EN2042102 วงจรไฟฟ้าและอิเล็กทรอนิกส์

Circuits and Electronics

บทที่ 5 สารกึ่งตัวนำ

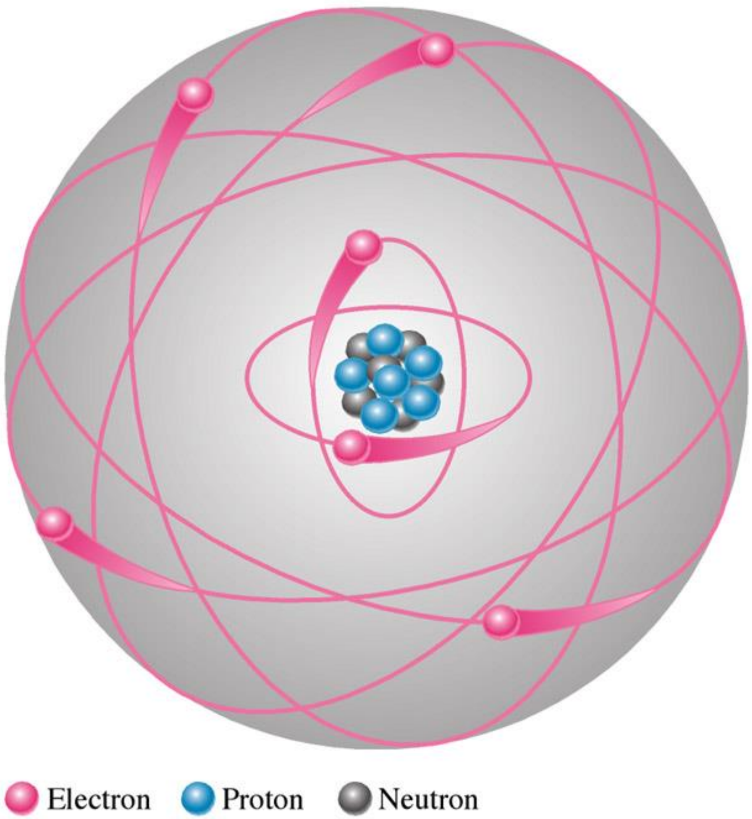
Semiconductor

สาขาวิชาวิศวกรรมคอมพิวเตอร์

คณะวิศวกรรมศาสตร์ มหาวิทยาลัยเทคโนโลยีราชมงคลพระนคร

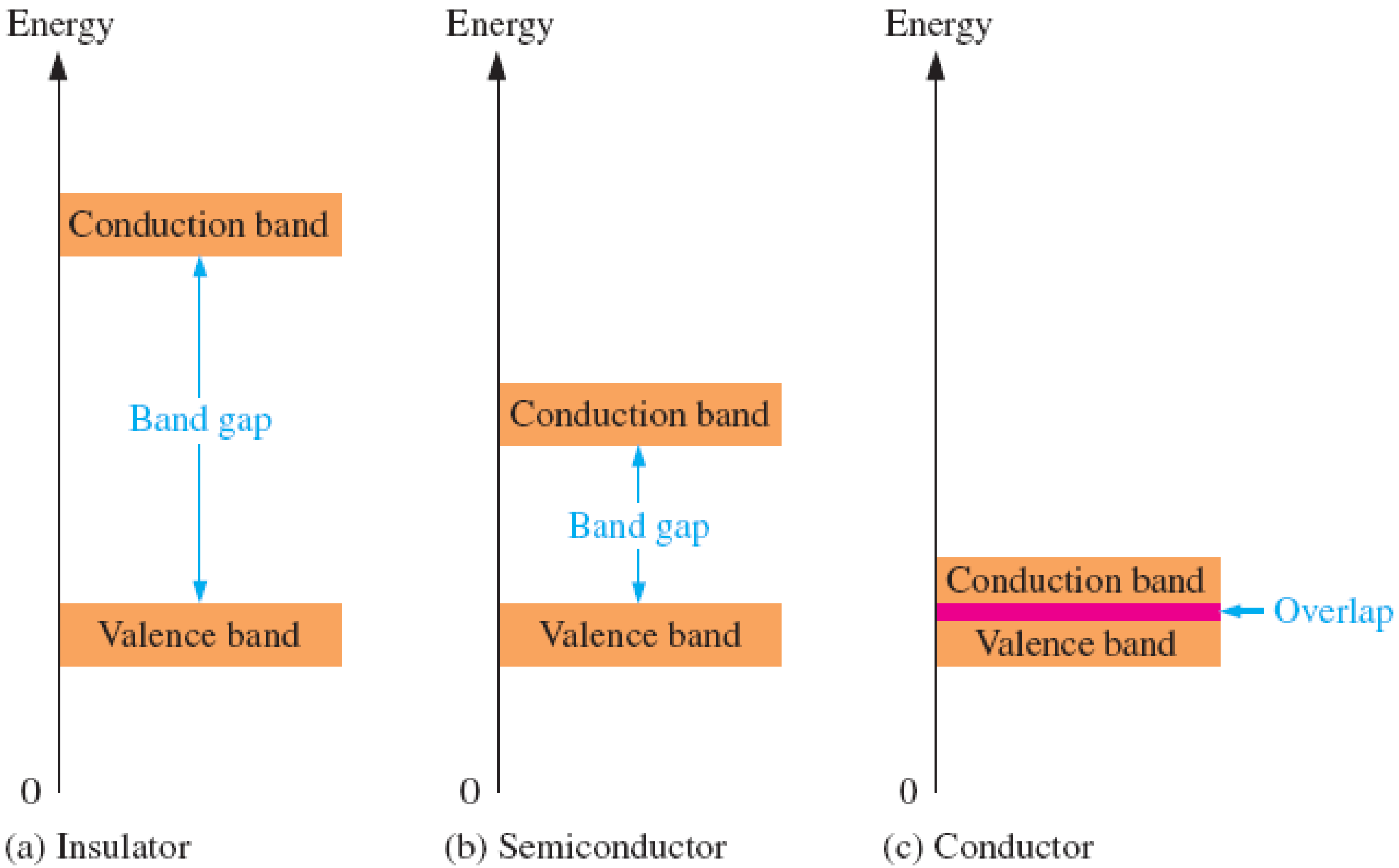
Bohr model of an atom

- As seen in this model, electrons circle the nucleus. Atomic structure of a material determines it's ability to conduct or insulate.



Conductors, Insulators, and Semiconductors

- The ability of a material to conduct current is based on its atomic structure.
- Each shell has a defined number of electrons it will hold. This is a fact of nature and can be determined by the formula, $2n^2$.
- The outer shell is called the valence shell.
- The less complete a shell is filled to capacity the more conductive the material is.


Energy
Conduction band
Band gap
Valence band
0
(a) Insulator
Energy
Conduction band
Band gap
Valence band
0
(b) Semiconductor
Energy
Conduction band
Overlap
Valence band
0
(c) Conductor

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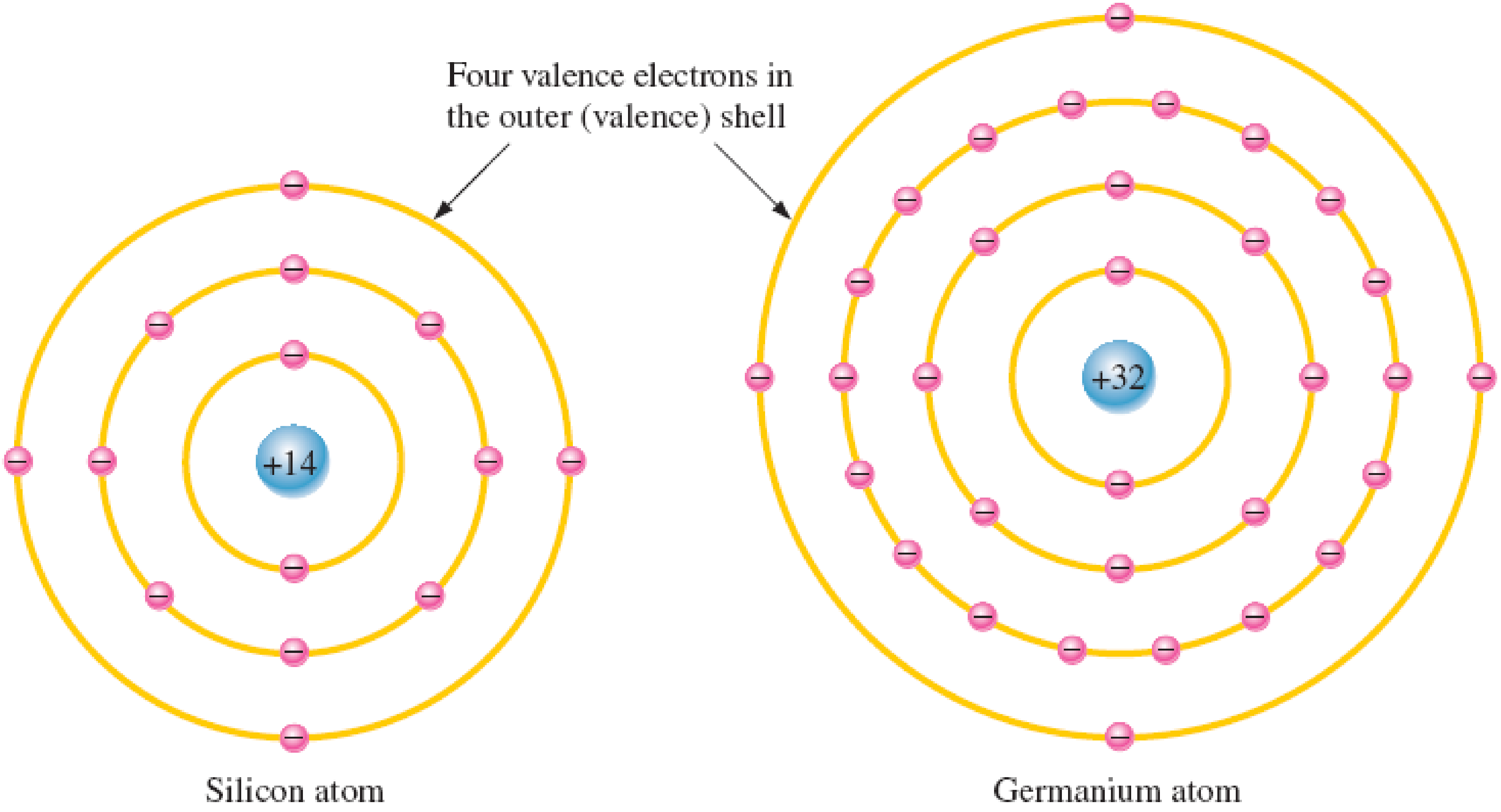
Comparison of Silicon & Germanium



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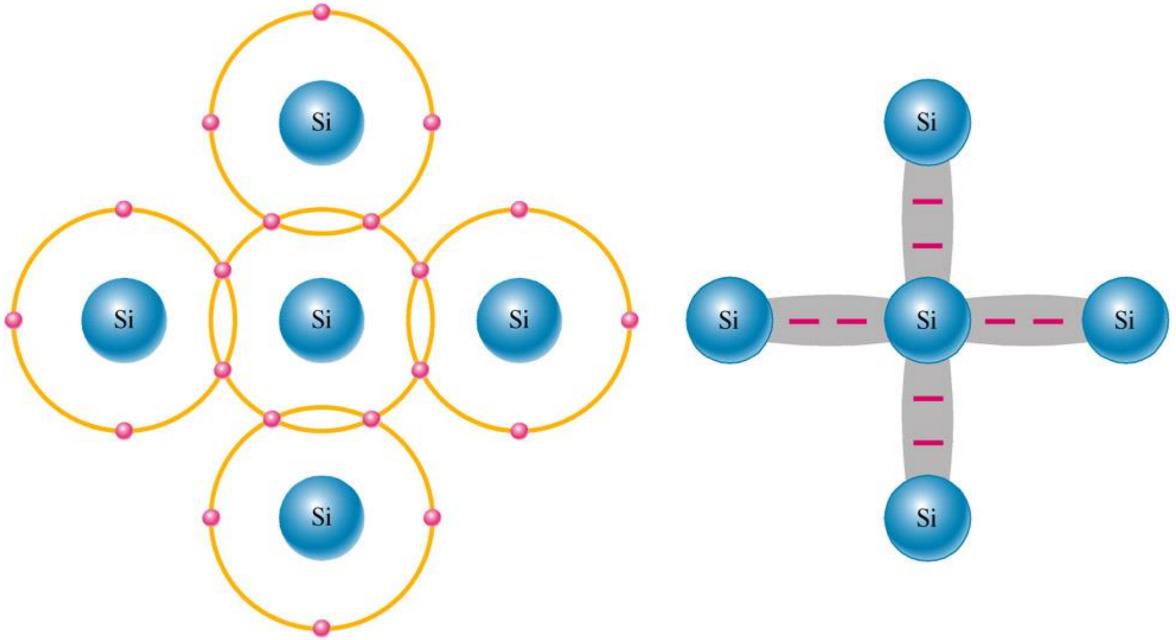
Covalent Bonding

- Covalent bonding is a bonding of two or more atoms by the interaction of their valence electrons.

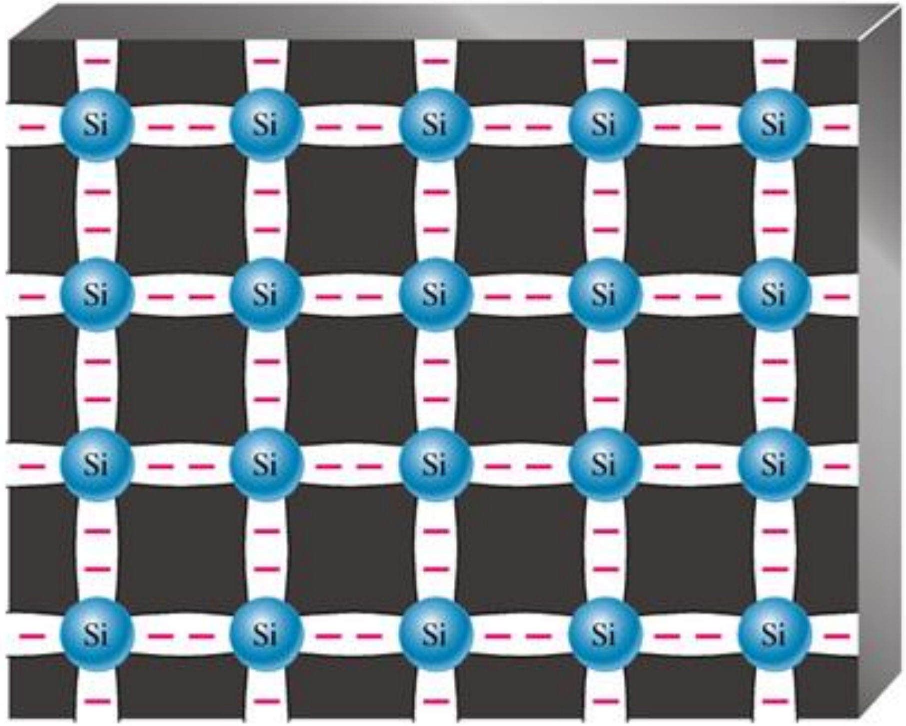


(a) The center atom shares an electron with each of the four surrounding atoms, creating a covalent bond with each. The surrounding atoms are in turn bonded to other atoms, and so on.

(b) Bonding diagram. The red negative signs represent the shared valence electrons.

Covalent Bonding

- Certain atoms will combine in this way to form a crystal structure. Silicon and Germanium atoms combine in this way in their intrinsic or pure state.



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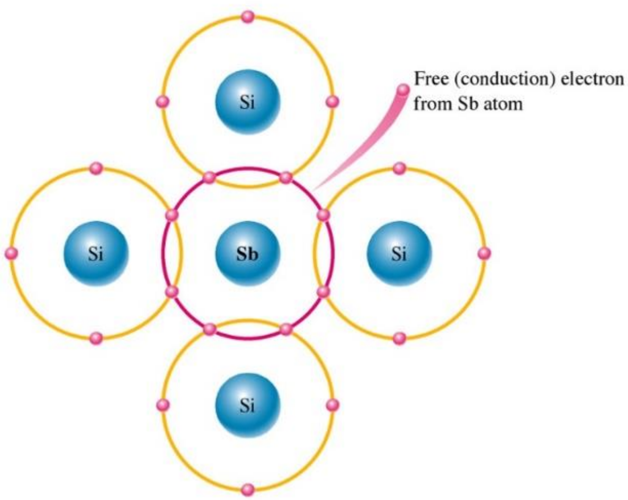
N-type and P-type Semiconductors

The process of creating N and P type materials is called doping.

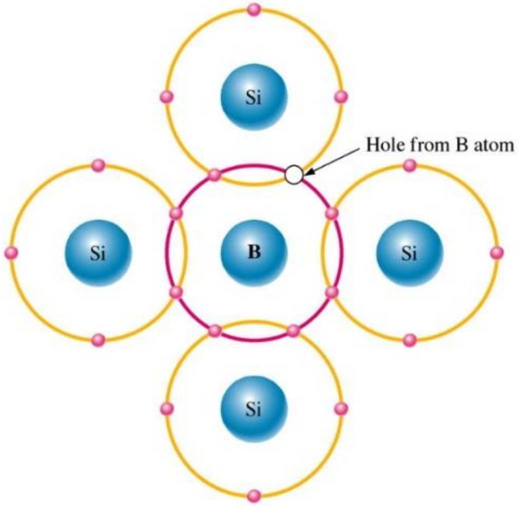
Other atoms with 5 electrons such as Antimony are added to Silicon to increase the free electrons.

Other atoms with 3 electrons such as Boron are added to Silicon to create a deficiency of electrons or hole charges.

N-type



P-type



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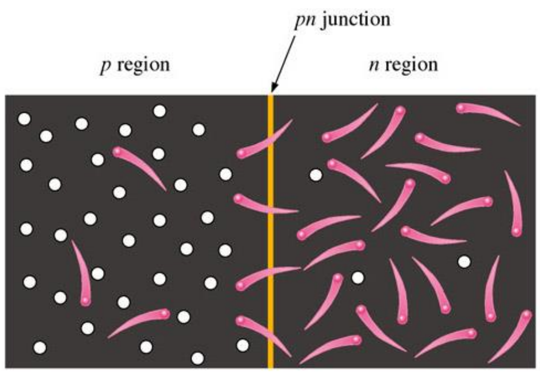
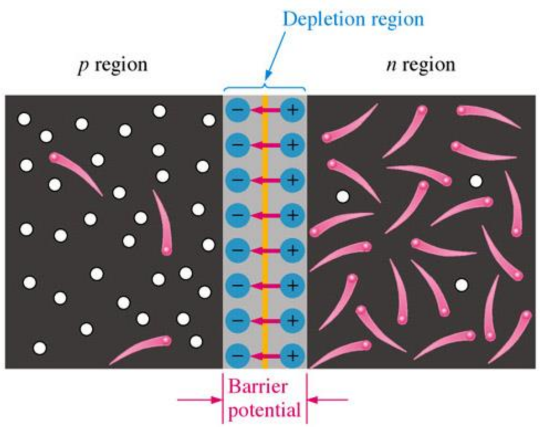
The Depletion Region

p region **n**



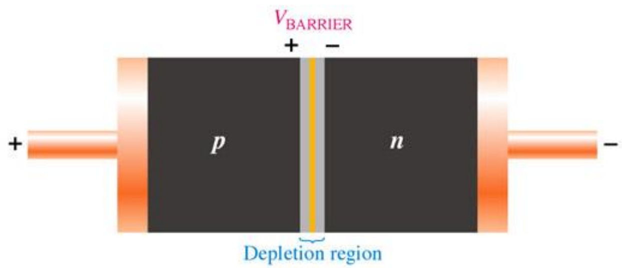
With the formation of the p and n materials combination of electrons and holes at the junction takes place.

p region **n region**

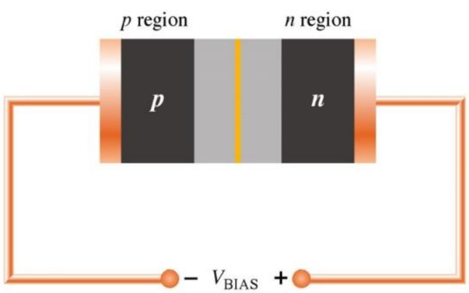


This creates the depletion region and has a barrier potential. This potential cannot be measured with a voltmeter but it will cause a small voltage drop.

Forward and Reverse Bias



(b) Forward bias narrows the depletion region and produces a voltage drop across the *pn* junction equal to the barrier potential.



Voltage source or bias connections are + to the p material and – to the n material

Bias must be greater than .3 V for Germanium or .7 V for Silicon diodes.

The depletion region narrows.

Voltage source or bias connections are – to the p material and + to the n material

Bias must be less than the break down voltage.

Current flow is negligible in most cases.

The depletion region widens.

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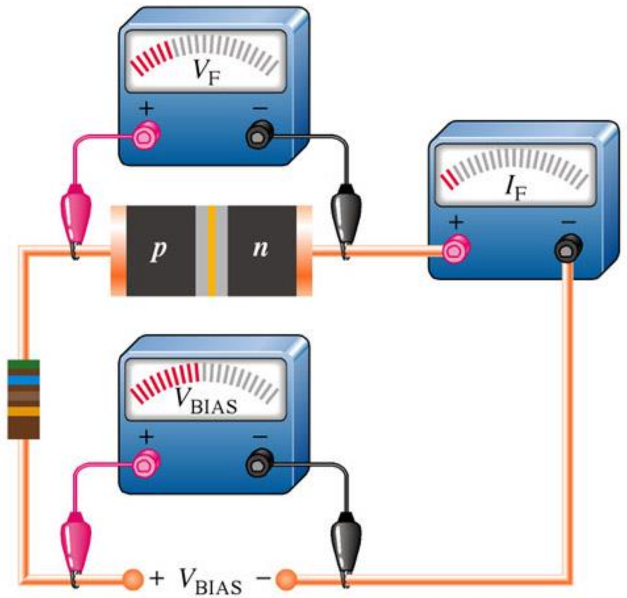
Forward Bias Measurements With Small Voltage Applied

In this case with the voltage applied is less than the barrier potential so the diode for all practical purposes is still in a non-conducting state. Current is very small.



(a) Small forward-bias voltage ($V_F < 0.7$ V), very small forward current.

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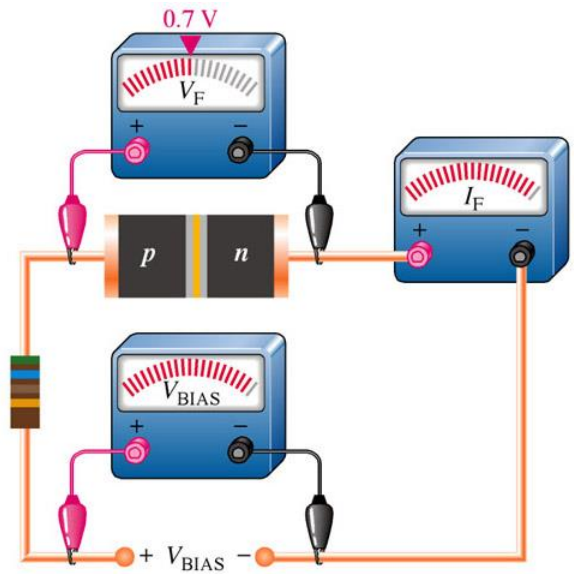
Forward Bias Measurements With Applied Voltage Greater Than the Barrier Voltage.

With the applied voltage exceeding the barrier potential the now fully forward biased diode conducts. Note that the only practical loss is the .7 Volts dropped across the diode.



(b) Forward voltage reaches and remains at approximately 0.7 V. Forward current continues to increase as the bias voltage is increased.

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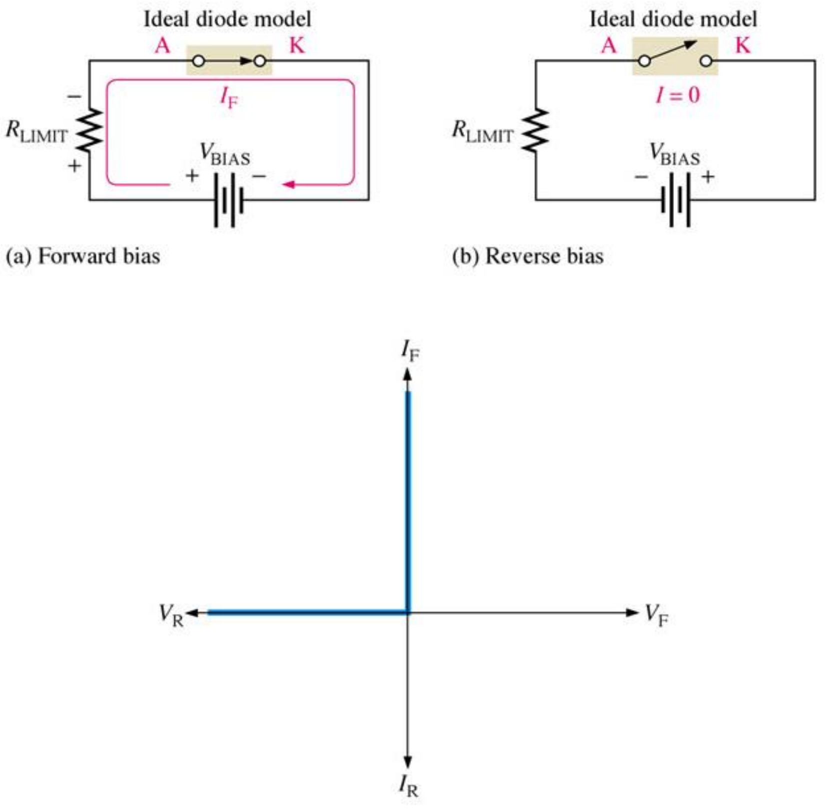
Ideal Diode Characteristic Curve

In this characteristic curve we do not consider the voltage drop or the resistive properties. Current flow proportionally increases with voltage.



(c) Ideal characteristic curve (blue)

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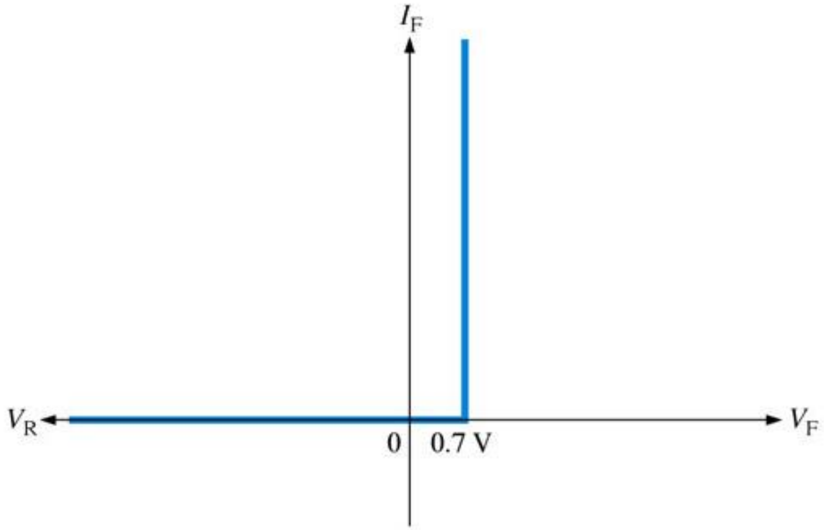
Practical Diode Characteristic Curve

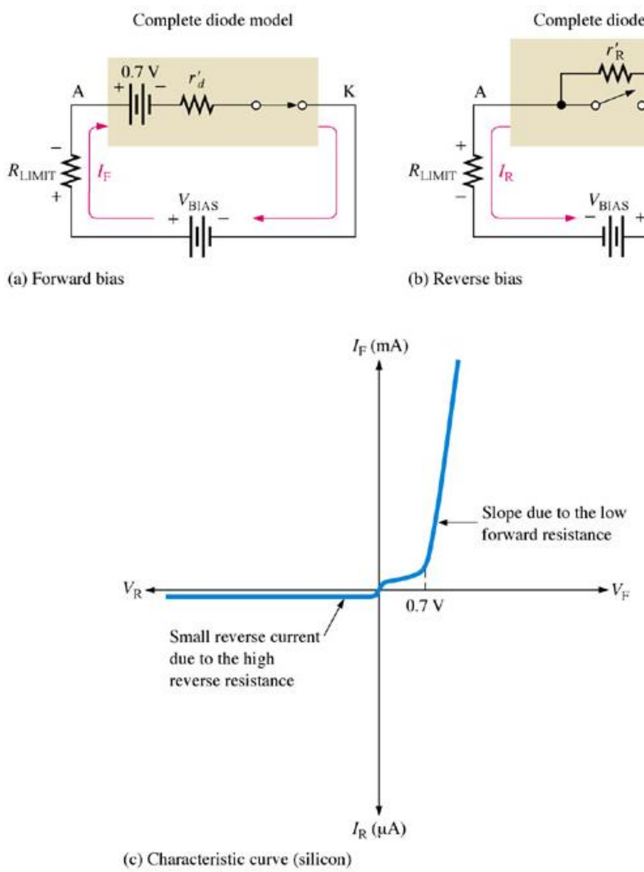
- In most cases we consider only the forward bias voltage drop of a diode. Once this voltage is overcome the current increases proportionally with voltage.This drop is particularly important to consider in low voltage applications.



(c) Characteristic curve (silicon)

Complex Characteristic Curve of a Diode

The voltage drop is not the only loss of a diode. In some cases we must take into account other factors such as the resistive effects as well as reverse breakdown.



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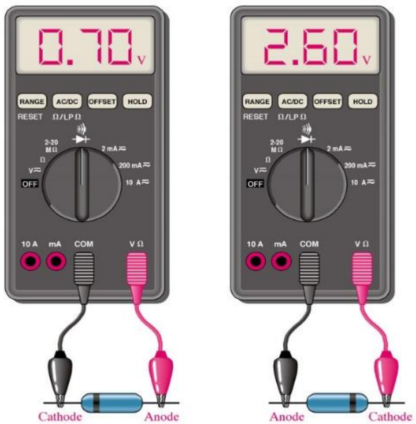
Troubleshooting Diodes

Testing a diode is quite simple, particularly if the multimeter used has a diode check function. With the diode check function a specific known voltage is applied from the meter across the diode.

With the diode check function a good diode will show approximately .7 V or .3 V when forward biased.

When checking in reverse bias the full applied testing voltage will be seen on the display.



(a) Forward-bias test (b) Reverse-bias test

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Troubleshooting Diodes

- An ohmmeter can be used to check the forward and reverse resistance of a diode if the ohmmeter has enough voltage to force the diode into conduction. Of course, in forward biased connection low resistance will be seen and in reverse biased connection high resistance will be seen.

Troubleshooting Diodes

❖ Open Diode

❖ In the case of an *open diode* no current flows in either direction which is indicated by the full checking voltage with the diode check function or high resistance using an ohmmeter in both forward and reverse connections.

❖ Shorted Diode

❖ In the case of a *shorted diode* maximum current flows indicated by a 0 V with the diode check function or low resistance with an ohmmeter in both forward and reverse connections.

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Diode Packages

- Diodes come in a variety of sizes and shapes. The design and structure is determined by what type of circuit they will be used in.

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Summary

- Diodes, transistors, and integrated circuits are all made of semiconductor material.
- P-materials are doped with trivalent impurities
- N-materials are doped with pentavalent impurities
- P and N type materials are joined together to form a PN junction.
- A diode is nothing more than a PN junction.
- At the junction a depletion region is formed. This creates barrier which requires approximately .3 V for a Germanium and .7 V for Silicon for conduction to take place.

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Summary

- A diode conducts when forward biased and does not conduct when reverse biased
- When reversed biased a diode can only withstand so much applied voltage. The voltage at which avalanche current occurs is called reverse breakdown voltage.
- There are three ways of analyzing a diode. These are ideal, practical, and complex. Typically we use a practical diode model.

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Thank You !