CS253 Architectures II

Lecture 7

Semiconductors

PN Junction diode

Charles Markham

How do FETs work? Some basic electronics so that we can understand static and dynamic ram better.

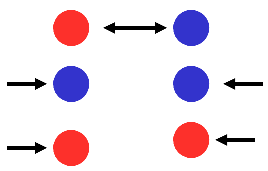
Charge

There are two types of charge, called positive and negative

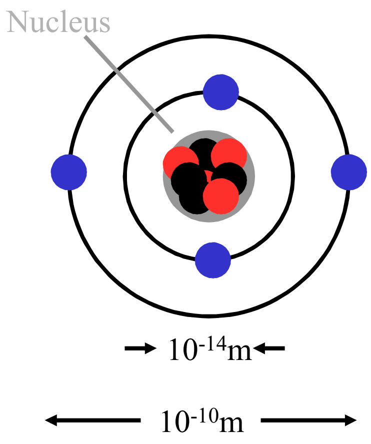
Charge is always conserved.

Unlike charges attract.

Like charges repel.



Matter



Particle	Mass	Charge
Protons	1AMU	+e
Neutrons	1AMU	0
Electrons	1/1787	-e

Equal number of protons and electrons.
Most of the mass in the nucleus.
Positive charge in the nucleus.
Electrons occupy space around atom.
Electrons discrete energy levels.

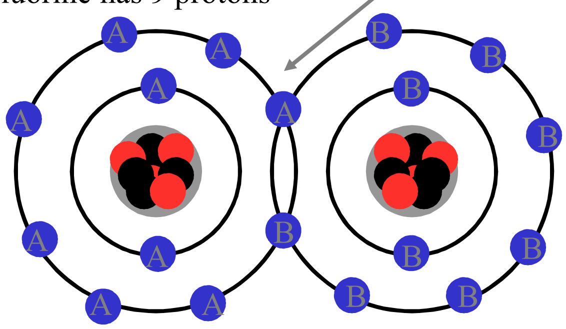
Covalent Bonds

Electrons are shared to form a stable configuration.

Stable Configurations 2, 8, 8...

e.g.Fluorine has 9 protons

Covalent bond, shared electrons

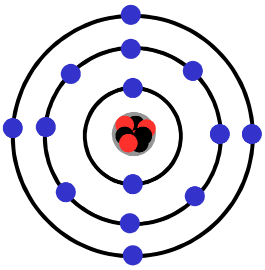


Both atoms have stable 8, (more to it)

Semiconductors

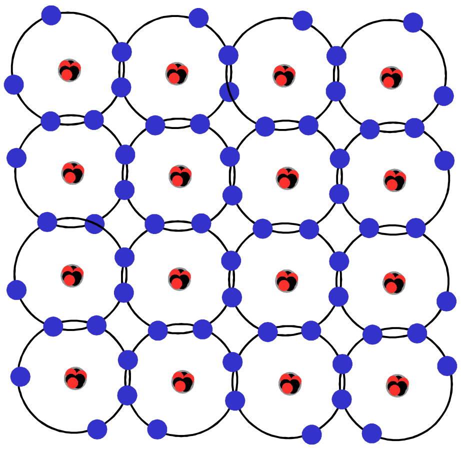
Semiconductors have a valence of 4 (join to 4 other atoms)

Silicon has 14 protons/electrons



Requires 4 covalent bonds to form stable 8 configuration

Silicon

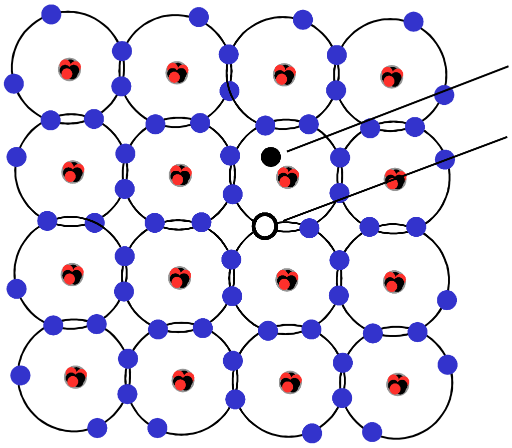


Every electron is covalently bonded.

No-free electrons

Very poor conductor

Silicon+Heat (Thermal energy)



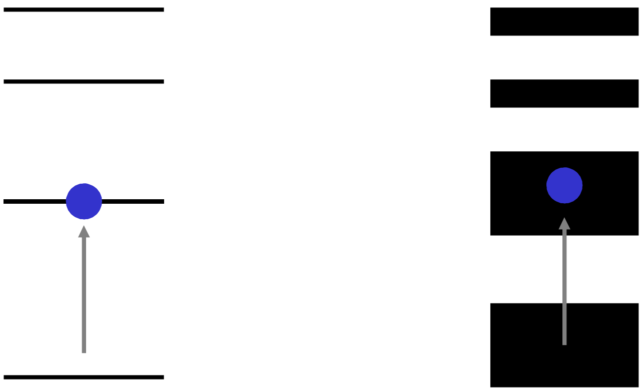
Free, conduction electron

The hole is free to move as well. Behaves like a positive charge.

The electrons that are bound are known as valence electrons.

Electrons that have broken free due to thermal energy are known a conduction electrons.

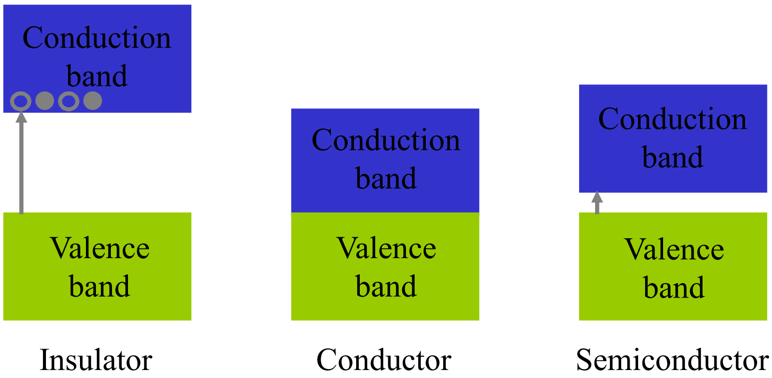
Energy Levels



Atoms: Discrete energy levels

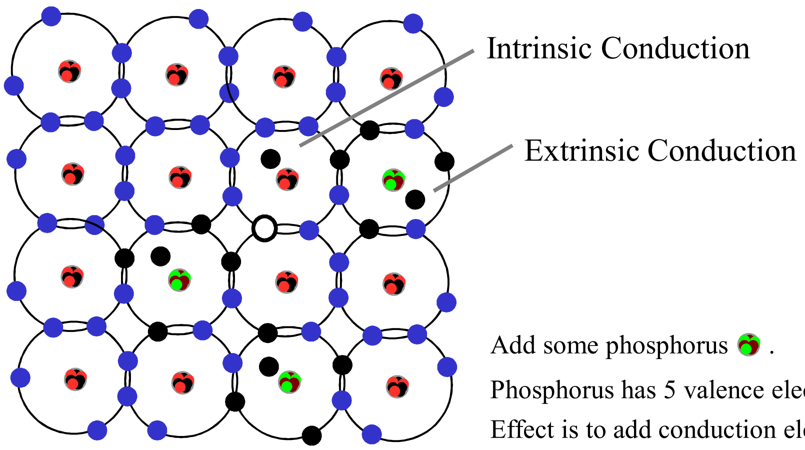
Solids: Discrete energy bands

Semiconductor band theory



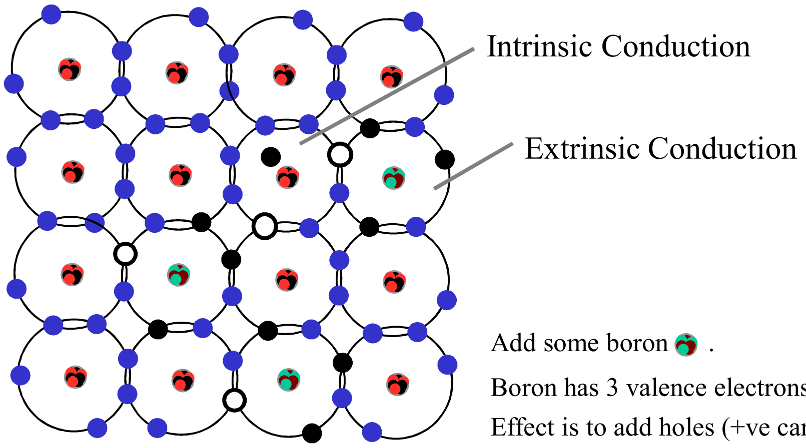
Insulators require a lot of energy to cause an electron to enter the conduction band.
Conductors require very little energy.
Semiconductors require around 1eV

N-type Silicon



Add some phosphorus .
Phosphorus has 5 valence electrons.
Effect is to add conduction electrons.

P-type Silicon

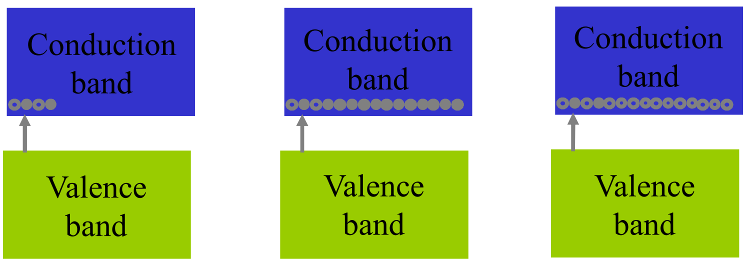


Add some boron .

Boron has 3 valence electrons.

Effect is to add holes (+ve carriers).

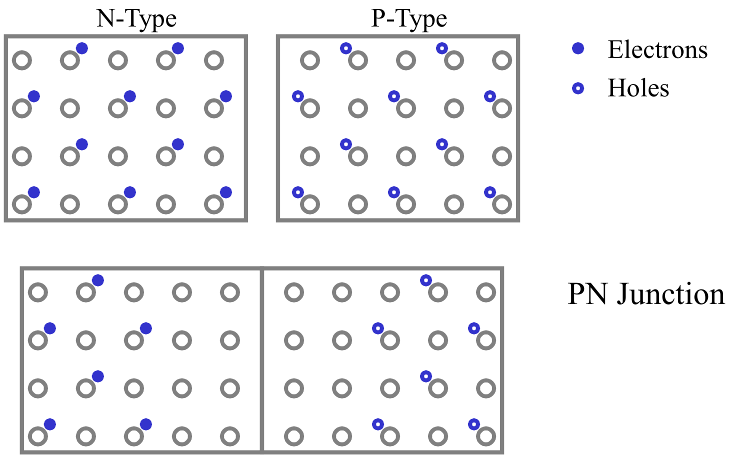
Intrinsic, N-type, P-Type



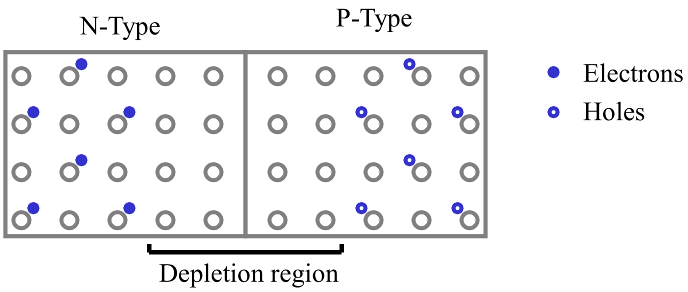
Intrinsic	N-Type	P-Type
Equal e^- and h^+	Extra electrons	Extra holes
Poor conductor	Good conductor	Good conductor
	Phosphorus	Boron

Diodes

A diode is formed at the junction of a N-type and P-type semiconductor.

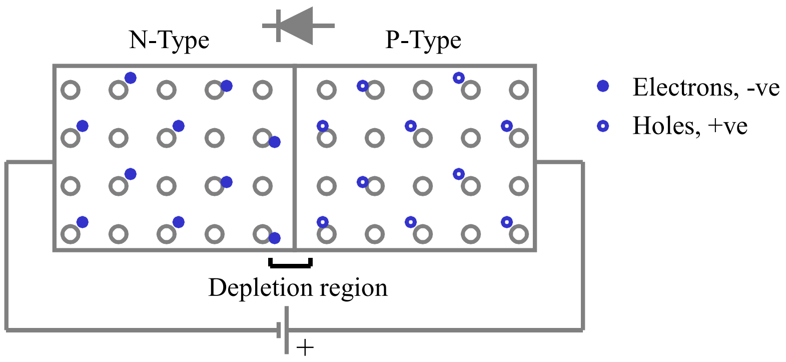


PN Junction Diode



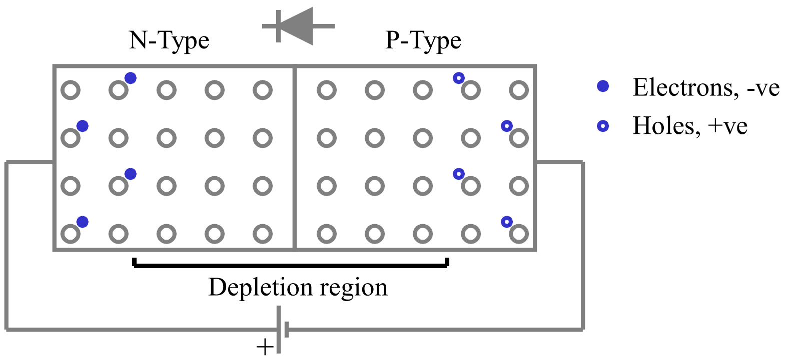
Electrons and holes move across the junction and combine. This creates a non-conducting region called the depletion region.

Forward biased PN Junction Diode



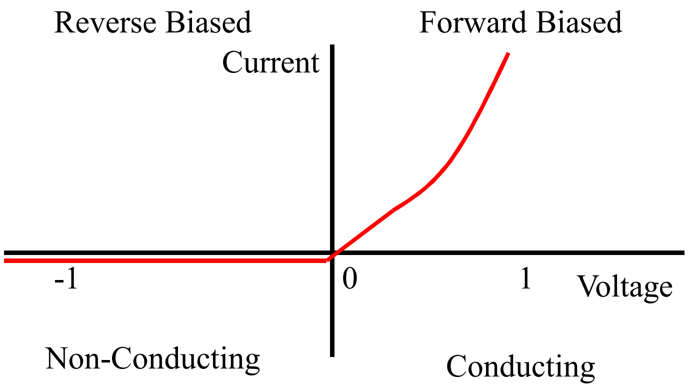
The positive terminal repels the holes, the negative terminal attracts the electrons. The depletion region disappears and the current flows through the circuit.

Reverse biased PN Junction Diode



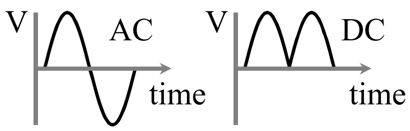
The positive terminal attracts the holes, the negative terminal repels the electrons. The depletion region gets bigger and no current flows through the circuit.

IV Curve of a diode

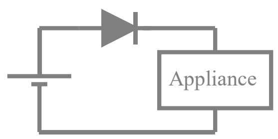


Uses of diodes

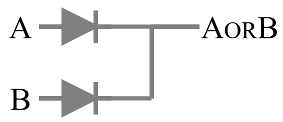
Rectification:
Convert alternating current to direct current.



Circuit protection:
Prevent damage to over voltage or incorrect polarity.



Logic:



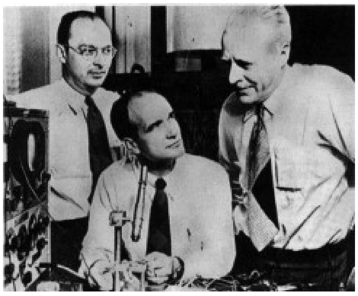
CS253 Architectures II

Lecture 8

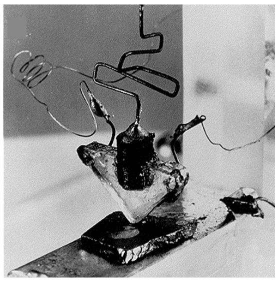
Transistors and FETS

Charles Markham

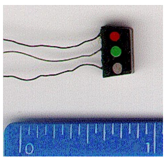
The Junction Transistor



1947 Bell Labs.
John Bardeen,
Walter H. Brattain,
William B. Shockley

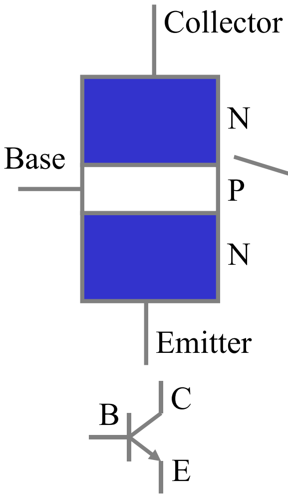


The first transistor, solid state



M1752 The first commercial transistor

Junction Transistors in brief



Current through collector is one hundred times bigger than that applied to the base.

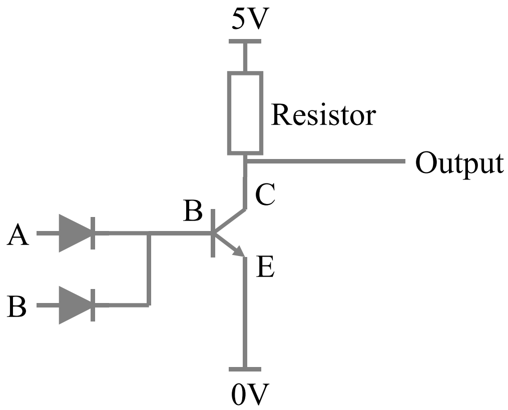
Small current reverse biased diode

+Ve bias on base causes e to flow into base region.

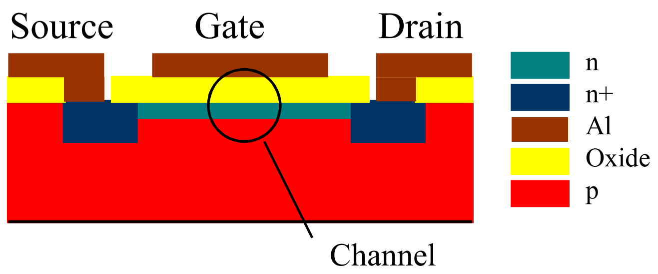
Since base is very thin most of the current passes out of collector rather than base.

=>current gain

NOR Gate formed with Transistors



MOS FETS

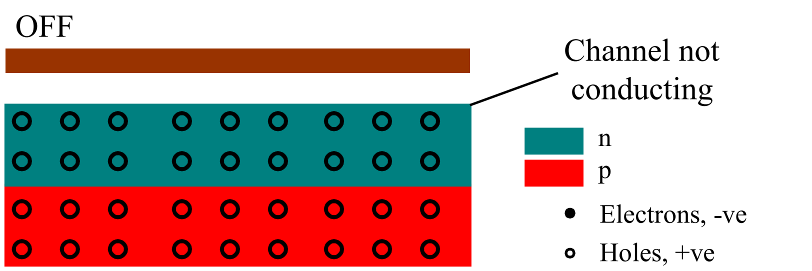


Channel width similar to width of depletion region.

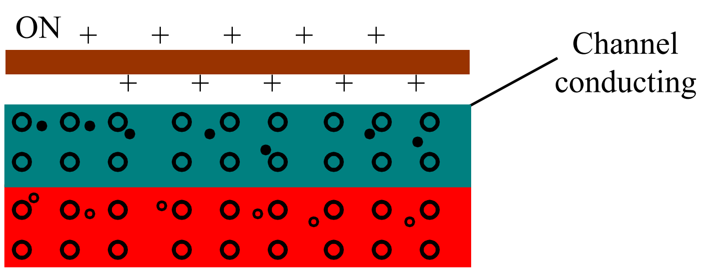
Channel conducts when gate has a +ve voltage on it.

Planar Technology, built on one side of a wafer.

MOS-Metal Oxide Semiconductor, FET-Field Effect Transistor

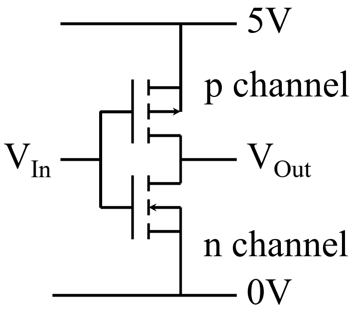


Holes and electrons meet, no carriers to carry current, channel off, non-conducting.



Electric field of the gate attracts electrons and repels holes, electrons are free to move in the channel, channel on (conducting).

CMOS Inverters



Note: there is only dissipation during switching

CMOS-Complementary Metal Oxide Semiconductor

Silicon for semiconductors

Start with Silica sand which is nearly pure SiO_2

Heated at 2000 C with Carbon SiO_2+C=Si +CO_2

Reacted with Hydrochloric Acid 4Si+6HCl=4$HSiCl_3$+H_2

The liquid tricholorsilane is distilled.

The pure trichlorsilane is then heated with hydrogen (1000 C)

4HSiCl3+H_2=4Si+6HCl very pure Si.

The Silicon is then melted in a quartz crucible.

Czochralski Process

The Silicon is then melted in a quartz crucible.

A small seed (perfect) crystal attached to a rod is dipped into the liquid Si.

This crystal is then withdrawn slowly allowing a large crystal to grow.

The crucible and rod rotate in the Si, a large cylindrical crystal know as a boule is created (about 300mm in diameter).

The boule is then cut into slices, creating Si wafers.

The wafers are polished on one side and chemically and mechanically polished on the other side.

Photo etching

The wafer is heated in an Oxygen environment, a layer of SiO_2 forms.

A photoresist is placed on the wafer and then spun to for a thin layer.

A mask is used to allow light to shine on areas of the wafer.

The exposed photoresist becomes soluble and is washed away.

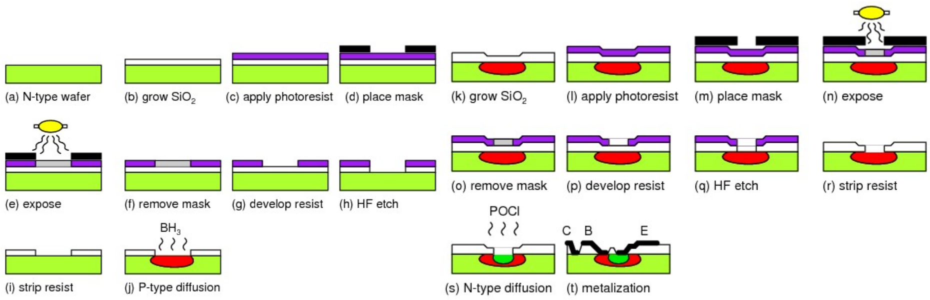
Hydrofluoric acid then dissolves the exposed SiO_2.

$SiO_2+4HF=2H_20+SiF_4$

Heating in boron or phosphorus allows re-doping of the wafer through the hole cut in the Silicon.

Creating a device

By repeatedly growing and etching holes and then doping through the holes is possible to build a device on one side of the Si (planar).



Bipolar Transistor [1]

[1] https://www.allaboutcircuits.com/textbook/semiconductors/chpt-2/semiconductor-manufacturing-techniques/