THE P-N JUNCTION DIODE

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p-n Junction Diode

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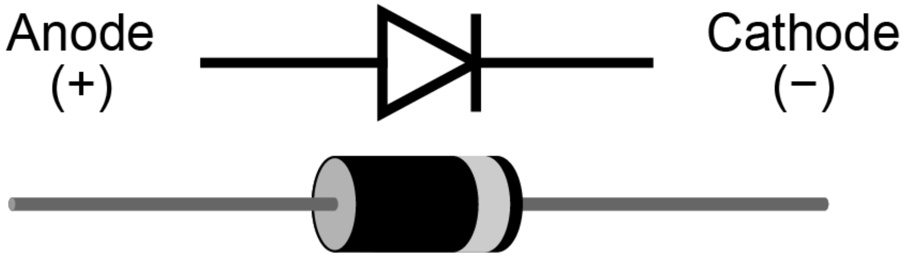
- ✓ Diodes are unidirectional devices that allow current to flow through them in only one direction.
- ✓ The p side of the diode is called the anode (A), whereas the n side of the diode is called the cathode (K).



p-n Junction Diode

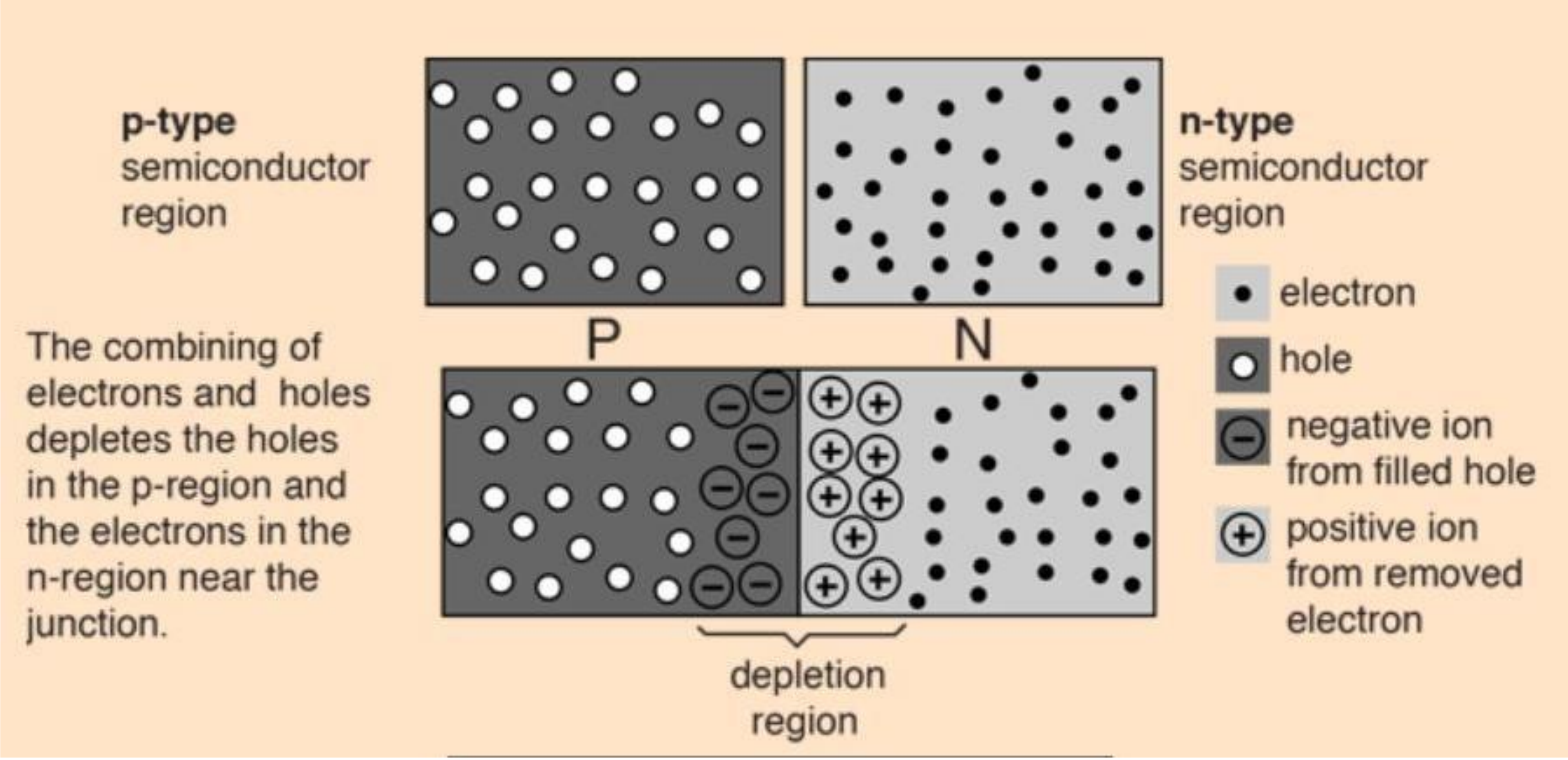
Used in numerous applications

- Switch,
- Rectifier,
- Regulator,
- Voltage multiplier,
- Clipping,
- Clamping, etc.

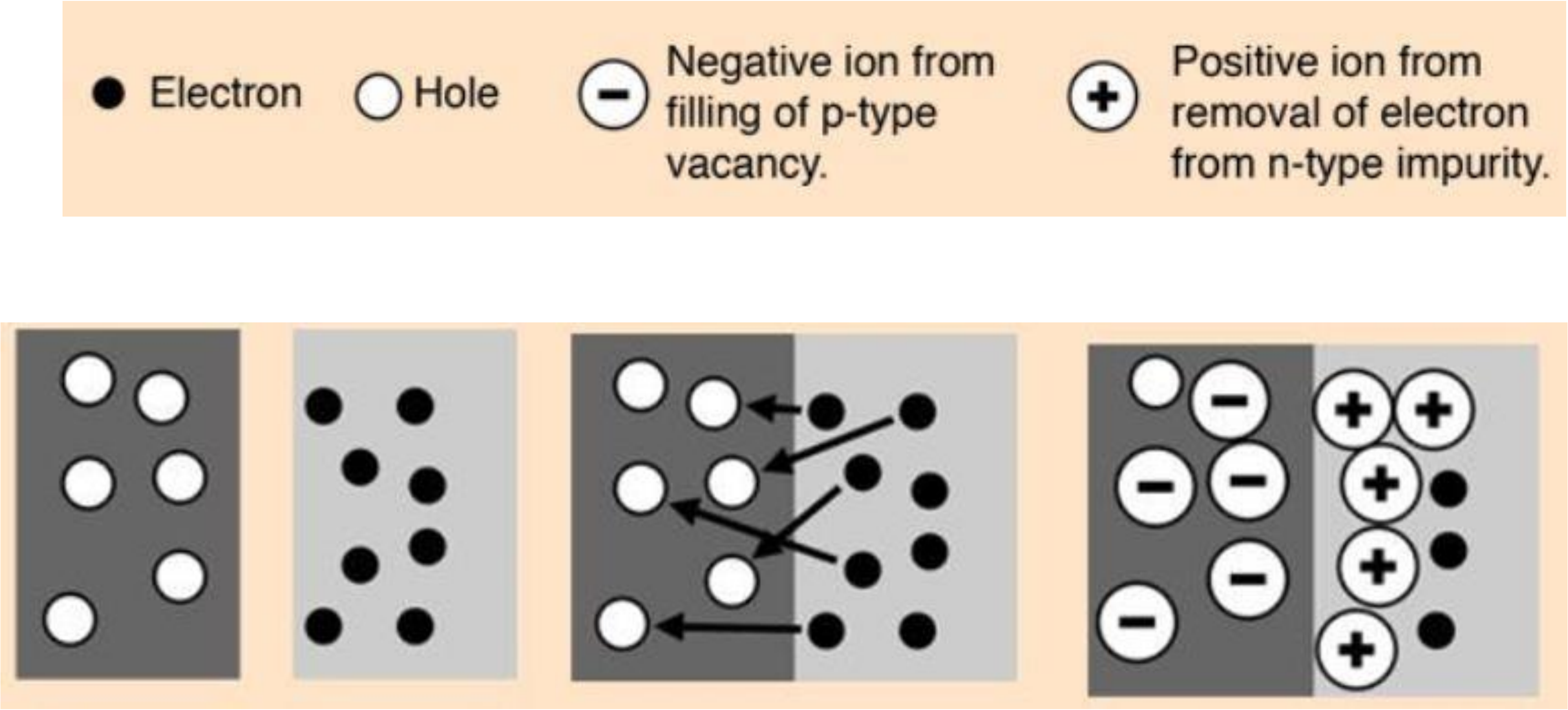
p-n Junction Diode: Depletion Zone

- ✓ When a p-n junction is formed, some of the free electrons in the n-region diffuse across the junction and combine with holes to form negative ions.
- ✓ In so doing they leave behind positive ions at the donor impurity sites.
- ✓ The area where the positive and negative ions are located is called the "depletion zone" (can also be called as depletion layer or depletion region).
- ✓ The word "depletion" is used because the area has been empty of all charge carriers.
- ✓ It inhibits any further electron transfer unless it is helped by putting a forward bias on the junction.

p-n Junction Diode: Depletion Zone

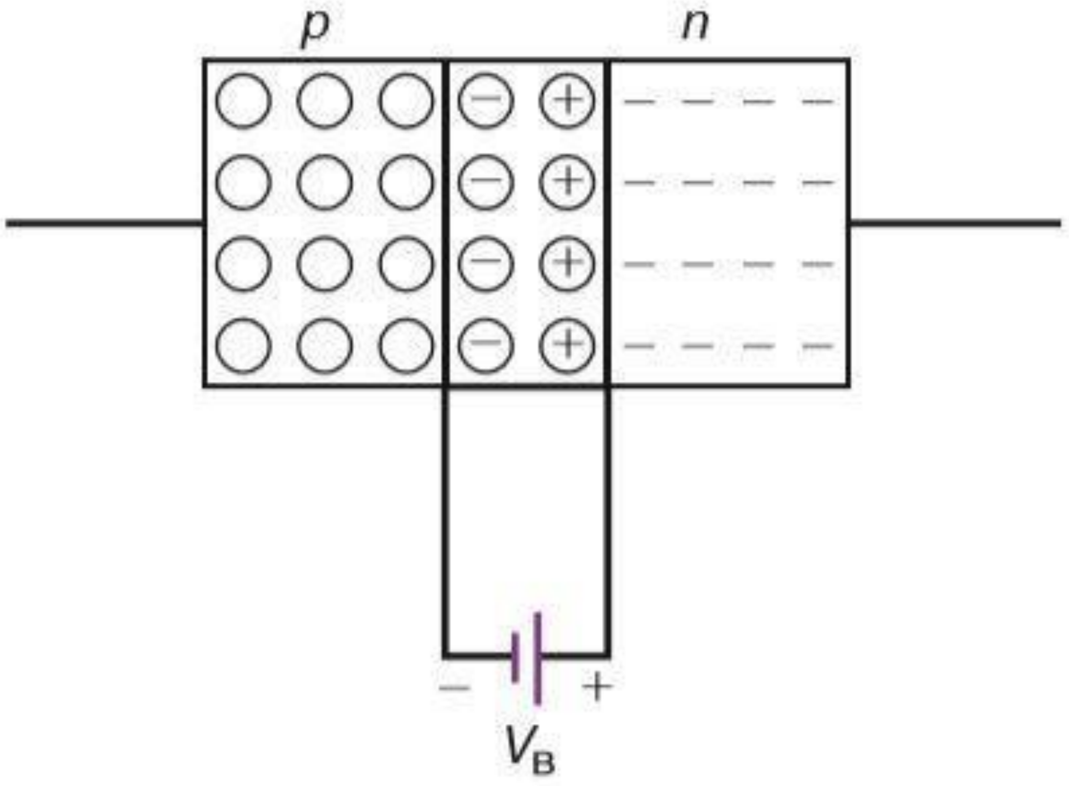


p-n Junction Diode: Depletion Zone



Barrier Potential, V_B

- ✓ Ions create a potential difference at the p-n junction.
- ✓ The barrier potential stops the diffusion of current carriers.
- ✓ Silicon = 0.7V
- ✓ Germanium = 0.3V



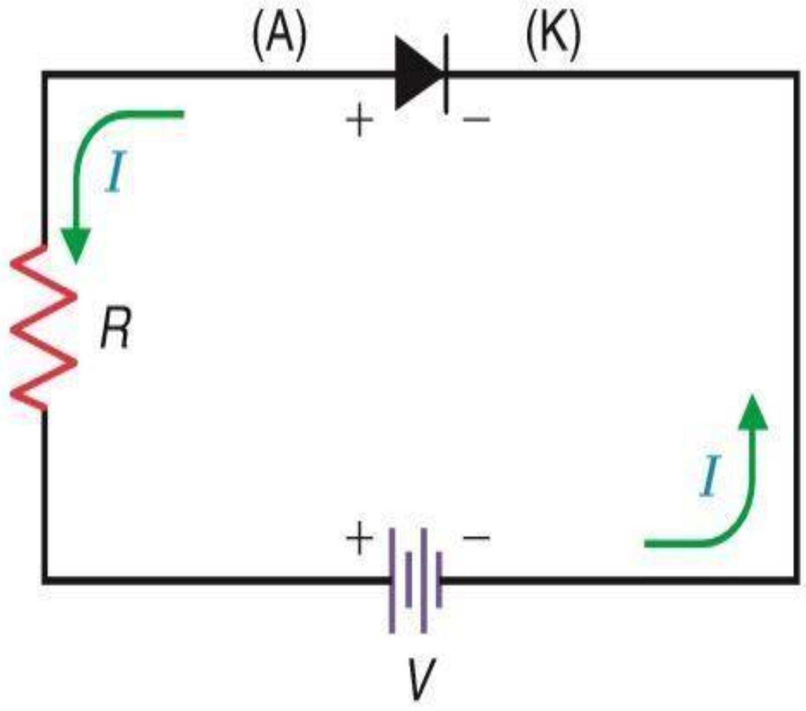
Conditions of P-N Junction Diode

- Zero bias: No external voltage is applied to the P-N junction diode.
- Forward bias: The positive terminal of the voltage potential is connected to the p-type while the negative terminal is connected to the n-type.
- Reverse bias: The negative terminal of the voltage potential is connected to the p-type and the positive is connected to the n-type.

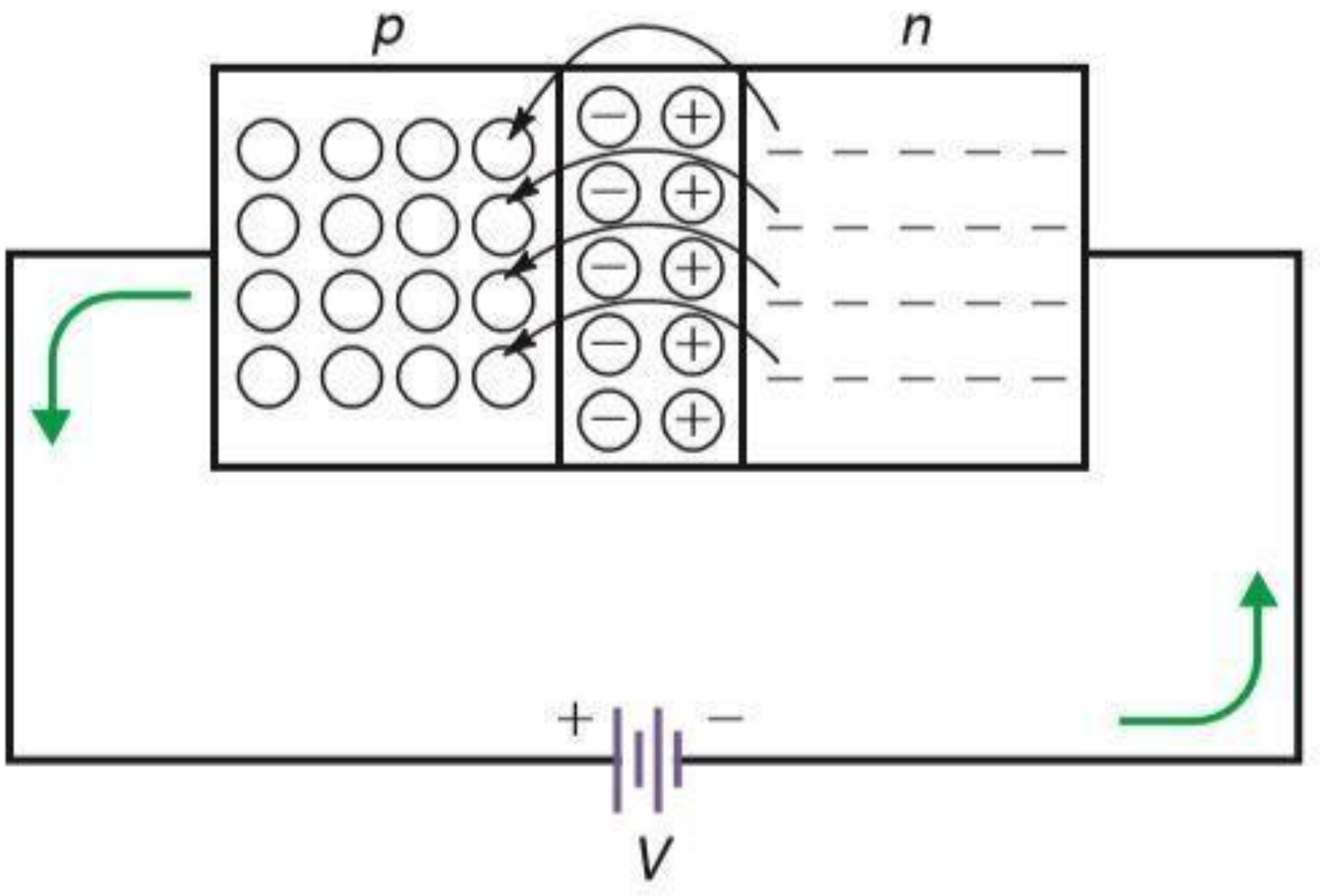
p-n Junction Diode: Forward-Biased

- ✓ Forward-biasing a diode allows current to flow easily through the diode.

- ✓ The voltage source (V) must be large enough to overcome the internal barrier potential (V_B)

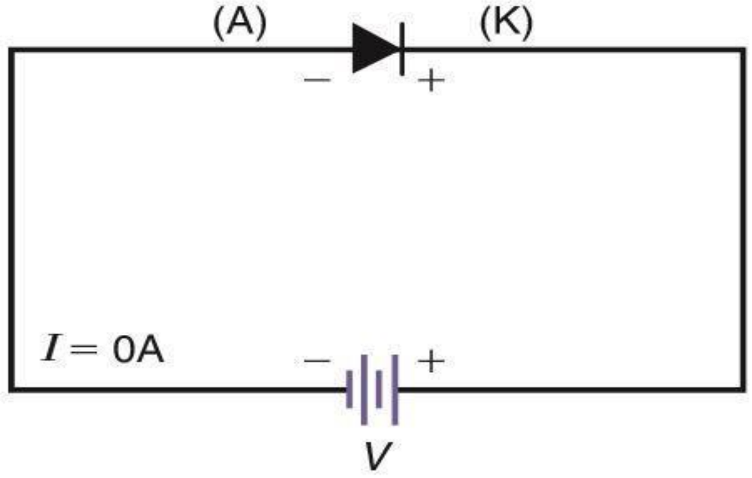


✓ For every free electron entering the n-side, one electron leaves the p-side.



p-n Junction Diode: Reverse-Biased

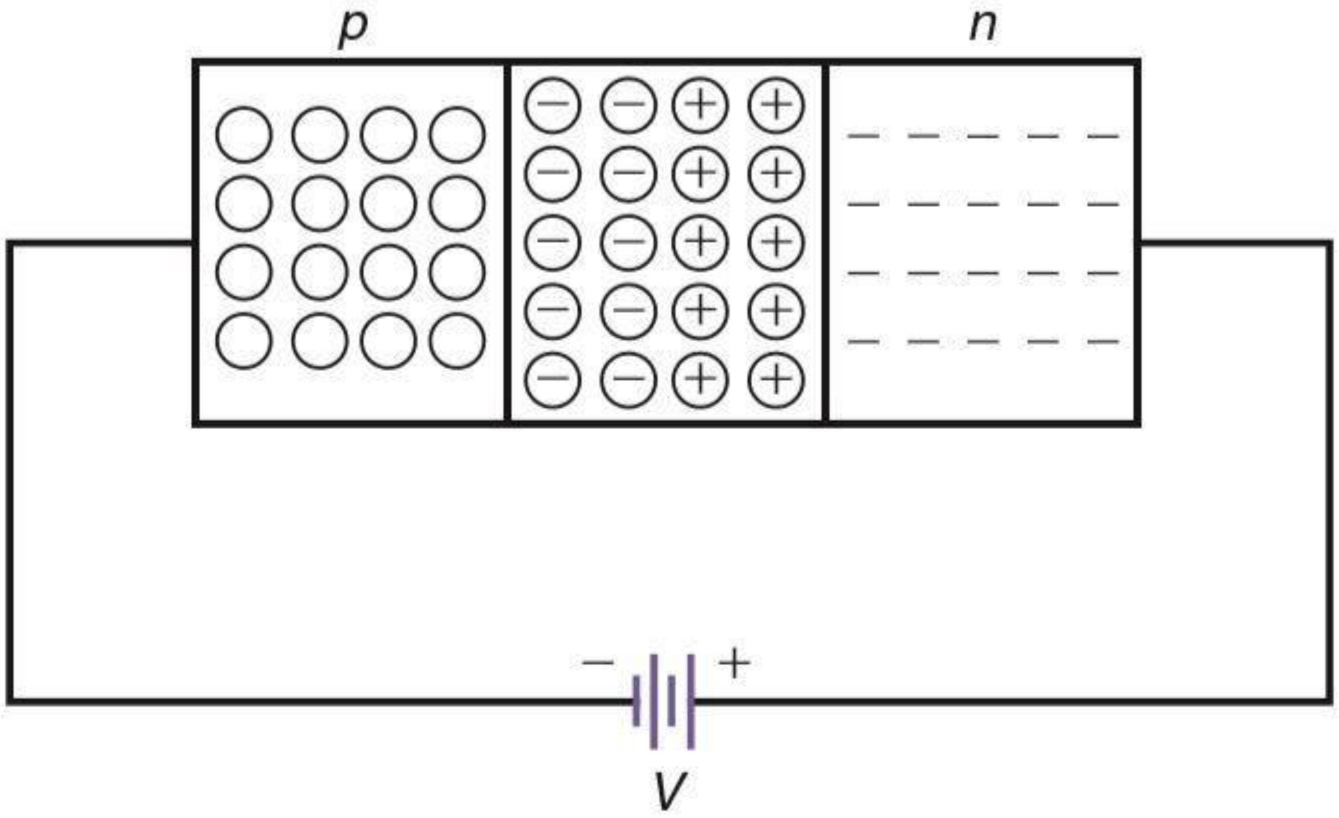
- ✓ Reverse-biasing a diode prevents current to flow easily through the diode.



- ✓ The effect is that charge carriers in both sections are pulled away from the junction.

- ✓ This increases the width of the depletion zone.

- ✓ Free electrons on the n-side are attracted away from the junction because of the attraction of the positive terminal of the voltage source (V). Likewise, holes in the p-side are attracted away from the junction because of the attraction by the negative terminal of the voltage source (V).



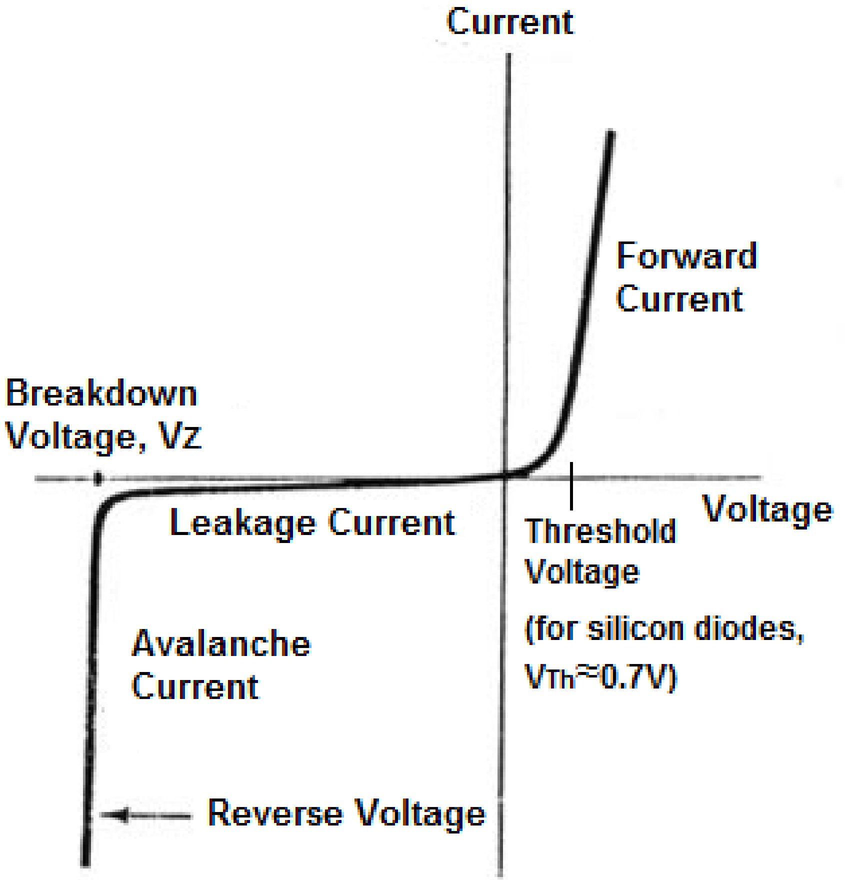
Current Flow in PN Junction

- The flow of electrons from the n-side towards the p-side of the junction takes place when there is an increase in the voltage.
- Similarly, the flow of holes from the p-side towards the n-side of the junction takes place along with the increase in the voltage. This results in the concentration gradient between both sides of the terminals.
- Due to the concentration gradient formation, charge carriers will flow from higher-concentration regions to lower-concentration regions.

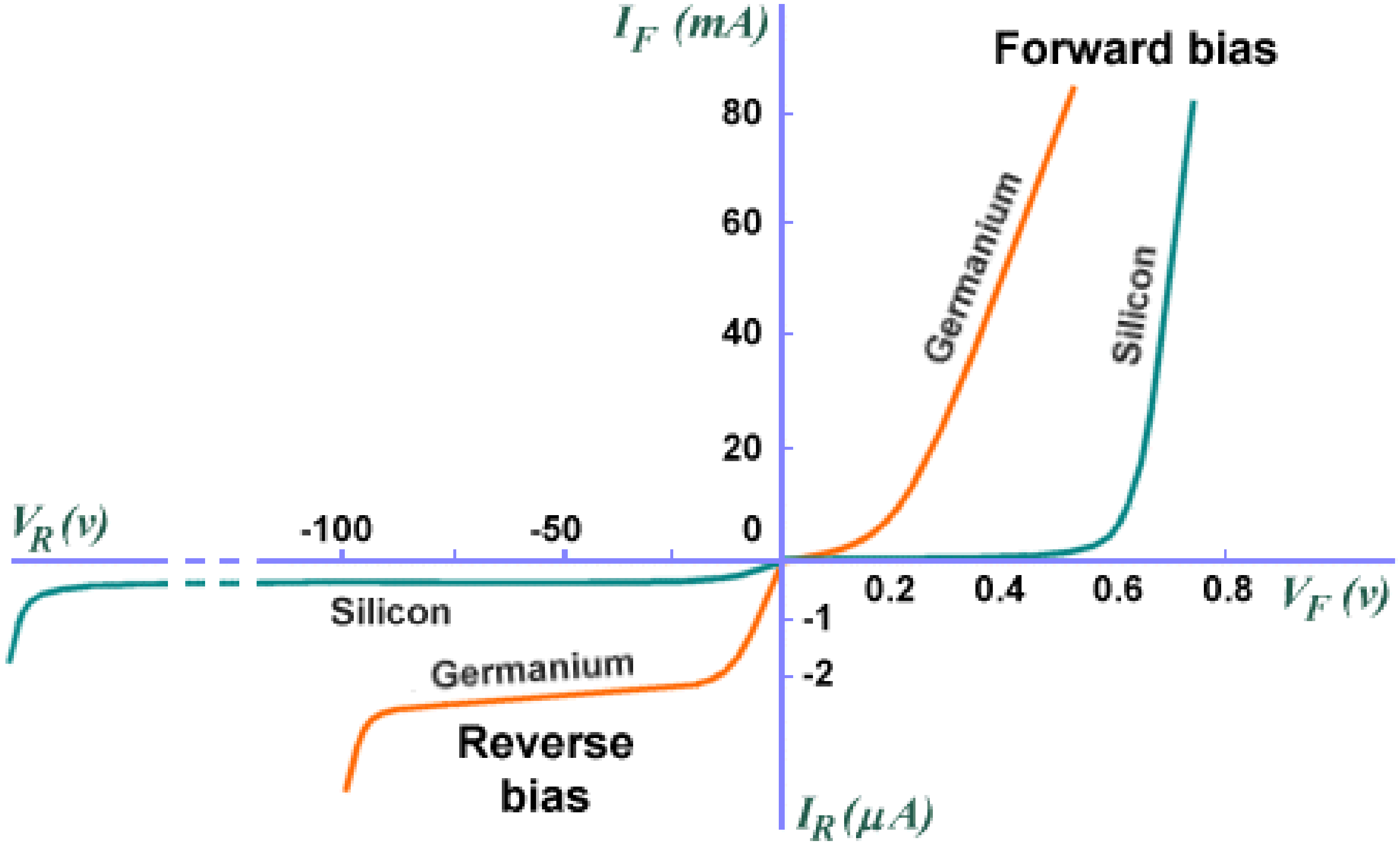
Applications of P-N Junction Diode

- P-N junction diode can be used as a photodiode as the diode is sensitive to the light when the configuration of the diode is reverse-biased.
- It can be used as a solar cell.
- When the diode is forward-biased, it can be used in LED lighting applications.
- It is used as rectifier in many electric circuits and as a voltage-controlled oscillator in varactors.
- The movement of charge carriers inside the P-N junction is the reason behind the current flow in the circuit.

I-V characteristic of practical diode



Silicon vs. Germanium



I-V characteristic of silicon and germanium practical diode

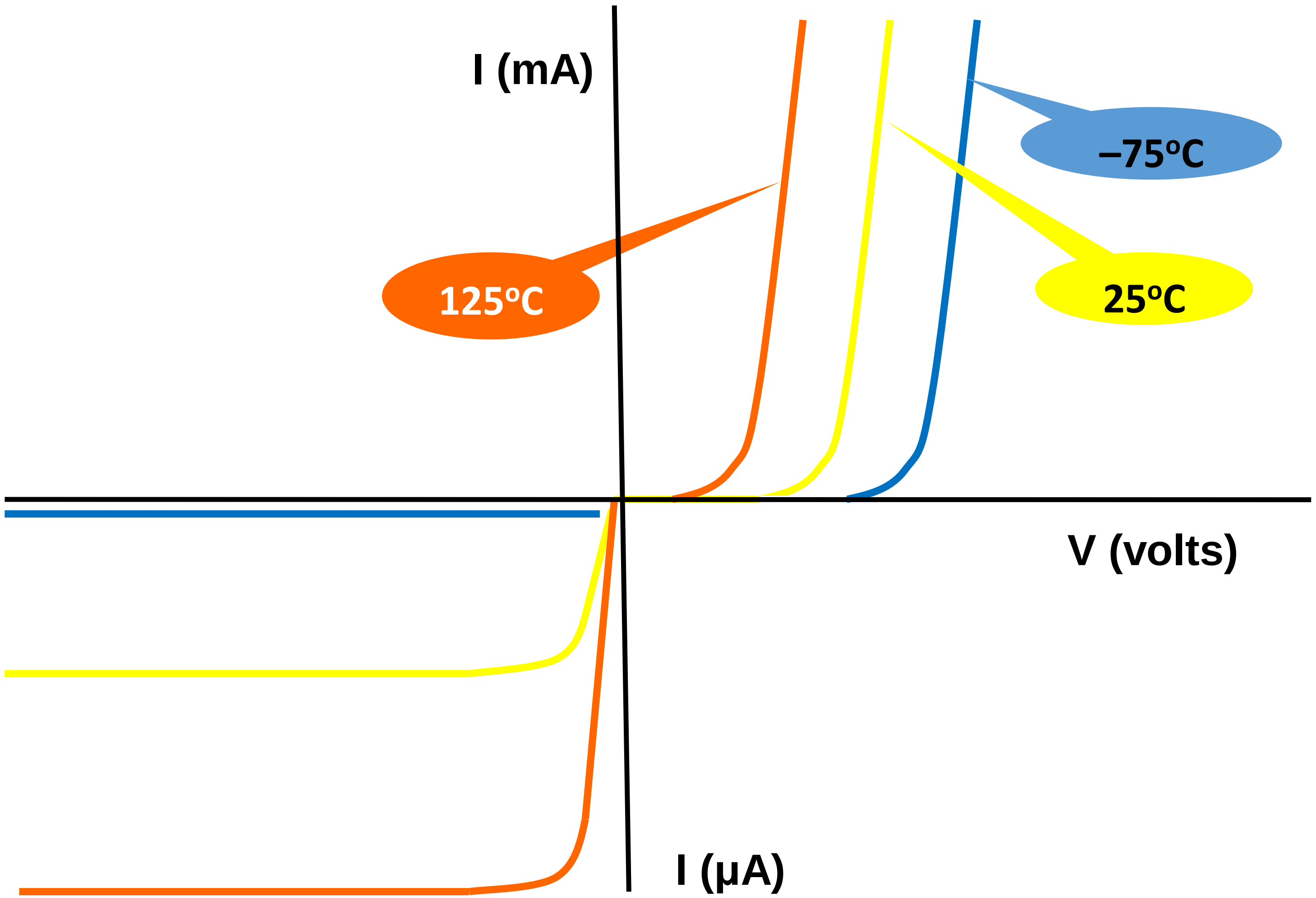
Breakdown phenomenon in diodes

Two breakdown mechanisms:

- **Avalanche breakdown**:
  - Occurs in Lightly doped diodes,
  - Occurs at high reverse Voltage.

- **Zener Breakdown**:
  - Occurs in heavily doped diodes.
  - at lower reverse bias voltages.

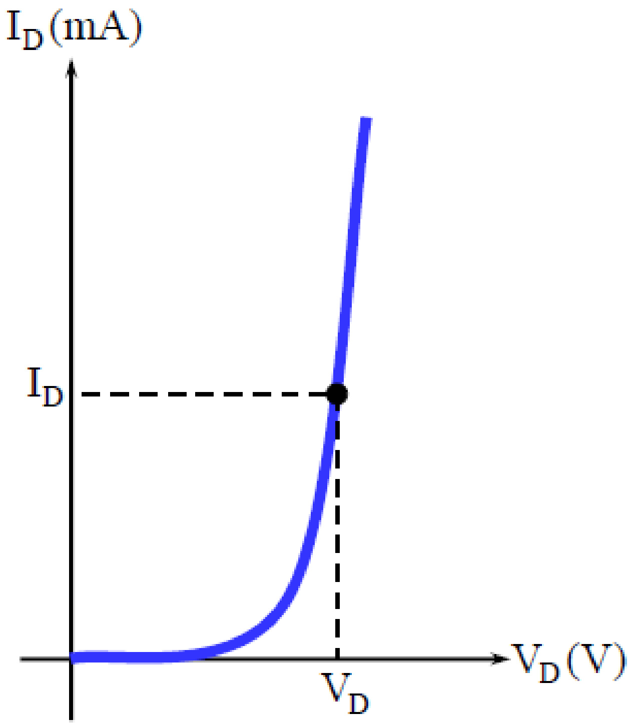
Effect of Temperature on the Reverse current



Diode resistances

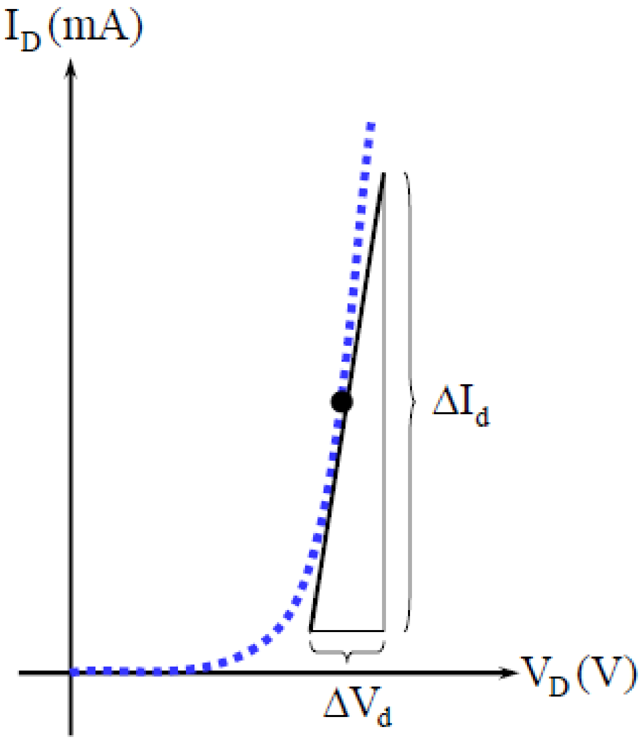
- **Static or DC resistance:**
  - ratio of diode voltage and diode current

$$R_D = \frac{V_D}{I_D}$$



AC resistance:

$$r_d = \frac{\Delta V_D}{\Delta I_D} \qquad r_d = \frac{\Delta V_D}{\Delta I_D} \approx \frac{\eta V_T}{I_D}$$



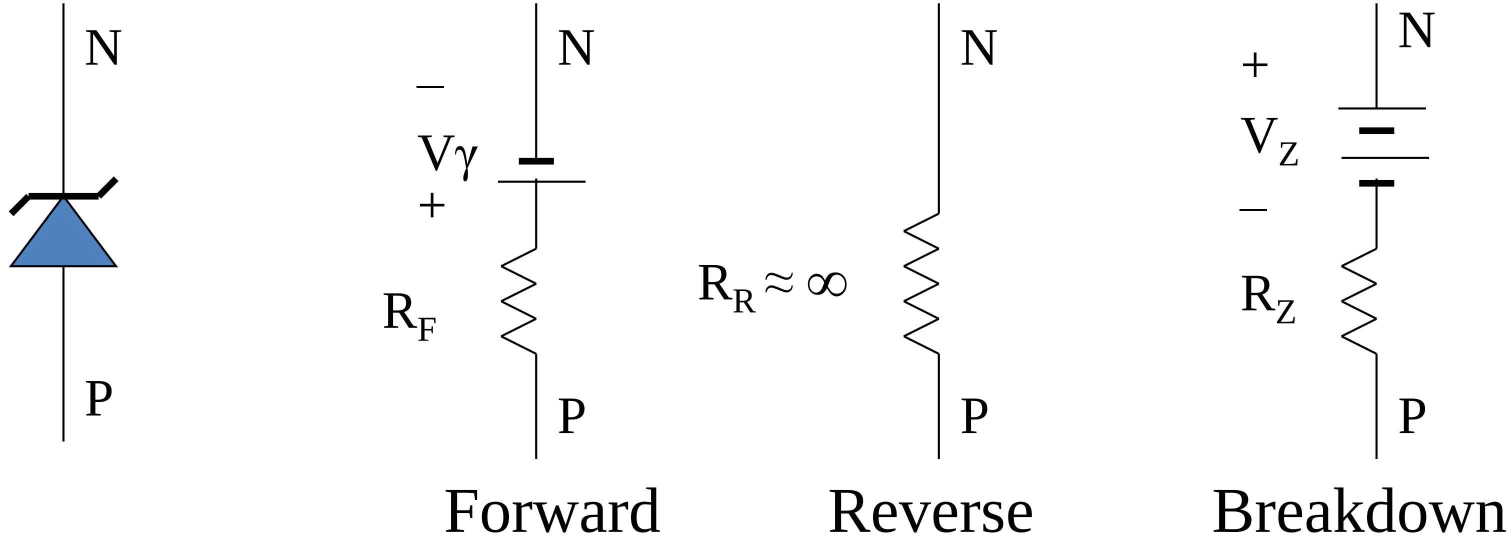
Ideal Diode

- Cut-in voltage is zero
- No barrier potential. Small forward bias voltage causes conduction through the device
- Forward resistance is zero
- Reverse resistance is infinity
- Conducts when forward biased and blocks conduction when reverse biased. Hence reverse saturation current is zero

Practical Diode

- For conduction, the barrier potential has to be overcome
- Forward resistance is in the range of tens of ohms
- Reverse resistance is in range of mega ohms
- Does not conduct when reverse biased. However there is reverse saturation current flowing through the device

Equivalent circuits of Zener diode



Note: R_Z is usually very small, can be neglected

Conclusion

A p–n junction diode allows electric charges to flow in one direction, but not in the opposite direction; negative charges (electrons) can easily flow through the junction from n to p but not from p to n, and the reverse is true for holes.