



CHAPTER 14 • SEMICONDUCTOR ELECTRONICS

n-Type Semiconductor

Understanding pentavalent doping, donor energy levels, and majority charge carriers.



EXAM FOCUS:

Pentavalent Impurities

Donor Levels

Carrier Concentration

1. THE DOPING PROCESS

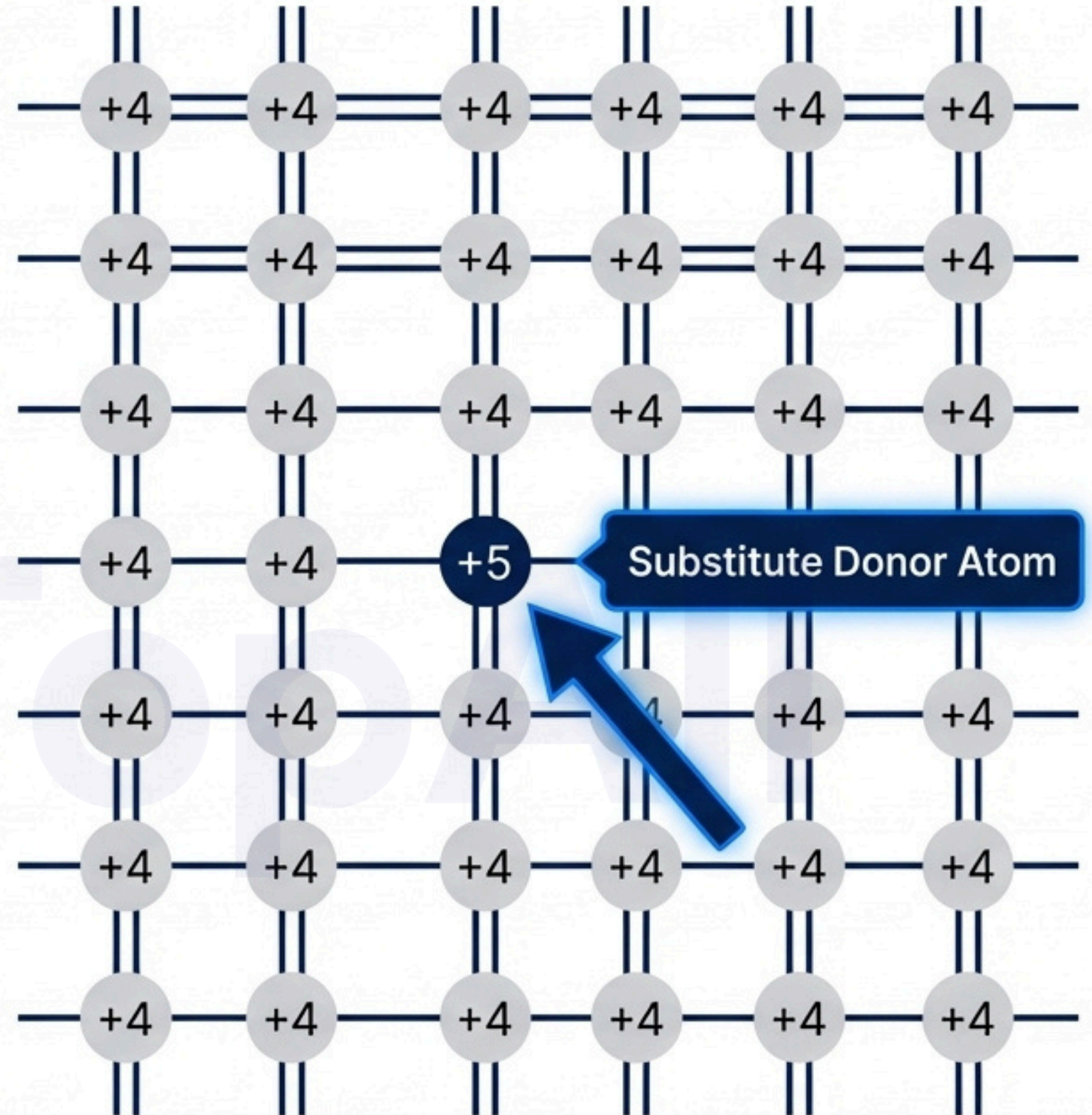
Introducing a Pentavalent Impurity

To increase the conductivity of intrinsic Si or Ge, we deliberately add a small amount (parts per million) of a pentavalent element.

The Dopant Rules

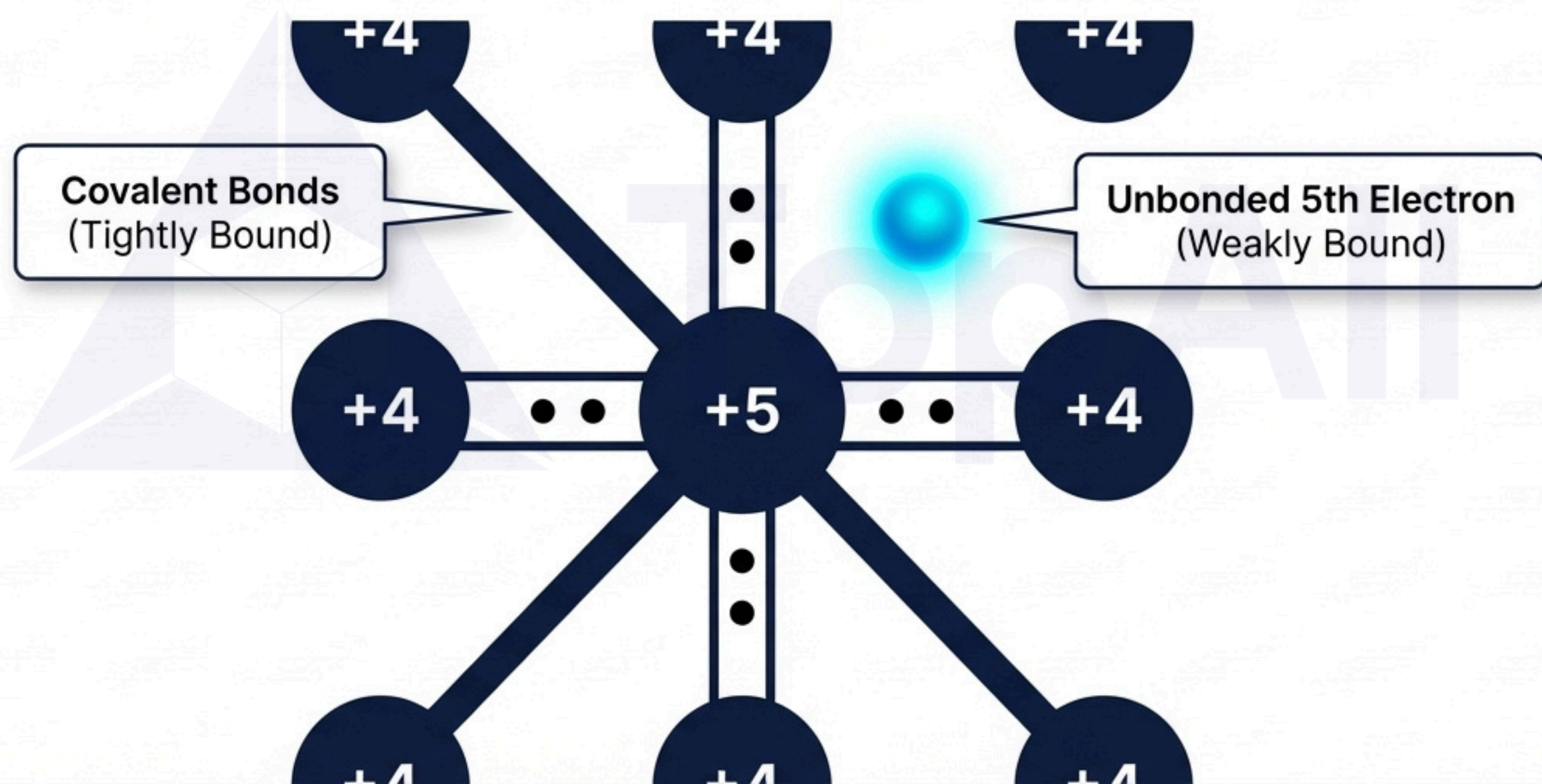
- **Valency:** Must have 5 valence electrons (e.g., Arsenic [As], Antimony [Sb], Phosphorous [P]).
- **Size:** Must be physically similar in size to host atoms to avoid distorting the pure crystal lattice.

14	15
Si	P
Ge	As
	Sb



Four Bonds and One Extra Electron

When the +5 valency atom occupies a lattice site, four of its valence electrons form strong covalent bonds with the four neighboring silicon atoms. The **fifth** valence electron is left out of the bonding process, remaining very weakly bound to its parent atom.





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$$E=mc^2$$



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3. ENERGY BAND MODEL

The Donor Level and Easy Release

Shielded by the other four electrons, the 5th electron requires extremely small ionization energy to be set free. It easily jumps into the conduction band at room temperature.

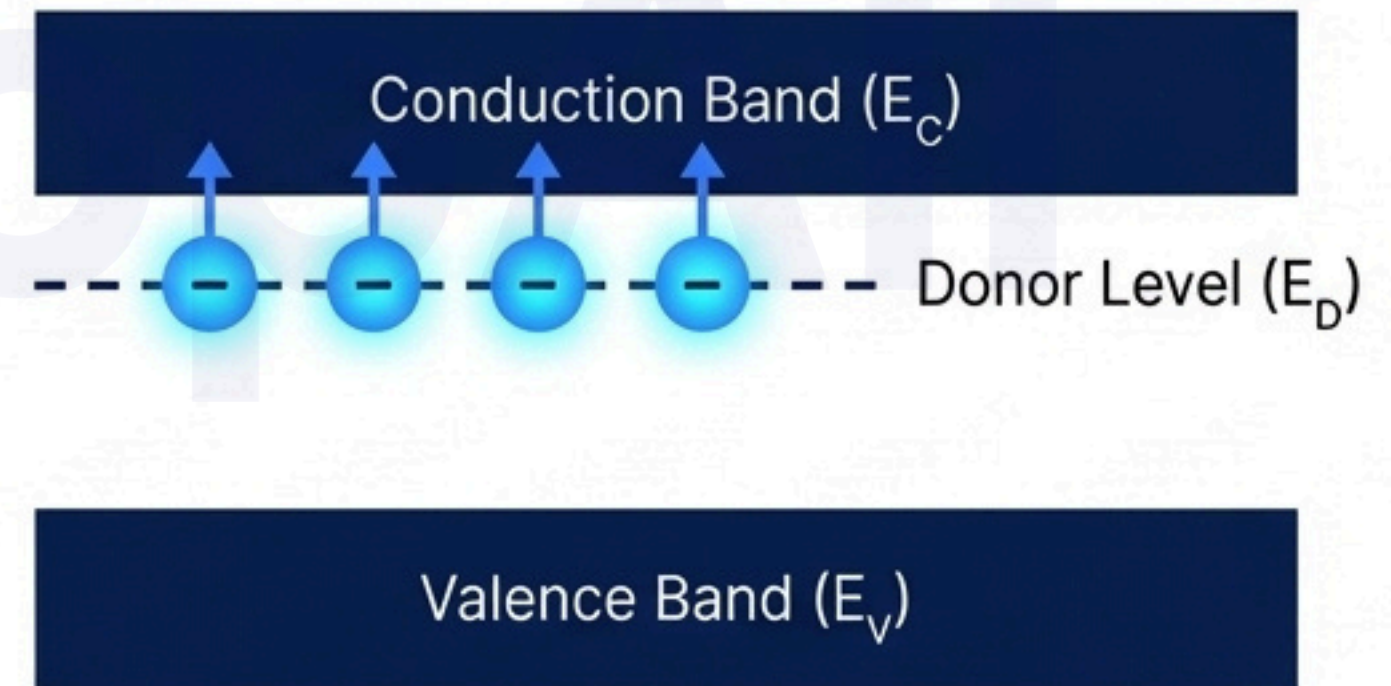
Germanium (Ge): ~ 0.01 eV

Silicon (Si): ~ 0.05 eV

Atomic View



Band Diagram View



4. CARRIER CONCENTRATION in 12px Inter



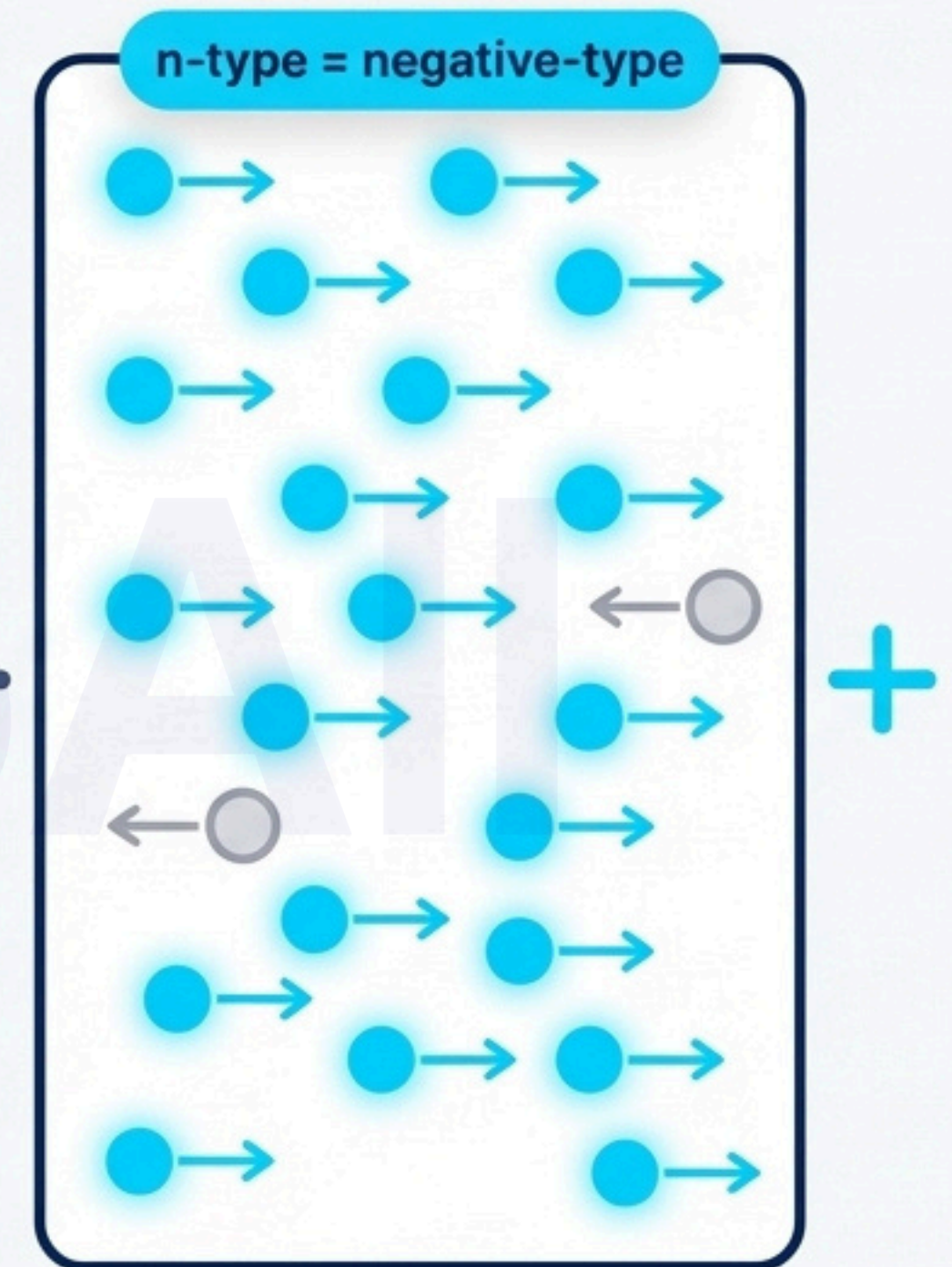
Electrons as Majority Carriers

The pentavalent dopant “donates” extra electrons independent of temperature. These abundant electrons increase the recombination rate with intrinsically generated holes, drastically reducing the hole count.

$$n_e \gg n_h$$

Number of electrons is much greater than number of holes.

Crucial Exam Fact: Overall Charge Neutrality: Despite excess free electrons, the n-type crystal remains electrically neutral. The negative charge of free electrons is perfectly balanced by the positive charge of fixed, ionized donor cores.



CHAPTER SUMMARY



Key Takeaways: n-Type Semiconductors



1. Dopant

Pentavalent elements (As, Sb, P) added to Si/Ge. Known as "Donor" impurities.



2. Mechanism

4 valence electrons bond; the 5th is weakly bound and easily freed for conduction.



3. Energy Band

A Donor Energy Level (E_D) is created slightly below the bottom of the conduction band (E_C).



4. Carriers

Electrons are majority carriers, holes are minority carriers ($n_e \gg n_h$). The crystal remains electrically neutral.





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