DEMONSTRATION 4
Notes for the Instructor

PURPOSE

To illustrate that LEDs of different colors may be produced by tuning the gap in energy between the top of the valence band and the bottom of the conduction band (band gap) by varying the chemical composition of semiconducting materials used to produce them.

METHOD

If LED materials are restricted to compounds having AZ stoichiometries, then the light produced by them is restricted to the band gap energies of the AZ solids. If, however, the LED is made of a solid solution comprising solids of the same structure with atoms of comparable size, then the light produced may be adjusted (tuned) by manipulating the chemical composition of the solid solution, which alters the band gaps in a predictable way. Zinc blende semiconductors such as GaAs and GaP are one pair of solids that can be combined to yield solid solutions having compositions that can be represented by GaP_xAs_{1-x} ($0 \leq x \leq 1$), where x and 1-x represent the probabilities that an atom occupying a specific site in the structure is P or As respectively. As was discussed in the background material for this unit, this change in composition results in unit-cell constants (edge lengths) that vary continuously between 5.45 Å and 5.65 Å with an accompanying change in band-gap from 1.4 eV to 2.3 eV. The light that is produced as electrons make the transition between the conduction and valance bands is roughly equivalent in energy to these gaps and correspond to wavelengths from 890 nm (GaAs) to 540 nm (GaP). This theory may be demonstrated by showing LEDs of several colors and relating those colors to both composition and band gap energies.

MATERIALS

GaP_xAs_{1-x} LEDs (See supplier information for Investigation 1 in the Diffraction Unit)

$GaP_{0.40}As_{0.60}$	Red	$GaP_{1.00}As_{0.00}$:N	Green
$GaP_{0.65}As_{0.35}$:N	Orange	GaN	Blue (optional)
$GaP_{0.85}As_{0.15}$:N	Yellow	GaN/phospor	White (optional)
1-kΩ resistor		Multimeter and leads	

9-V battery

Battery snap

LED socket

PROCEDURE

1. Construct the LED circuit by wiring the resistor in series with the battery and LED socket.

2. Plug the LEDs into the socket and note the composition and color of the light emitted. The recommended order would be red, orange, yellow, and green.

3. Attach the multimeter leads across each side of the LED circuit and set the meter to read voltage. Record the voltage for each LED.

FOLLOW-UP QUESTIONS

1. Which color LED represents light with the lowest energy? **Red** Highest? **Green** Explain. **$E = (hc)/\lambda$, since red has a longer λ, its energy is smaller.**

2. What is a band-gap energy? **The difference in energy between the valance and conduction bands in materials.**

3. How is light produced by the LED? **The applied electric field supplies enough energy to promote electrons into the conduction band. They are not stable in this excited state and return to the ground state releasing energy as they do so. Much of this energy is in the form of light.**

4. Which color LED contains the smallest band gap? **Red.** Largest? **Green** . How can you tell? **Red light has a lower frequency and therefore lower energy. The photon energy roughly approximates the band gap. Green light has a higher frequency and higher energy.**

5. From the information provided to you during the demonstration, what factor(s) appear to be responsible for the change in band gap? **The obvious answer is composition. This would be a good time to discuss these changes in terms of periodic properties like size, valence level configurations, etc.**

6. Why can't blue light be produced from LEDs of this general composition? **The green LED has a composition that is essentially GaP. Since the band gap varies directly with the unit cell constant and since that unit cell constant has reached its minimum value when the ratio of P to As in the LED has reached its maximum, no larger band-gaps can be expected with this particular family of LEDs. Since blue light would require a larger band gap, blue LEDs can not be produced by this method.**

7. What relationship (if any) exists between the band gap energy and the measured voltage across each LED? **When voltage is applied across the the LED, nothing happens unless the energy is sufficient to excite an electron from its localized bond. Voltage is directly proportional to energy and therefore the voltage and band gap energy should be directly related.**

Student Questions after Demonstration #4

1. Which color LED represents light with the lowest energy? Highest energy? Explain.

2. What is the band-gap energy?

3. How is light produced by the LED?

4. Which color LED contains the smallest band-gap? Largest? How can you tell?

5. From the information provided to you during the demonstration, what factor(s) appear to be responsible for the change in band-gap?

6. Why can't blue light be produced from LEDs of this general composition?

7. What relationship (if any) exists between the band gap energy and the measured voltage across each LED?