Nanomaker

Lab #3: Light Emitting Diode (LED)

Display Technology

Lighting Technology

Electroluminescence

Display Technology

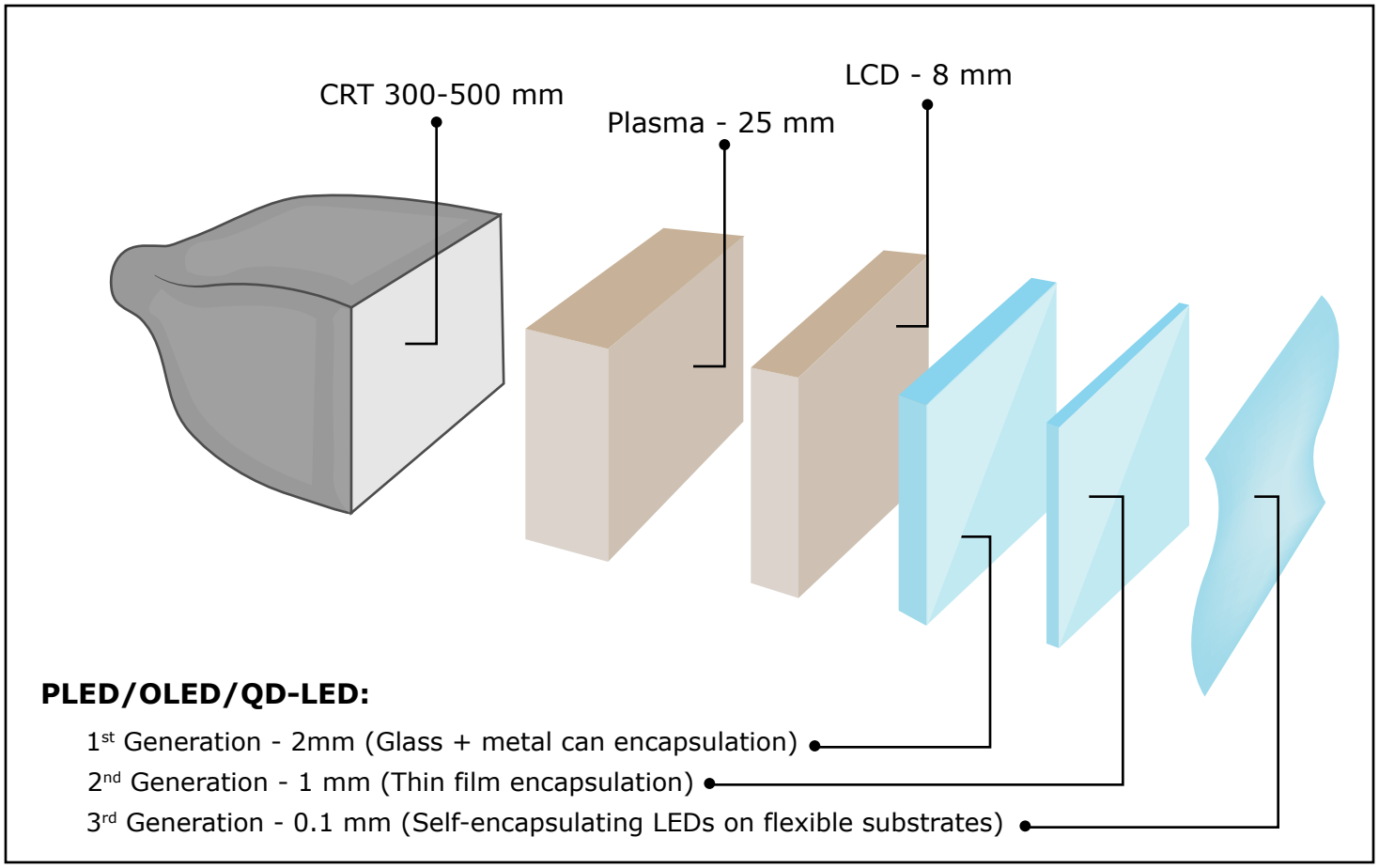
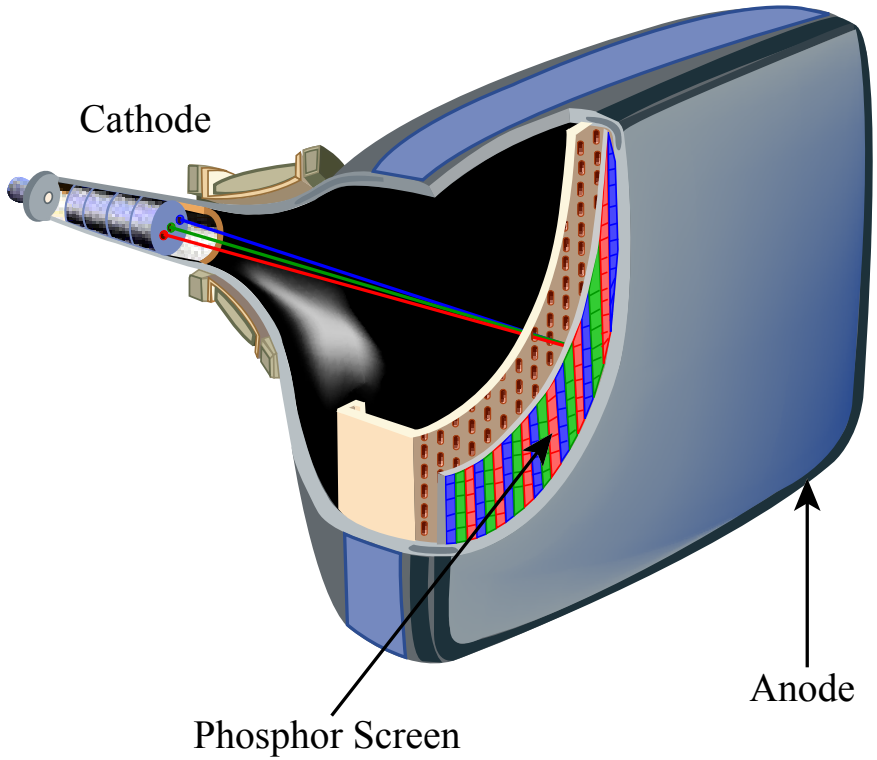


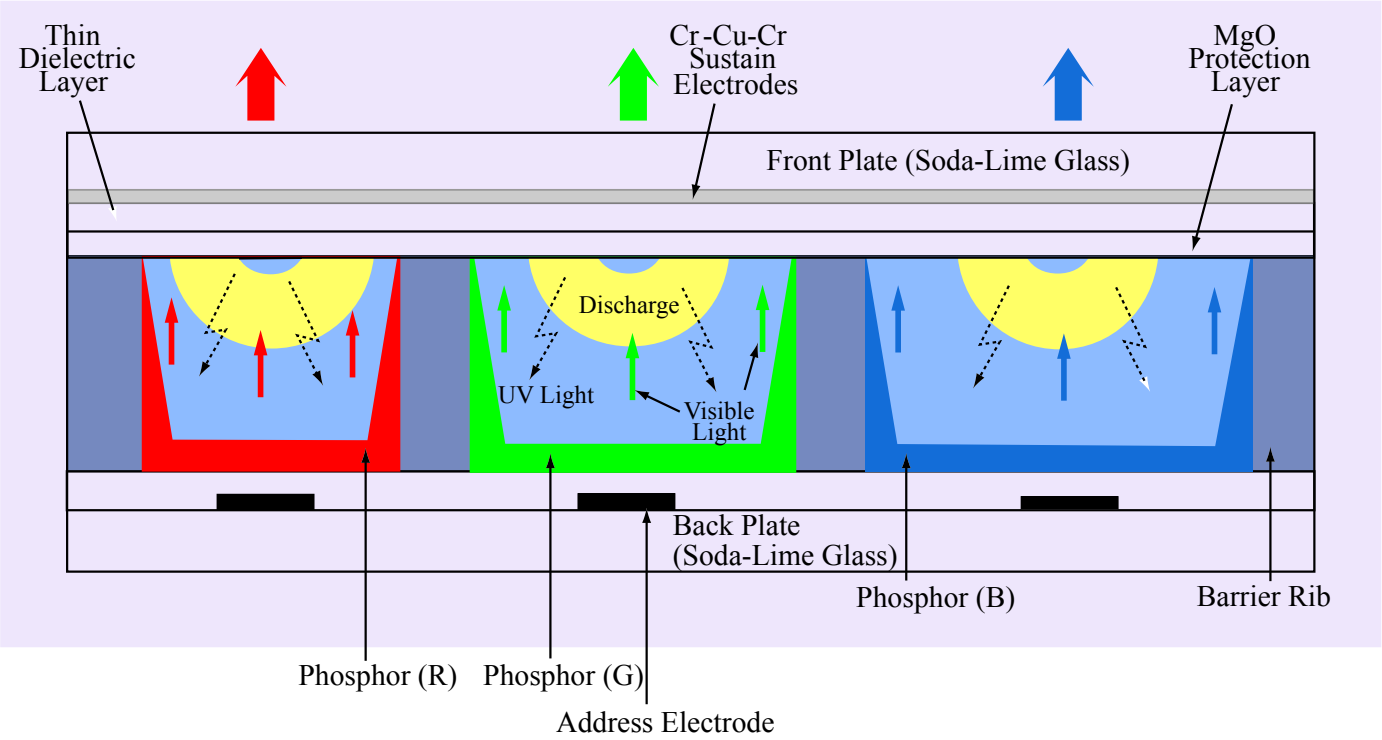
Image by MIT OpenCourseWare.

Cathode Ray Tube Displays



- Electrons beam boiled off a metal by heat (thermionic emission) is sequentially canned across a phosphor screen by magnetic deflection.
- The electrons are accelerated to the screen acquiring energy and generate light on reaching the screen (cathodoluminescence).

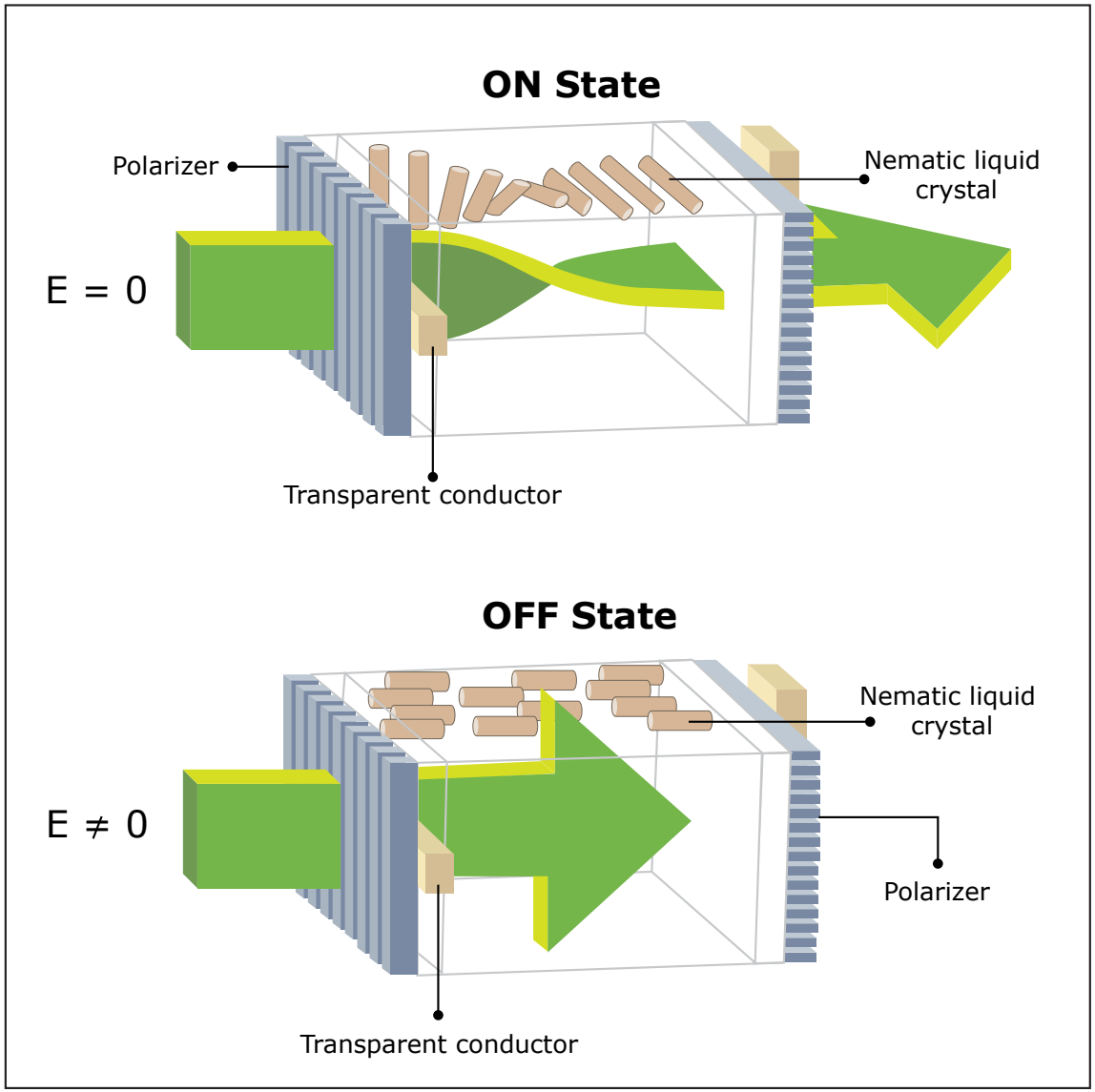
Plasma Displays



- Electrons are accelerated by voltage and collide with gasses resulting in ionization and energy transfer
- Excited ions or radicals relax to give UV photons which cause hole-electron generation in phosphor and visible light emission

Liquid Crystal Displays

- Liquid Crystals rotate the plane of polarization of light when a voltage is applied across the cell



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Display Technology

Lighting Technology

Electroluminescence

Incandescent, Fluorescent and LED

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	LED	Fluorescent	Incandescent
Life Span	50000 hrs	8000 hrs	1200 hrs
Heat Emission	3.4 btu/hr	30 btu/hr	85 btu/hr
Power	0.01 Watt/ Lumen	0.02 Watt/ Lumen	0.075 Watt /Lumen
CO2 Emission	15 pounds/yr	35 pounds/yr	150 pounds/yr

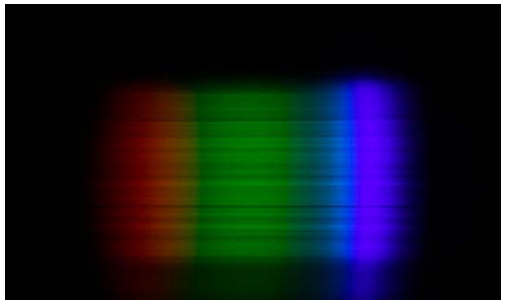
Incandescent: heating a metal filament wire to a high temperature until it glows
Fluorescent: gas-discharge lamp that uses electricity to excite mercury vapor
LED: recombination of electrons and holes, known as electroluminescence

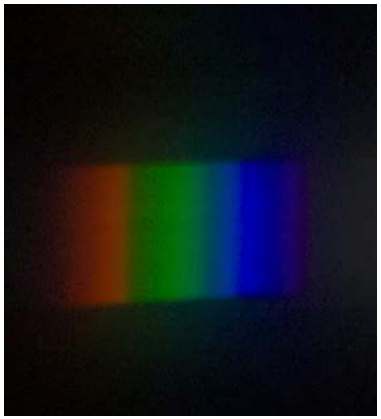
Difference Spectra

LED

fluorescent

incandescent



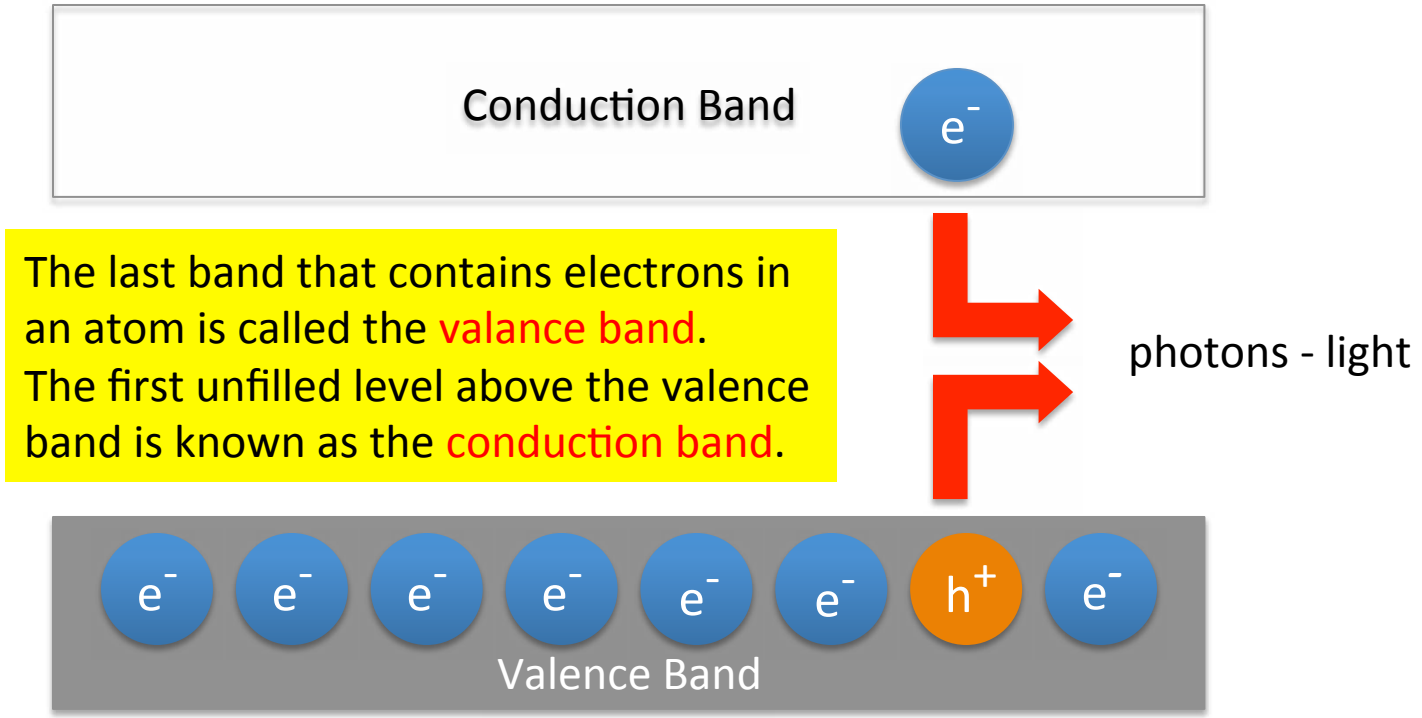


Display Technology

Lighting Technology

Electroluminescence

Electroluminescence

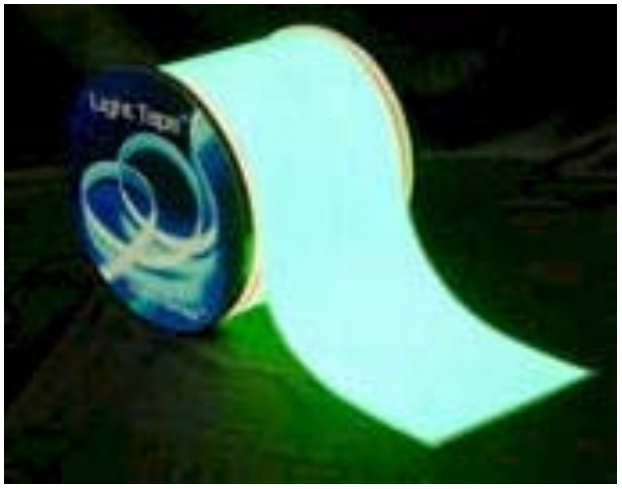


- Electroluminescence is the result of recombination of electrons and holes in a material, usually a semiconductor.
- The excited electrons release their energy as photons – light.

Electroluminescence

Electrons and holes may be separated either by

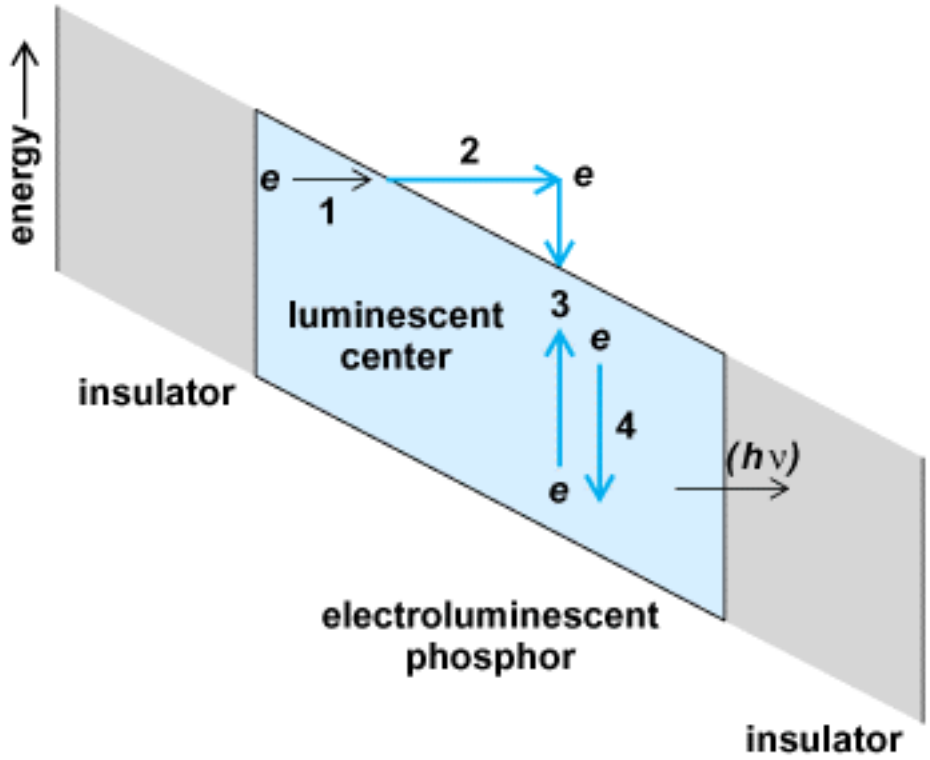
- excitation by a strong electric field (10^8 V/m) (light tape)
- doping the material to form a p-n junction (LED)



Courtesy of Electro-LuminX È Lighting Corporation. Used with permission.

Photo courtesy of tudedude on Flickr.

Light Tape



(1) Tunnel electrons from interface states, (2) acceleration of electrons to high energies, (3) impact excitation or impact ionization of the luminescent center, and (4) de-excitation of the excited electron by photon generation

Light Emitting Diode

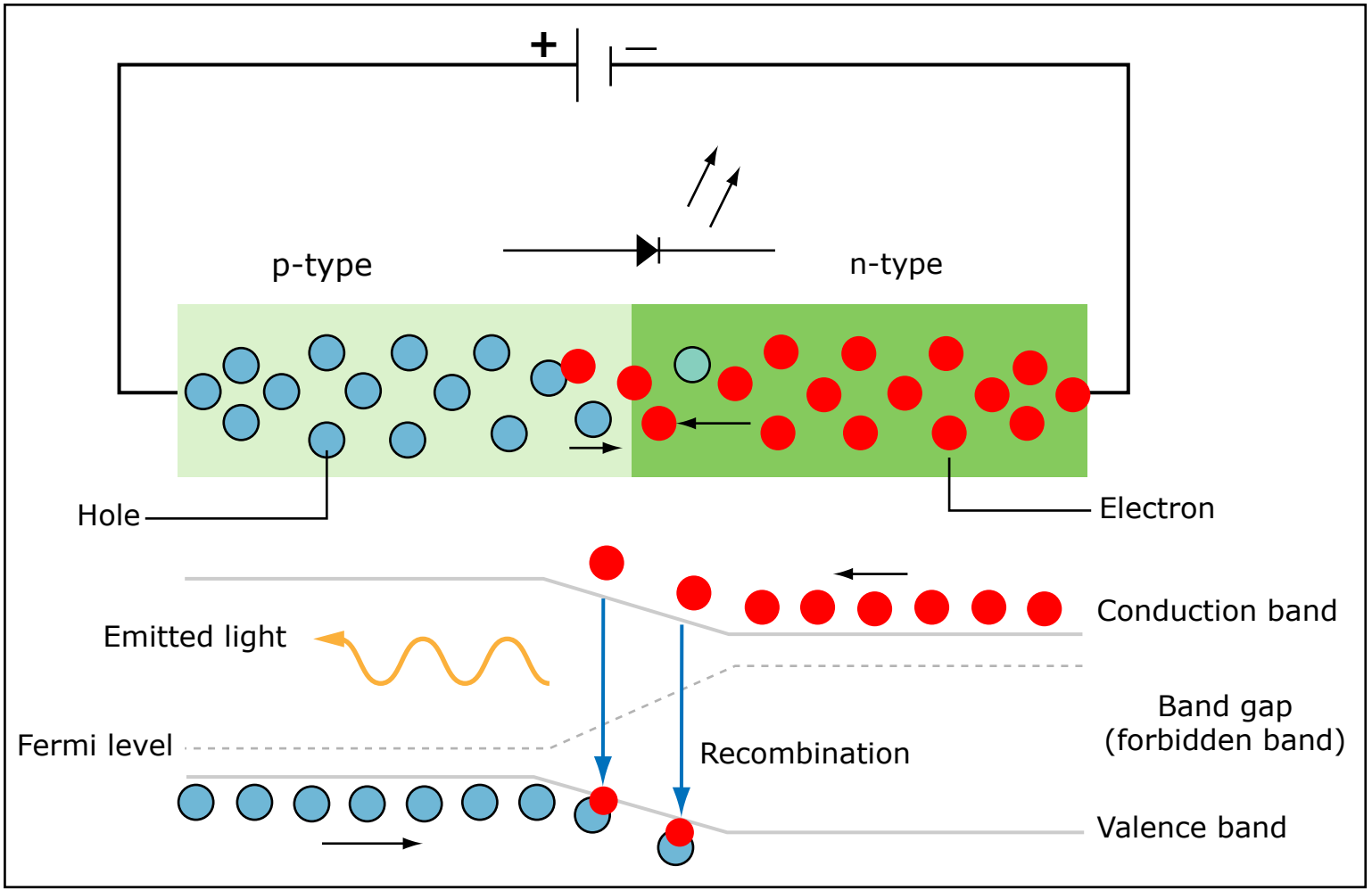
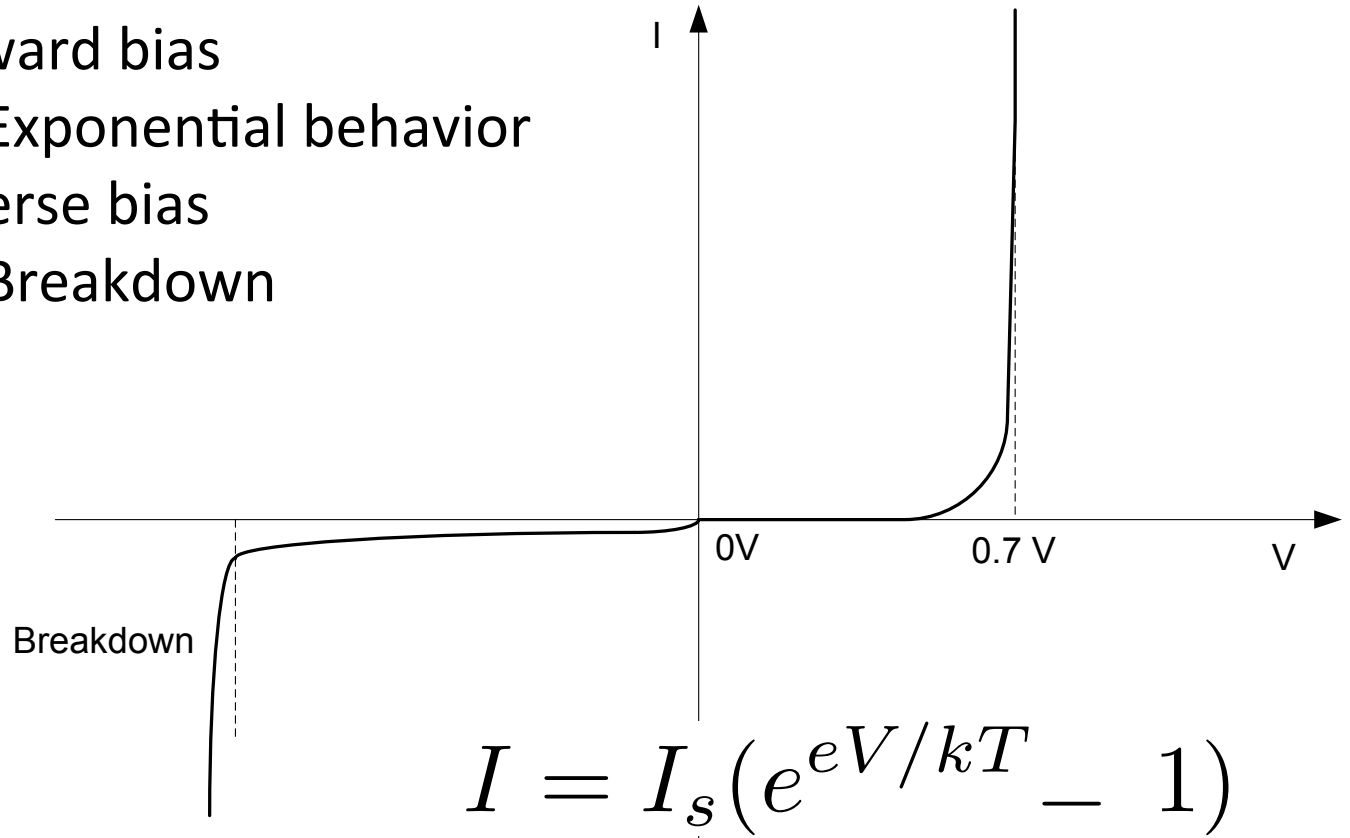


Image by MIT OpenCourseWare.

When a light-emitting diode is forward biased, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons.

Diode

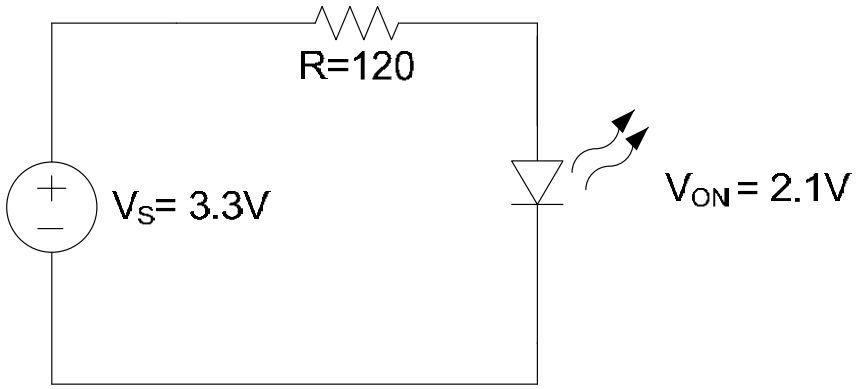
- Forward bias
  - Exponential behavior
- Reverse bias
  - Breakdown



$$I = I_s(e^{eV/kT} - 1)$$

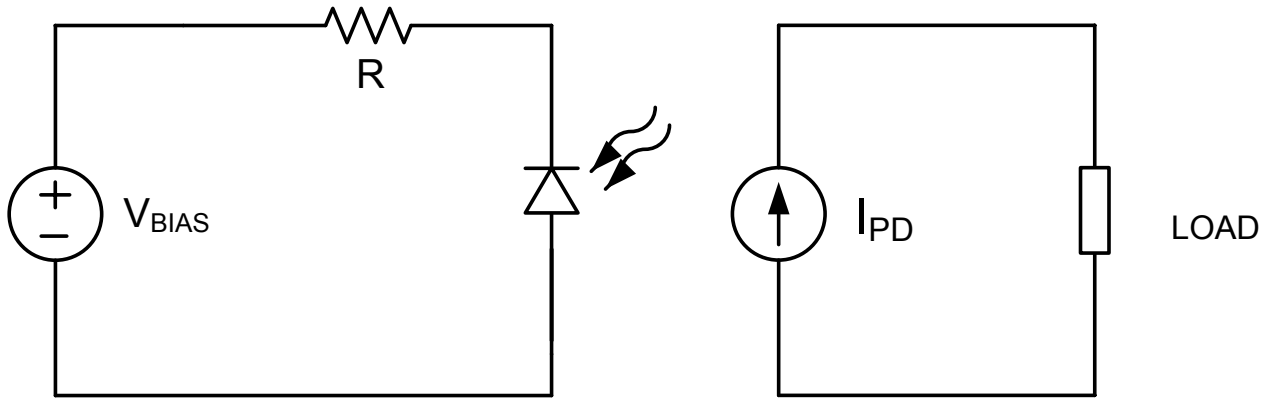
Light Emitting Diode

- Light emitting diode (0.7-5V turn-on)
- High power for lighting
- Need to limit current

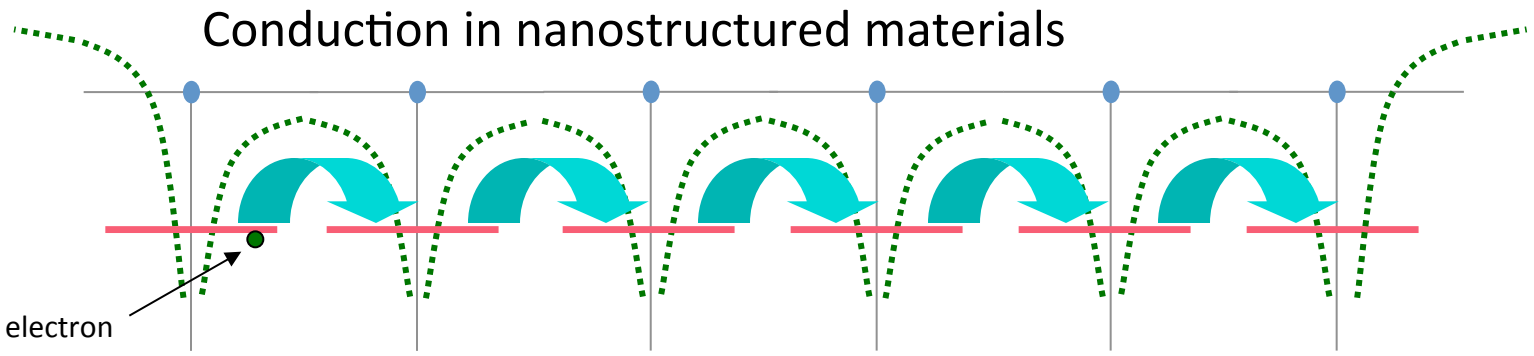


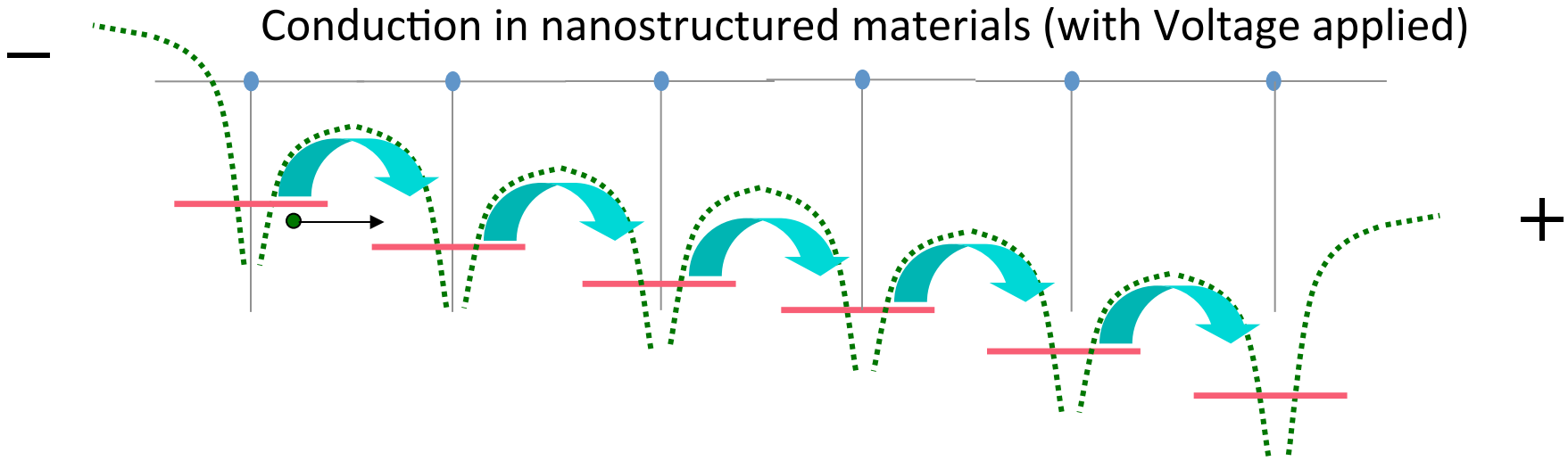
Photodiode

- Photons generate electron-hole pairs
- Apply reverse bias voltage to increase sensitivity
- Key specs
  - Sensitivity
  - Spectral response
  - Reverse break voltage
  - Dark current

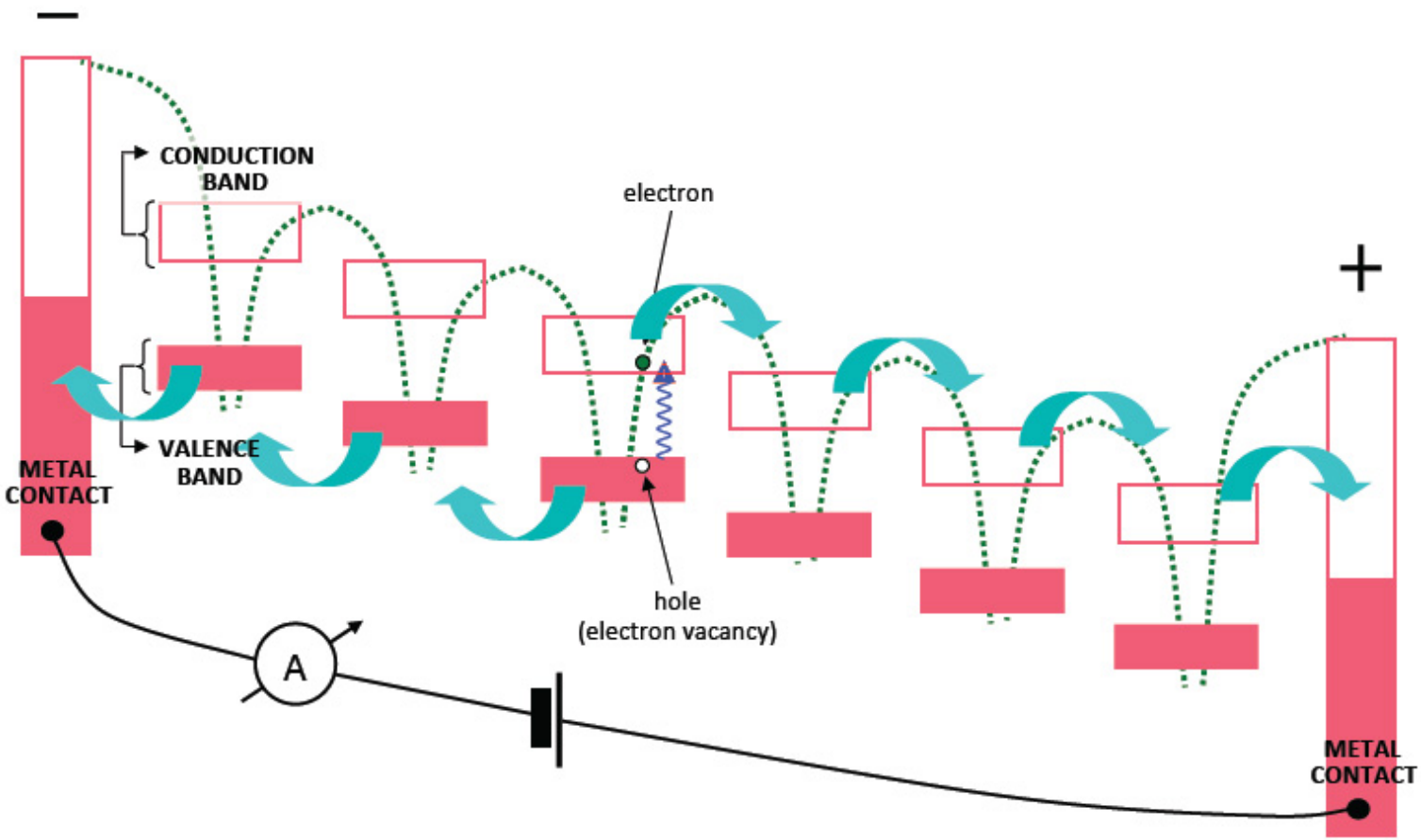


Conduction


Conduction in nanostructured materials
electron


Conduction in nanostructured materials (with Voltage applied)
–
+

Photodiode



1. Photon can excite an electron from
   Valence Band (ground state) to Conduction Band (excited state)
2. The externally applied bias (that generates the electric field in the semiconductor) will separate the photo-generated electron and hole
3. The electron and a hole will reach the metal contacts, be collected by the bias battery, and be measures as a photocurrent.
4. If more photons are absorbed by the semiconductor, more current we will measured

Conclusions

- Diode

$$I = I_s(e^{eV/kT} - 1)$$

- Electroluminescence
  - High voltage
  - Lower voltage + doping

6.S079 Nanomaker

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