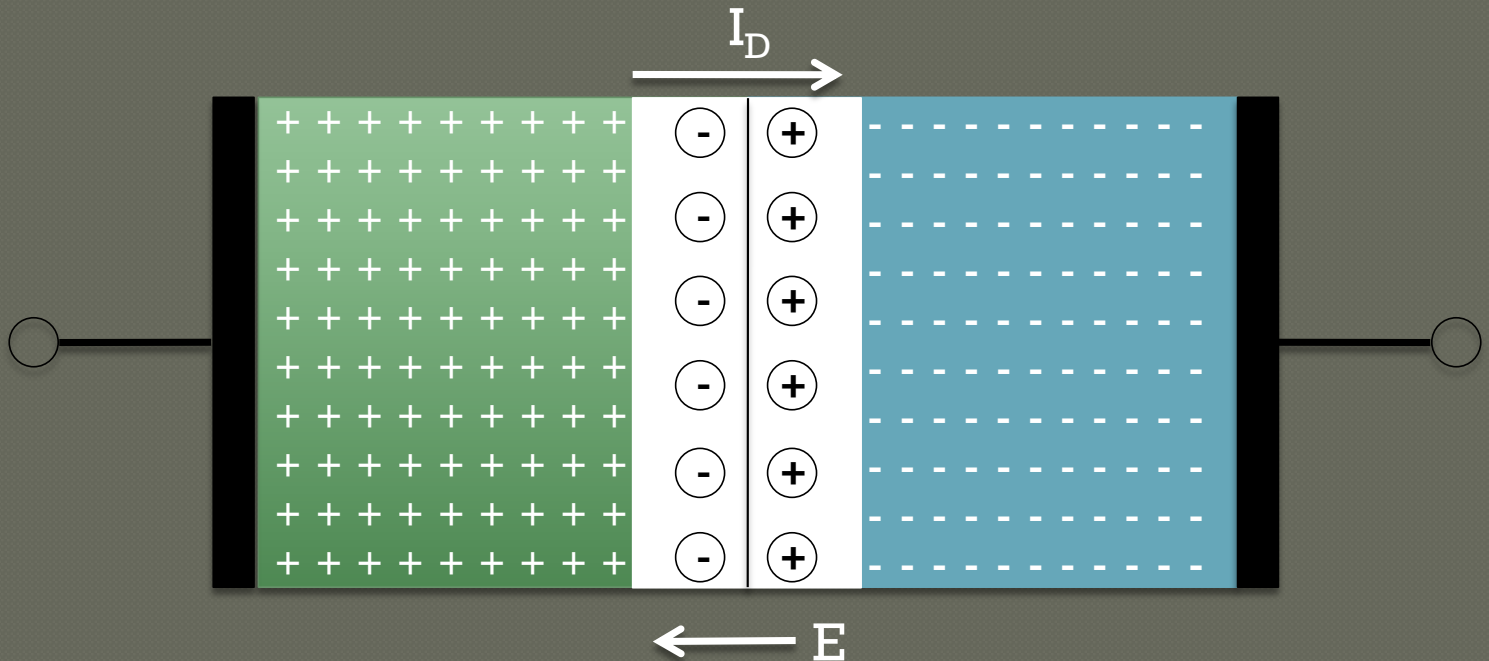
# What's a micron?

- 1 micron =  $1 \times 10^{-6}$  meters
- Dust mite length: 250-300 microns
- Human hair diameter: 10-100 microns
- Red blood cell diameter: 7 microns



# The pn junction: Barrier Voltage

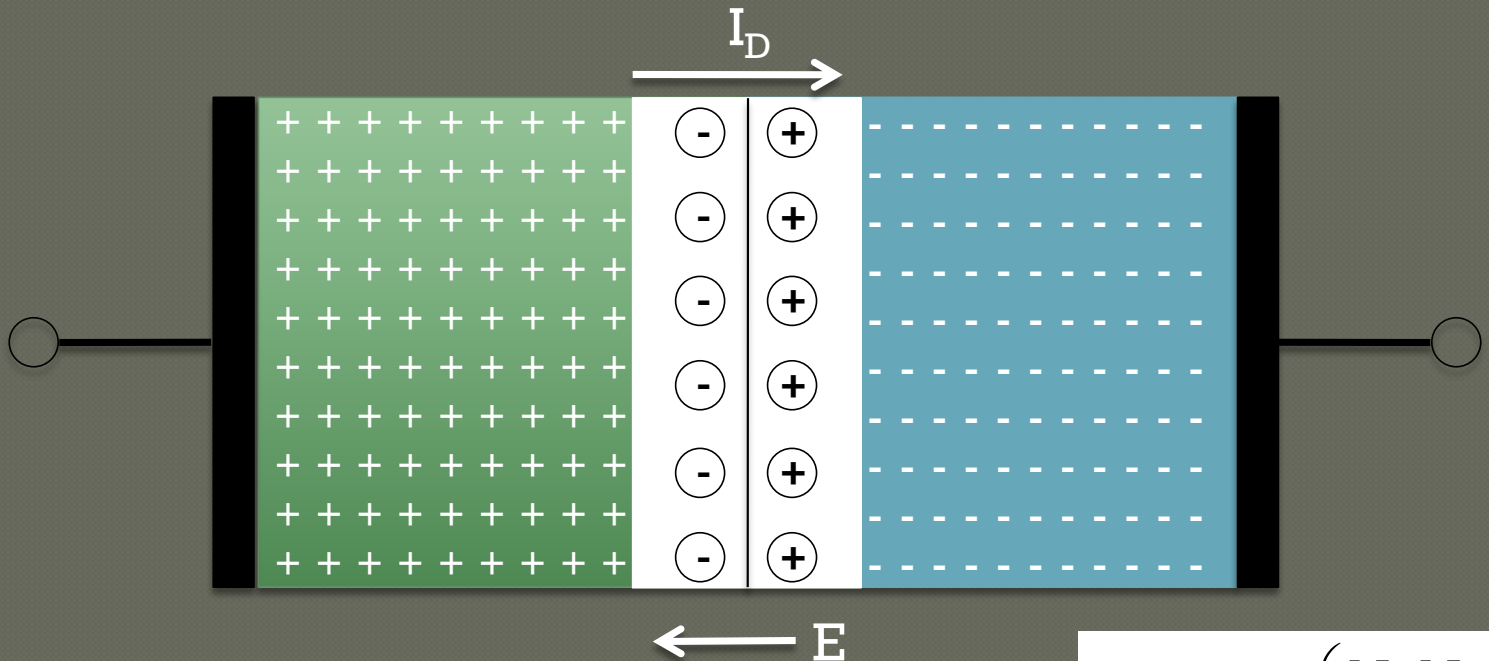
- The charges on each side of the depletion region establish an electric field (i.e. a voltage drop across the region)





# The pn junction: Barrier Voltage

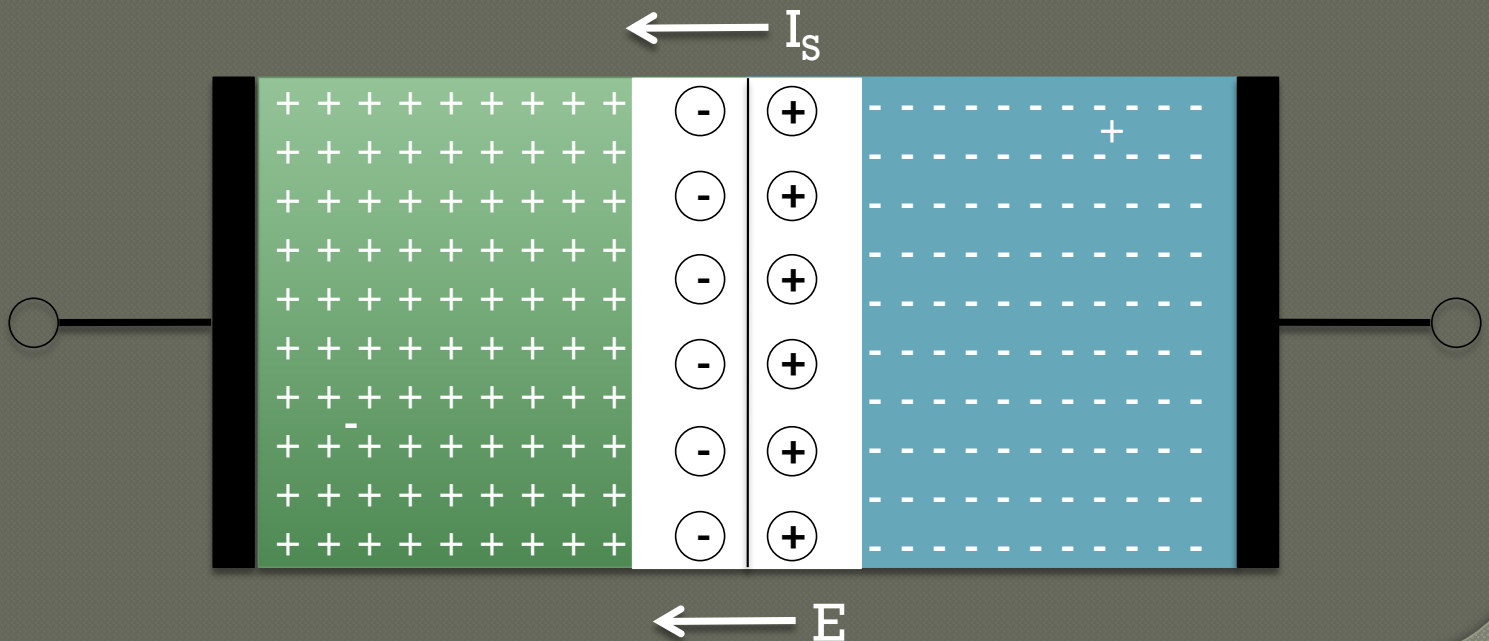
- This voltage drop – *the barrier voltage* - will limit the number of carriers that can diffuse across the region and thus limits  $I_D$



$$V_O = V_T \ln \left( \frac{N_A N_D}{n_i^2} \right)$$

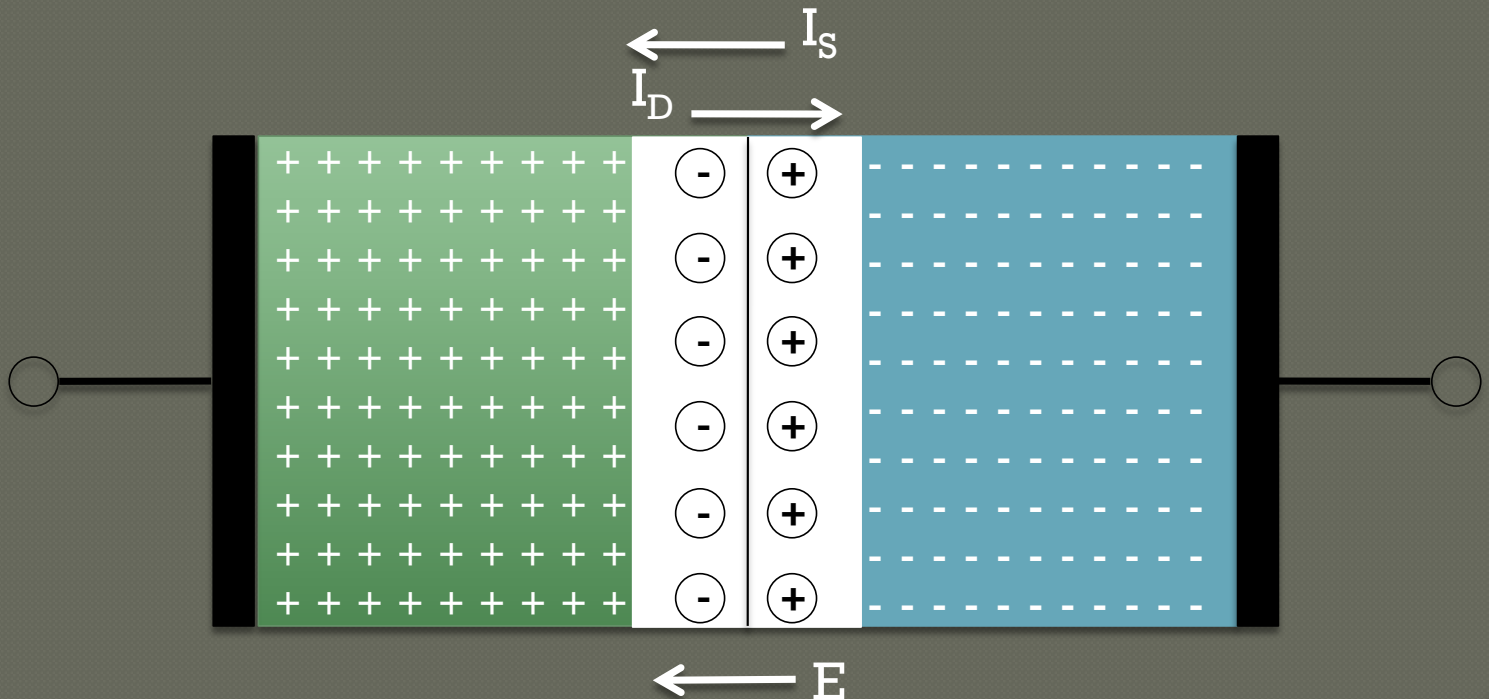
# The pn junction: Drift Current

- Minority carrier drift current ( $I_s$ ) occurs when thermally generated holes (n-type Si) and electrons (p-type Si) move towards the edge of the depletion region.
- The electric field sweeps the minority carriers across the junction creating current flow.



# The pn junction: Equilibrium

- Under open-circuit conditions (i.e. no external voltage), the drift current will equal the diffusion current.
- The barrier voltage ensures this equilibrium.



# The pn junction: Forward Bias

- When a voltage,  $V_F$ , is applied the barrier voltage is decreased by that voltage and the depletion region narrows.
- The diffusion current will increase.

