Light Emitting Diodes

Description: This activity illustrates the properties of LEDs and semiconductor materials and how they applicable in every day situations. Students learn the difference between conductors, semiconductors, and insulators. Investigations include understanding the electromagnetic spectrum, periodic table elements, and energy.

Physics/Chemistry Principles:

- Bohr Model
- Semiconductors
- Electromagnetic Spectrum
- Light Emitting Diodes

Bohr Model:

- Each atom has a ground state, which is a stable state with the lowest energy for that atom. Higher states are excited states that can be brought about by thermal energy (higher temperatures) or electrical energy (a battery) so an electron can jump to an excited state. When this happens, the electron jumps right back to the lower state and emits a photon of energy, and for some atoms this photon is in the visible range of the electromagnetic spectrum.

- Depending on the distance of the electron orbit from the nucleus, that electron has potential energy, measured in electron volts (eV).

- The farther an electron in orbit is from the nucleus, the higher potential energy it has and vice versa.

Semiconductors:

- Electrons in a solid collection of atoms that form a semiconductors also have energy levels. The filled energy levels tend to be clustered close together and there is an energy "gap" before the unfilled levels start, but the unfilled levels are also clustered close together. Thus these two clusters (filled and vacant) are referred to as the valence and conduction bands. If the gap between the bands is large (~10 eV), then the material is referred to as an insulator because it is difficult for electrons to move from one band to another. If the gap is nearly non-existent, then the material is called a conductor. If the gap is moderate in size (~1 eV), then the material is called a semiconductor.

- In all materials at the low temperatures, electrons are in the valence band, but in conductors MANY electrons are in the conduction band which allows current to flow through the conducting material. At these low temperatures, the semiconductors are not very good conductors.

- At higher temperatures, some electrons pick up kinetic energy, which means they have more total energy and thus move into the conduction band from their original energy level in the valence band.

- Natural conductors are elements that are on either edge of the periodic table. They are elements with their outermost electrons in unfilled shells which makes those shells very loosely bound. Elements with filled or nearly filled subshells are typically semiconductors and are found in the periodic table in the top left of group IIIA to the bottom left of group VIIA on the (B, Si, Ge, As, Sb, Te, At).

- As in the Bohr model, the total energy of the outermost electrons depends inversely on the size of the atom, thus electrons far from the nucleus requiring less energy to move to a higher energy state than the outermost electrons from smaller atoms. Thus the size of the energy gap also depends upon the size of the atoms in the material.

- Some semiconductors are created by mixing metals (like In, Ga, Cd, Zn) and nonmetals (P, S, O) or metals and natural semiconductors (As, Te) to obtain certain energy gaps. Since the energy gap determines the energy released as an electron makes a transition from the conduction to the valence band, the color of light emitted by various materials is affected by the location of the elements in the periodic table. Some examples are: InP, GaP, GaAs, CdS, CdTe, ZnO, ZnS.

Electromagnetic Spectrum:

- The light emitted when an electron jumps from the excited state back to the ground state is dependent on the energy gap between the orbits.

- Higher energy corresponds to short wavelengths of light or toward the ultraviolet end of the electromagnetic spectrum.

- Lower energy corresponds to longer wavelengths of light or toward the infrared end of the electromagnetic spectrum.

Light Emitting Diodes and How It Applies to this Kit:

- A diode is a device that allows electric current to flow in one direction but not in another (you can see this when you connect your diodes to the socket, they will only work when plugged in the right way).

- An LED is a semiconductor that has the band gap spacing just right so electrons can make their transitions and emit light in the visible part of the electromagnetic spectrum.

- The material making up an LED emits light in response to the electric current passing through it. This is different from emission of light in an incandescent bulb where the electric current heats a filament (usually tungsten) causing light emission.

- By mixing elements (as described above), their resistivity can be changed. If the semiconductor has 4 valence electrons (e.g. Si), an element with 5 valence electrons (e.g. As) is introduced and only 4 of the 5 electrons of the As will participate in bonding with Si. The extra electron can conduct through the material and makes the Si more of a conductor than it was previously. Similarly, an element with fewer valence electrons (say 3) can be introduced with an element with 4 valence electrons and leave a hole behind that similarly can move through the material and electrons from the Si move to fill the holes.

- Light emission in semiconductors is similar to emission by gaseous atoms, except discrete atomic energy levels are replaced by bands.

- Electrons become excited electrically (by a battery in this case) and move across the band gap, where it will then return from the conduction band to the valence band and emit a photon of energy seen as light emission (the color of which is approximately the band gap energy).

- See the worksheet and PowerPoint presentation associated with this activity at: http://www.hope.edu/csi/Activity_kits.html#LEDs

Questions to Investigate:

- Have students draw a circuit diagram corresponding to their setup.
- See the worksheet associated with this activity at: http://www.hope.edu/csi/Activity_kits.html#LEDs
- See pages included in the kit with various investigations from *Ellis, et al*. 1993.

Online Resources:

- PhysicsLAB Atomic models and spectra (see Related Documents at the bottom of the page and select each subtopic for more classroom ideas): http://dev.physicslab.org/Document.aspx?doctype=3&filename=AtomicNuclear_AtomicModelsSpectra.xml
- PhysicsLAB Energy level diagrams (see Related Documents at the bottom of the page and select each subtopic for more classroom ideas): http://dev.physicslab.org/Document.aspx?doctype=3&filename=AtomicNuclear_EnergyLevelDiagrams.xml
- Physics Classroom Electromagnetic Spectrum: http://www.physicsclassroom.com/Class/light/U12L2a.html
- Helpful Information about Bond Lengths and Energies: http://www.science.uwaterloo.ca/~cchieh/cact/c120/bondel.html

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