

SEMICONDUCTOR PHYSICS • CHAPTER 14

How a p-n Junction Forms

The step-by-step microscopic process of diffusion, depletion, and equilibrium.



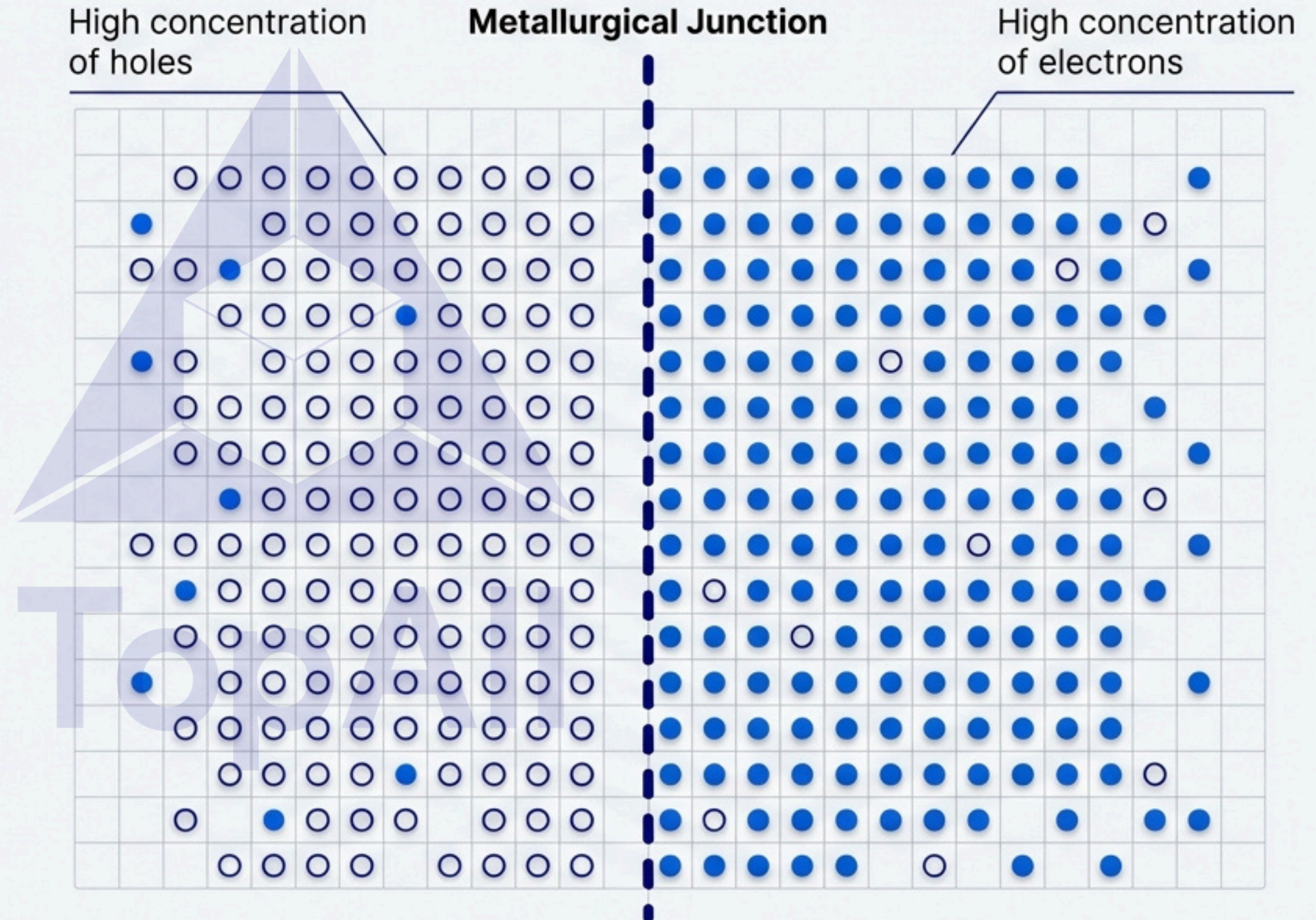
PHASE 1 OF 5 • THE STARTING STATE

The Initial Concentration Gradient



When a p-n junction is first formed, there is a massive difference in charge carrier concentration across the metallurgical boundary.

NET CURRENT: 0

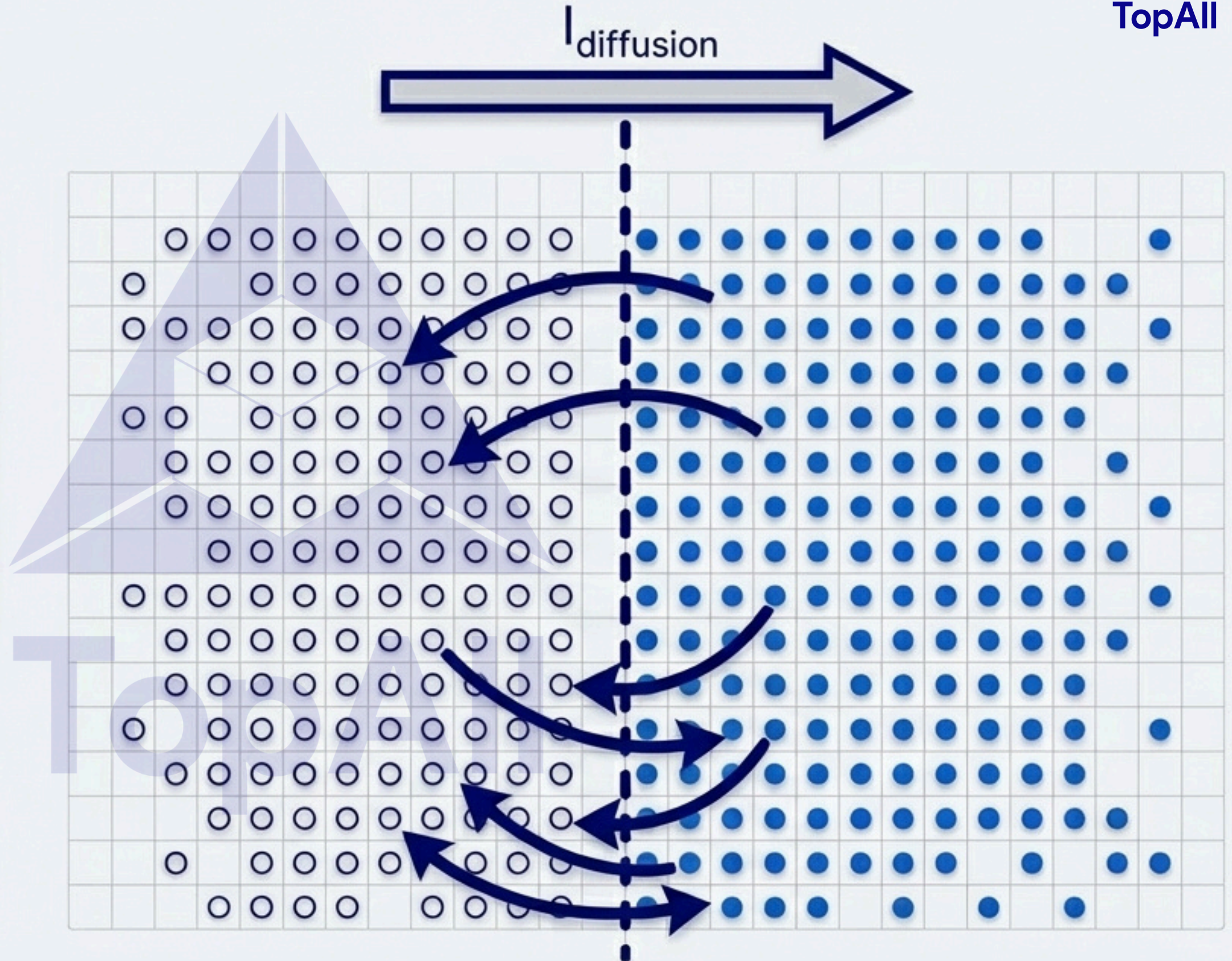


PHASE 2 OF 5 • CARRIER MOVEMENT

Diffusion Across the Junction

Driven by the steep concentration gradient, majority carriers naturally diffuse across the junction to the opposite side (electrons $n \rightarrow p$, holes $p \rightarrow n$).

**DIFFUSION CURRENT:
HIGH | DRIFT CURRENT: 0**





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$$E=mc^2$$



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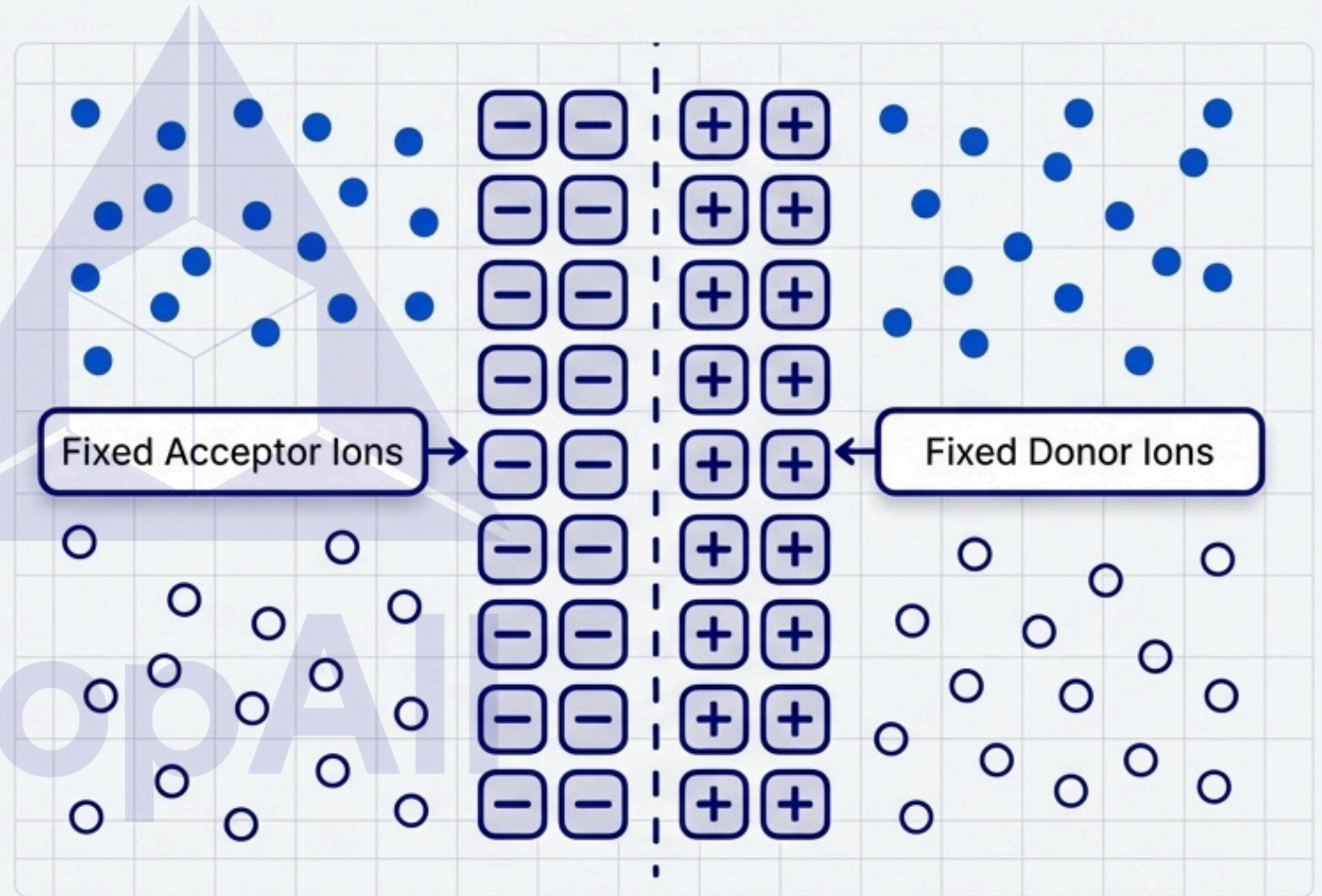


PHASE 3 OF 5 • UNCOVERING IONS

Exposing the Space-Charge Region

As electrons diffuse $n \rightarrow p$,
they leave behind fixed,
positively charged donor ions.
As holes diffuse $p \rightarrow n$, they
leave behind fixed, negatively
charged acceptor ions.

FORMATION OF FIXED CHARGES

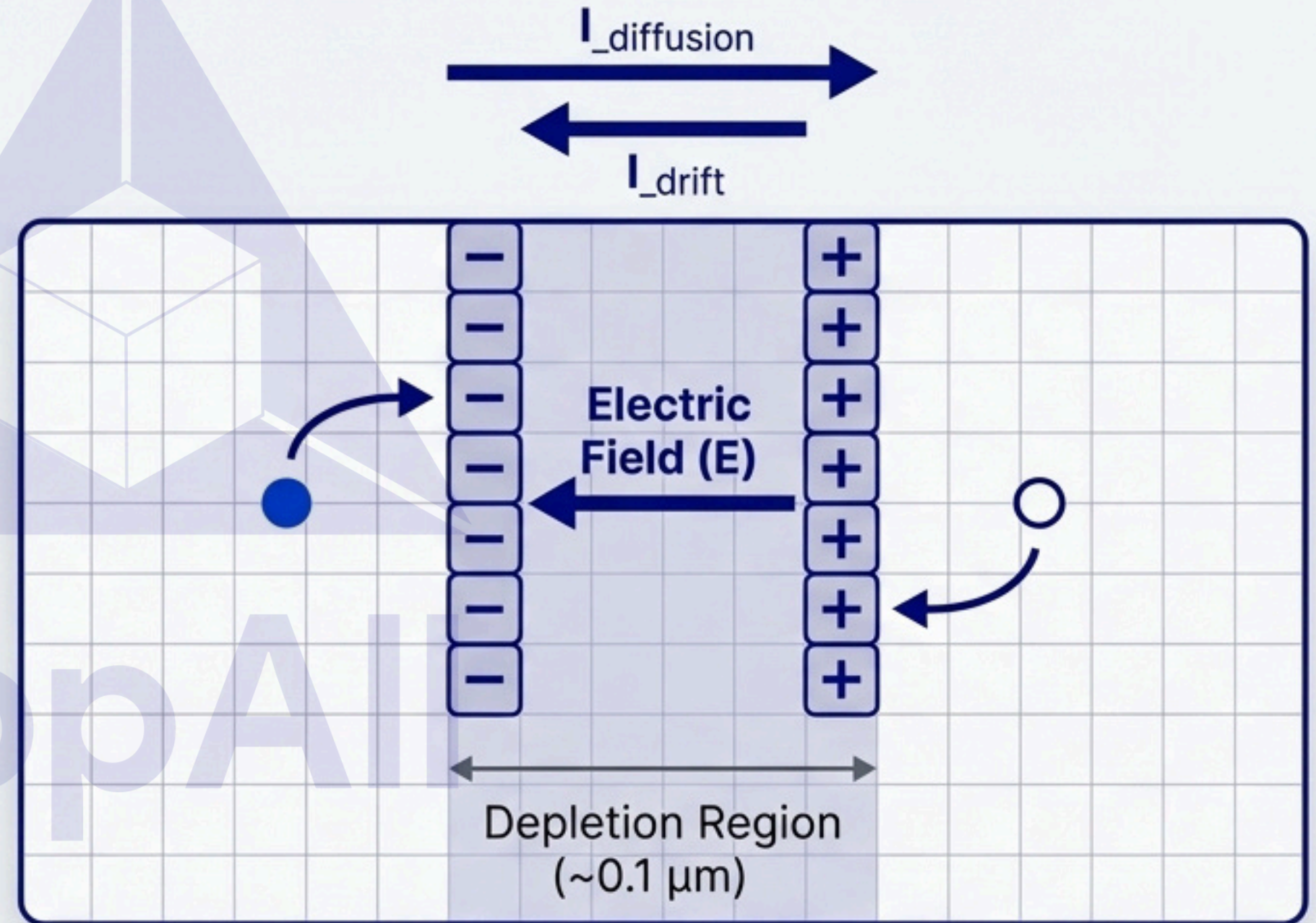


PHASE 4 OF 5 • OPPOSING FORCES

The Depletion Region & Electric Field

The central zone is **depleted of free charges**. The exposed ions create a strong internal Electric Field (**E**), which sweeps minority carriers across the junction (Drift).

● DRIFT CURRENT INCREASING



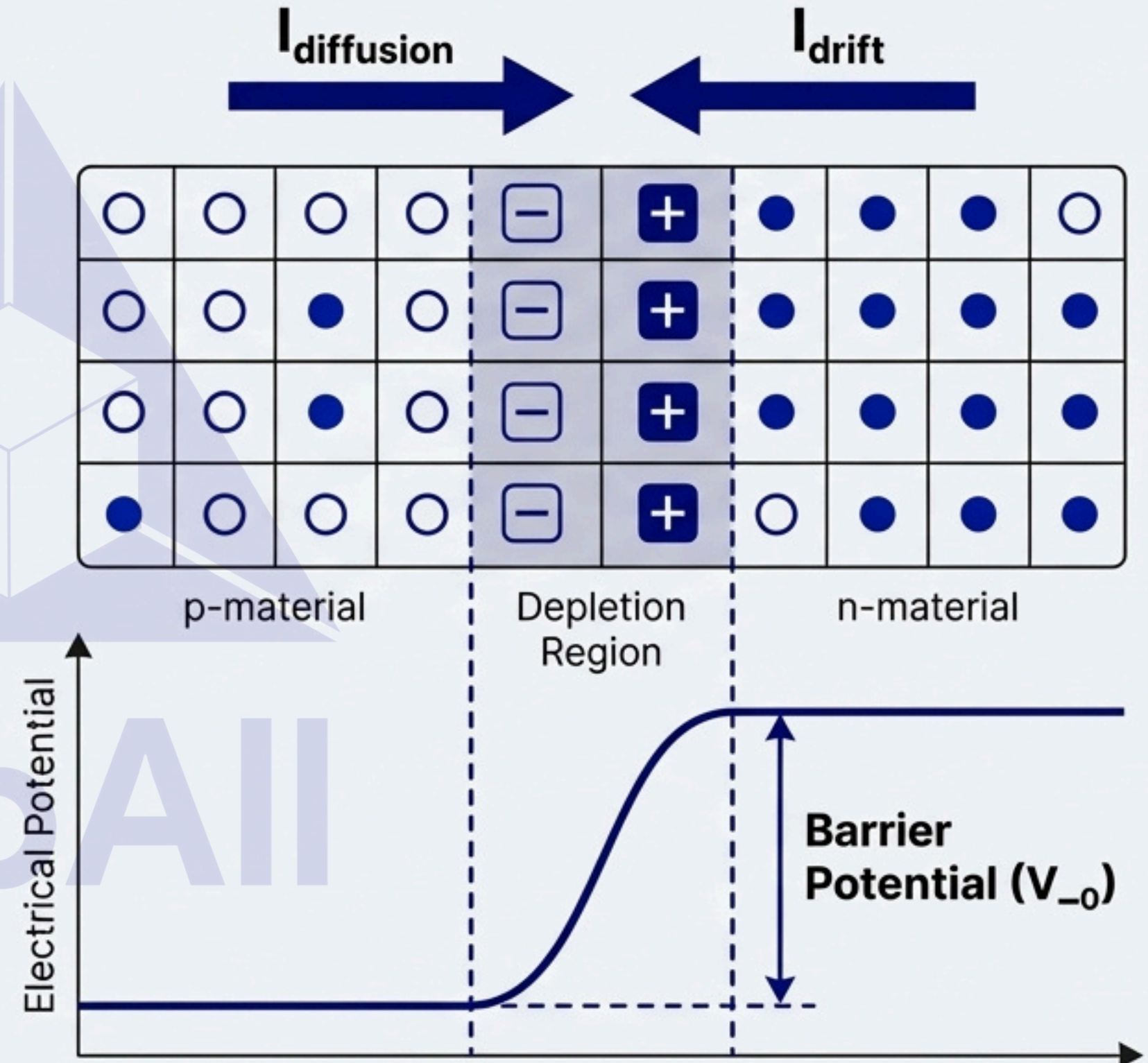
PHASE 5 OF 5 • STEADY STATE

Dynamic Equilibrium & Barrier Potential

The expanding Electric Field causes drift current to exactly equal diffusion current.

A Barrier Potential (V_0) is established, making the n-material positive relative to the p-material and preventing further net movement.

$$I_{\text{diffusion}} = I_{\text{drift}} \mid \text{NET CURRENT: 0}$$



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p-n Junction Formation: Key Takeaways

Diffusion vs. Drift

Diffusion is driven by concentration gradients (majority carriers moving). Drift is driven by the internal electric field (minority carriers being swept).

The Depletion Region

A space-charge region ($\sim 0.1 \mu\text{m}$ thick) at the junction completely devoid of mobile carriers, containing only fixed, immobile lattice ions.

Equilibrium State

Reached when Diffusion Current exactly equals Drift Current ($I_{\text{diffusion}} = I_{\text{drift}}$). The net current across the unbiased junction is zero.

Barrier Potential (V_0)

The built-in potential difference that opposes further carrier diffusion. At equilibrium, the n-region is at a positive potential relative to the p-region.



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