Technology Brief 5: Light-Emitting Diodes (LEDs)

Light-emitting diodes (LEDs) are a mainstay of lighting in many manufactured products, from consumer electronics to home appliances to high-efficiency tail-lights for cars. These solid-state semiconductor devices can be fabricated to emit light (Fig. TF5-1) in very narrow bands, centered around any desired wavelength in the spectral range encompassing the infrared, visible, and ultraviolet segments of the electromagnetic spectrum. Modern LEDs are manufactured in a staggering variety of shapes, sizes, and colors. Compared with conventional phosphorescent light bulbs, LEDs have many advantages. Light-emitting diodes respond much faster (microseconds or less), can be made to emit light in a very narrow wavelength band (appear to be a single color), emit more light per watt of electrical energy input, have very long lifetimes (>100,000 hours), and can be integrated directly into semiconductor circuits, printed circuit boards, and in light-focusing packages. LEDs are now inexpensive enough that they are being integrated routinely into street lights, automobile lights, high-efficiency flashlights, and even woven into clothes (e.g., Philips Research Lumalive textiles)!

LEDs are a specific type of the much-larger diode family, whose basic behavior we discussed earlier in Section 2-7. When a voltage is applied in the forward-biased direction across an LED, current flows and photons are emitted (Fig. TF5-2). This occurs because as electrons surge through the diode material they recombine with charge carriers in the material and release energy. The energy is released in the form of photons (quanta of light). The energy of the emitted photon (and hence, its wavelength) depends on the type of material used to make the diode. For example, a diode made of aluminum gallium arsenide (AlGaAs) emits red light, while a diode made from indium gallium nitride (InGaN) emits bluish light. Extensive research over many decades has yielded materials that can emit photons at practically any wavelength across a broad spectrum, extending from the infrared to the ultraviolet. Various "tricks" also have been employed to modify the emitted light after emission. To make white light diodes, for example, certain blue light diodes can be coated with crystal powders which convert the blue light to broad-spectrum "white" light. Other coatings that modify the emitted light (such as quantum dots) are still the subject of research.

In addition to semiconductor LEDs, a newer class of devices called ***Organic Light Emitting Diodes (OLEDs)*** are the subject of intense research efforts. OLEDs operate in an manner analogous to conventional LEDs, but the material used is composed of organic molecules (often polymers). OLEDs are lighter, often flexible, and have the potential to revolutionize handheld and lightweight displays, such as those used in phones, PDAs and flexible screens (see Technology Brief 6 on page 106).

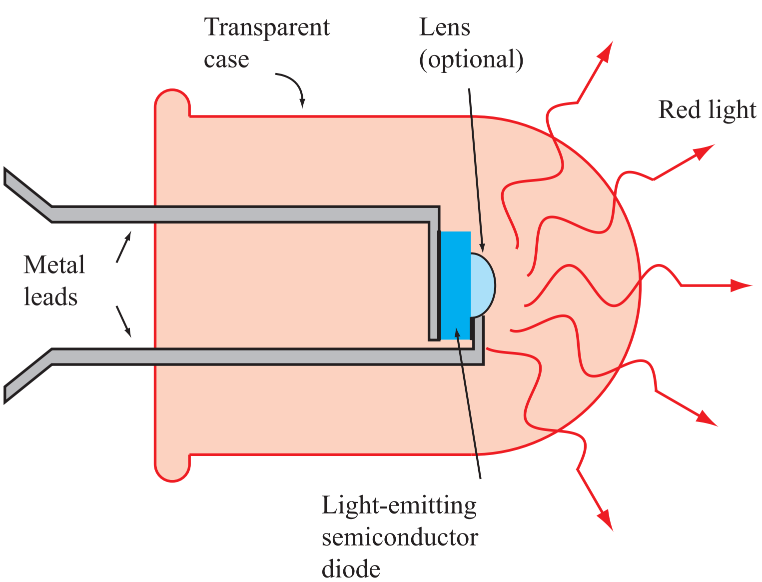

Figure TF5-1: Basic configuration of an LED.

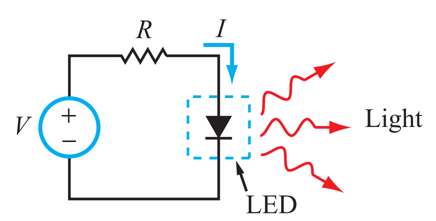

Figure TF5-2: Circuit diagram for an LED circuit; the flow of current through the LED results in the emission of light photons. The light intensity is proportional to *I*.