Quick Start Micro Training LLC, Dr. Ted Dellin
Semi Devices I: Semiconductors and Junction

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SAMPLE SLIDES

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Sample Slides From Basic Very Quick Start Portion of Course

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Engineering Semiconductor Properties Leads to Useful Devices

Semiconductors Have Electronic Special Properties

We Can Engineer (Control) Those Properties
During Design & Manufacturing — *By Applying Voltages During Device Operation*

2 Basic Building Blocks of Electronic & Optoelectronics
Junctions (Semi/Semi, Semi/Metal) — *MOS Capacitor*

Very Useful Devices
Rectifiers, Transistors, ICs, Photodetectors, Solar Cells, LEDs, Lasers

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The Special Properties of Semiconductors

- Electrons And Holes
- Bands & Bandgap
- Adding Dopant Atoms Makes n and p Type
- Special Properties of Junctions
- Can Modify Junction Properties With Voltage
- MOS Field Effect

These special properties are not found in metals

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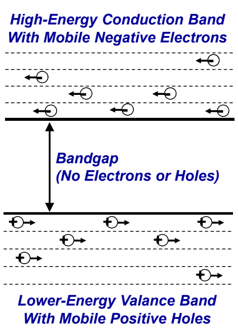
Semiconductors Have a Conduction Band, Valance Band and Bandgap



- Higher-energy conduction band with mobile negative electrons
- Lower-energy valance band with mobile positive holes
- Separated by a bandgap with no electrons or holes

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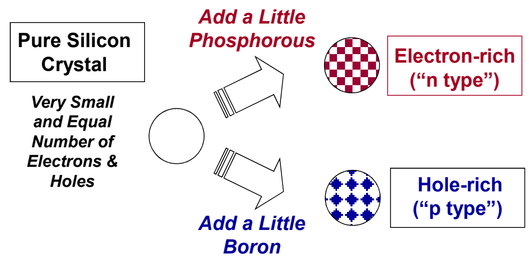
Semiconductor "Alchemy": *Adding Trace Impurities Makes Large Changes in Electrical Properties*



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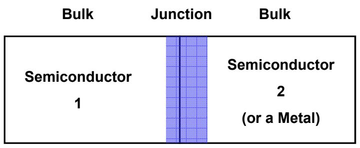
A "Junction" Is Formed Whenever Two Different Semiconductors Are Joined



- "Bulk" regions of the semiconductors remained essentially unchanged
- Inside the junction many interesting effects can occur
  - E.g., built-in voltage and electric field and diffusion barriers

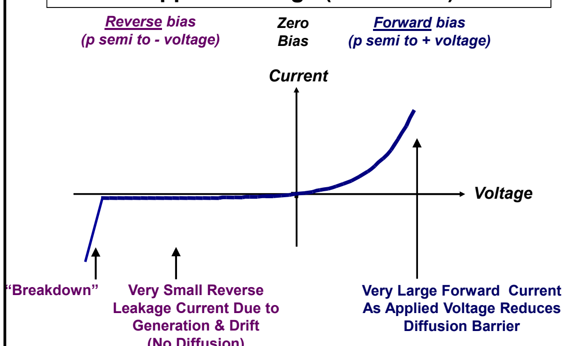
The Features of the Junction Leads to Interesting Electronic Devices

Junction Property	Impact of the Junction Property
Built-in Barrier	Leads to diode behavior *-Forward bias: high currents* *-Reverse bias: low currents*
Depletion Region	Limits the minimum size of transistors
Electric Field Exists Across Junction	Generates an electric current when light is absorbed in the junction Junction breakdown under large reverse biases
Increased Recombination Under Forward Bias	Efficient conversion of electricity into light

Special Properties of Junctions Can Be Modified By Applying an External Voltage

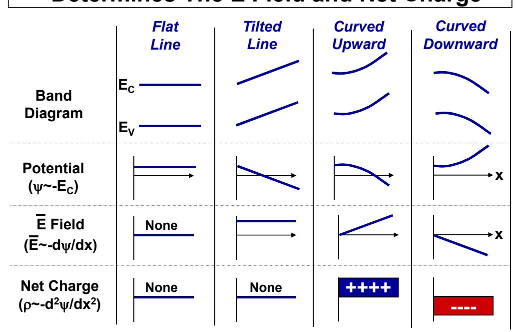
Reverse Biased	Junction Property	Forward Biased
- Raises Barrier *- Small Leakage Currents*	Height of Current Barrier	*- Lowers Barrier* *- Large Currents (Diode)*
- Increases *- Limits Transistor Size*	Width of Depletion Region	*- Shrinks*
- Increases *- Breakdown* *- Photo Detector*	Magnitude of Electric Field	*- Decreases* *- Solar Cell*
- Decreases *- No Light*	Amount of Recombination	*- Increases* *- Light Emission (In Some Semis)*

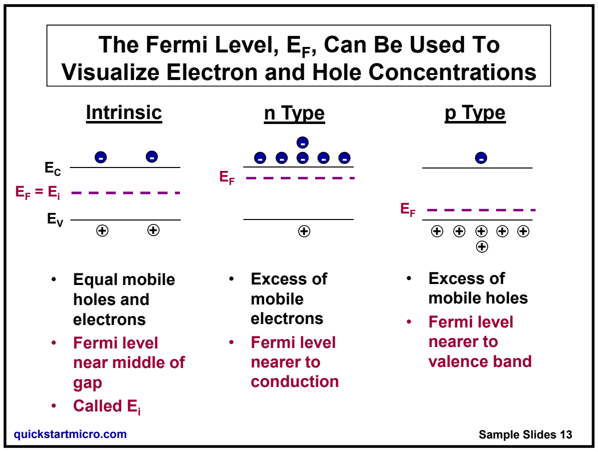
Current Through Junction Vs. Externally Applied Voltage ("IV Curve")



Sample Slides From Supplemental "Digging Deeper" Portion of Course

The Shape of the Energy Vs. Position Determines The E Field and Net Charge




The Fermi Level, E_F, Can Be Used To Visualize Electron and Hole Concentrations
Intrinsic
n Type
p Type
E_C
$E_F = E_i$
E_V
E_F
E_F
• Equal mobile holes and electrons
• Fermi level near middle of gap
• Called E_i
• Excess of mobile electrons
• Fermi level nearer to conduction
• Excess of mobile holes
• Fermi level nearer to valence band
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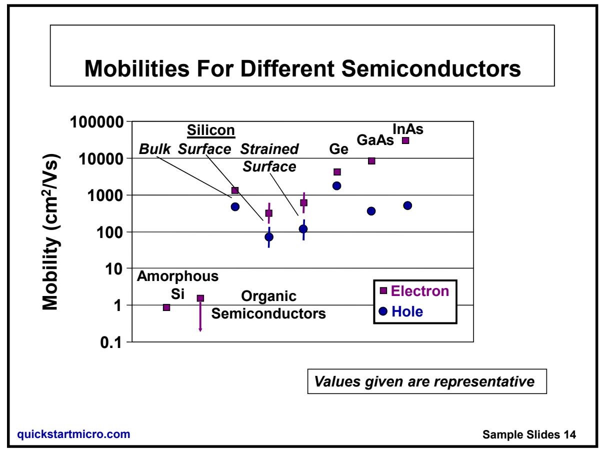
Mobilities For Different Semiconductors
Mobility (cm^2/Vs)
100000
10000
1000
100
10
1
0.1
Silicon
Bulk Surface Strained Surface
Ge
GaAs
InAs
Amorphous Si
Organic Semiconductors
Electron
Hole
Values given are representative
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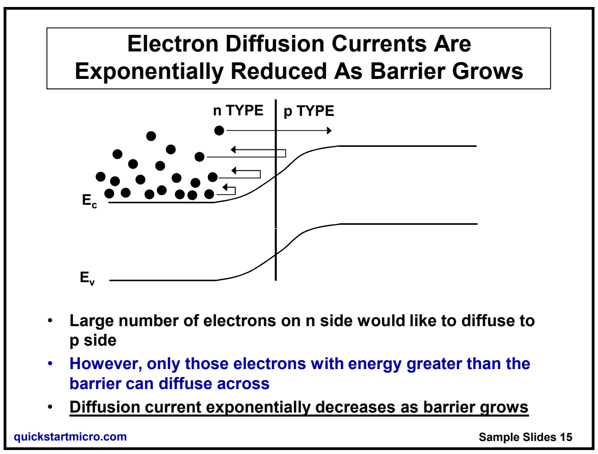
Electron Diffusion Currents Are Exponentially Reduced As Barrier Grows
n TYPE
p TYPE
E_c
E_v
• Large number of electrons on n side would like to diffuse to p side
• However, only those electrons with energy greater than the barrier can diffuse across
• Diffusion current exponentially decreases as barrier grows
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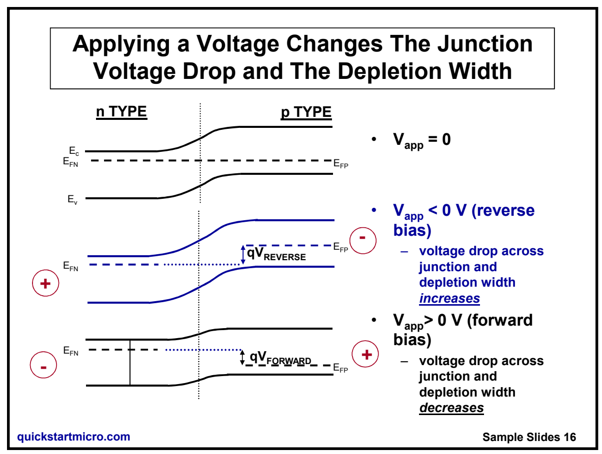
Applying a Voltage Changes The Junction Voltage Drop and The Depletion Width
n TYPE
p TYPE
E_c
E_{FN}
E_{FP}
E_v
$qV_{REVERSE}$
$qV_{FORWARD}$
• V_{app} = 0
• V_{app} < 0 V (reverse bias)
– voltage drop across junction and depletion width increases
• V_{app} > 0 V (forward bias)
– voltage drop across junction and depletion width decreases
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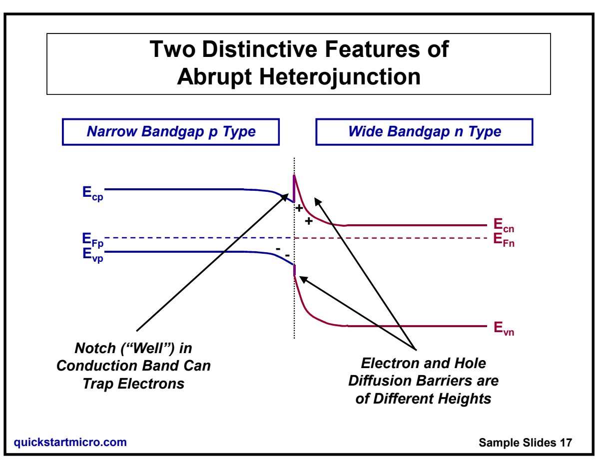
Two Distinctive Features of Abrupt Heterojunction
Narrow Bandgap p Type
Wide Bandgap n Type
E_{cp}
E_{Fp}
E_{vp}
E_{cn}
E_{Fn}
E_{vn}
Notch ("Well") in Conduction Band Can Trap Electrons
Electron and Hole Diffusion Barriers are of Different Heights
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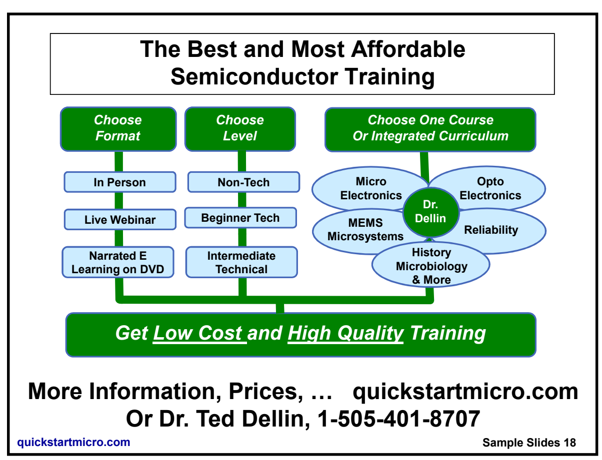
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