20.10 SOLAR CELLS

In recent years there has been increasing interest in the solar cell as an alternative source of energy. When we consider that the power density received from the sun at sea level is about 100 mW/cm^2 (1 kW/m^2), it is certainly an energy source that requires further research and development to maximize the conversion efficiency from solar to electrical energy.

The basic construction of a silicon *p-n* junction solar cell appears in Fig. 20.42. As shown in the top view, every effort is made to ensure that the surface area perpendicular to the sun is a maximum. Also, note that the metallic conductor connected to the *p*-type material and the thickness of the *p*-type material are such that they ensure that a maximum number of photons of light energy will reach the junction. A photon of light energy in this region may collide with a valence electron and impart to it sufficient energy to leave the parent atom. The result is a generation of free electrons and holes. This phenomenon will occur on each side of the junction. In the *p*-type

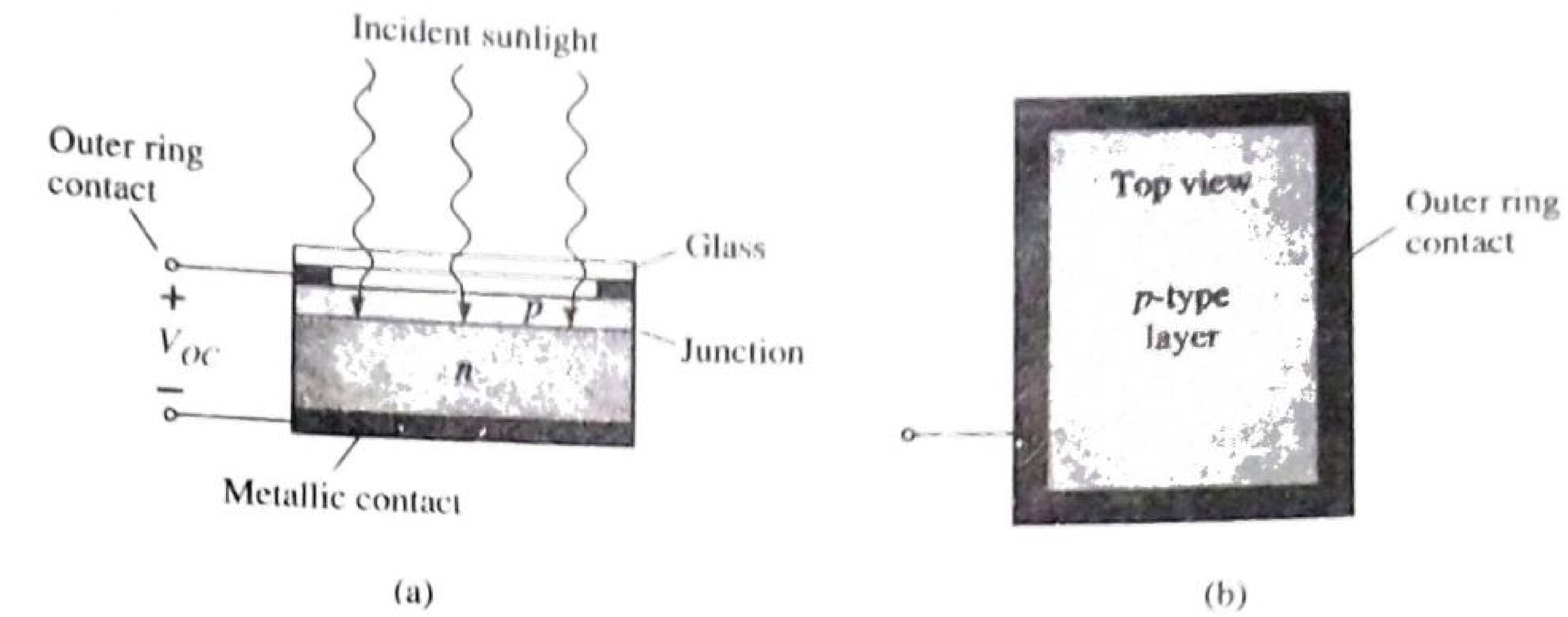

Figure 20.42 Solar cell: (a) cross section; (b) top view.

materia the newly generated electrons are minority carriers and will move rather freely across the junction as explained for the basic p-n junction with no applied bias. A similar discussion is true for the holes generated in the n-type material. The result is an increase in the minority-carrier flow which is opposite in direction to the conventional forward current of a p-n junction. This increase in reverse current is shown in Fig. 20.43. Since $V = 0$ anywhere on the vertical axis and represents a short-circuit condition, the current at this intersection is called the *short-circuit current* and is represented by the notation I_{SC}. Under open-circuit conditions ($i_d = 0$) the *photovoltaic* voltage V_{OC} will result. This is a logarithmic function of the illumination, as shown in Fig. 20.44. V_{OC} is the terminal voltage of a battery under no-load (open-circuit) conditions. Note, however, in the same figure that the short-circuit current is a linear function of the illumination. That is, it will double for the same increase in illumination (f_{C_1} and $2f_{C_1}$ in Fig. 20.44) while the change in V_{OC} is less for this region. The major increase in V_{OC} occurs for lower-level increases in illumination. Eventually, a further increase in illumination will have very little effect on V_{OC}, although I_{SC} will increase, causing the power capabilities to increase.

Selenium and silicon are the most widely used materials for solar cells, although gallium arsenide, indium arsenide, and cadmium sulfide, among others, are also

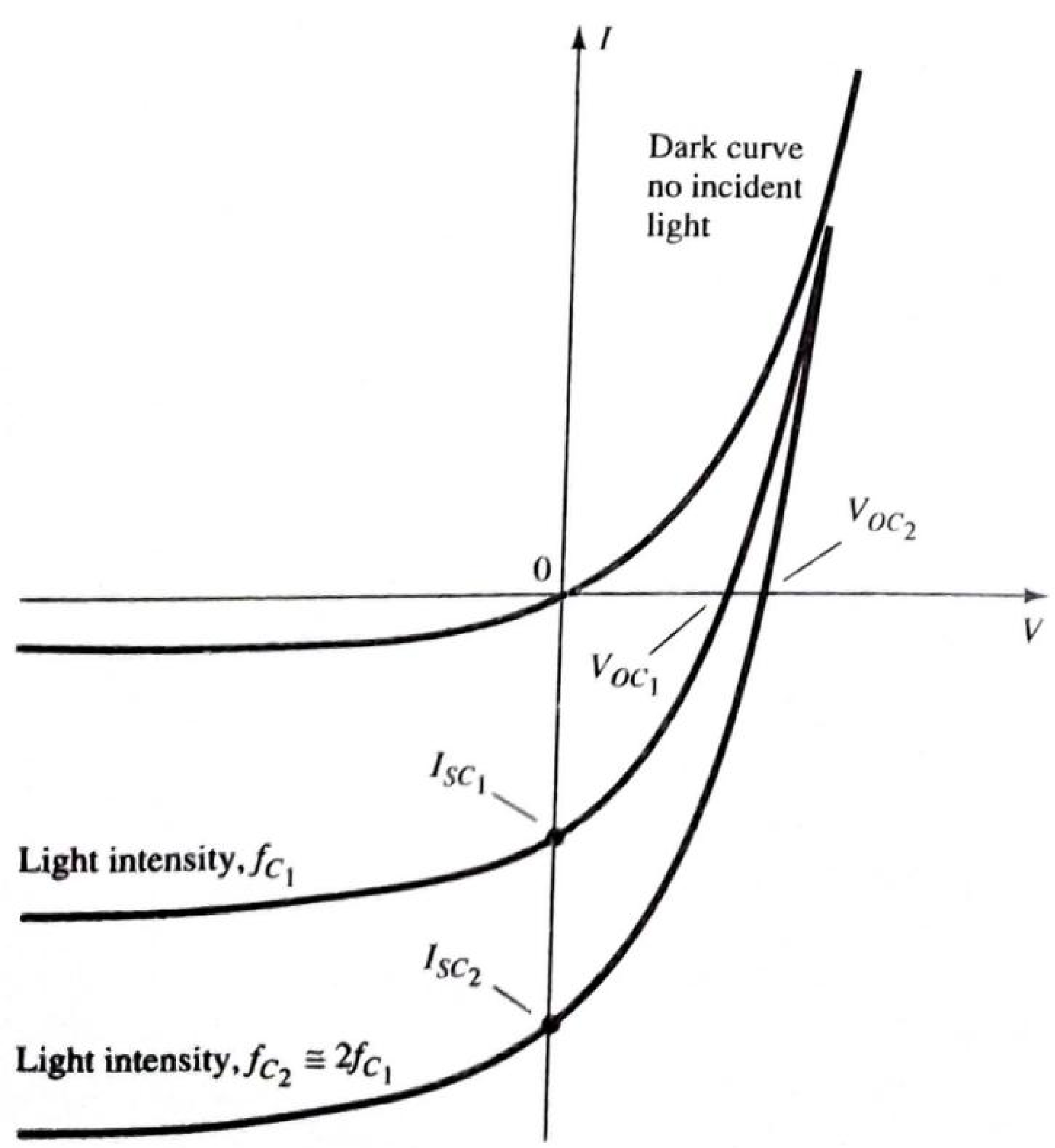

Figure 20.43 Short-circuit current and open-circuit voltage versus light intensity for a solar cell.

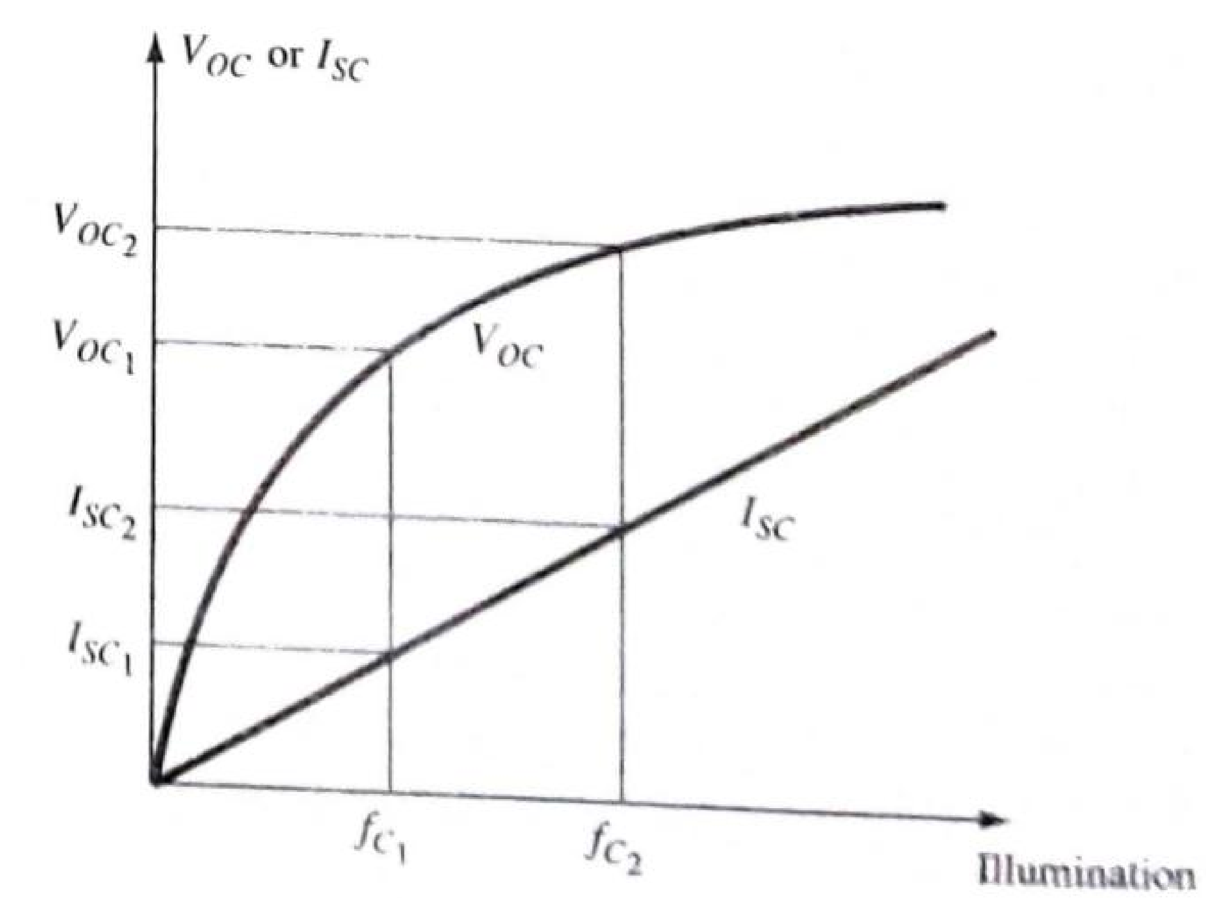

Figure 20.44 V_{OC} and I_{SC} versus illumination for a solar cell.

used. The wavelength of the incident light will affect the response of the p-n junction to the incident photons. Note in Fig. 20.45 how closely the selenium cell response curve matches that of the eye. This fact has widespread application in photographic equipment such as exposure meters and automatic exposure diaphragms. Silicon also overlaps the visible spectrum but has its peak at the 0.8 μm (8000 Å) wavelength, which is in the infrared region. In general, silicon has a higher conversion efficiency and greater stability and is less subject to fatigue. Both materials have excellent temperature characteristics. That is, they can withstand extreme high or low temperatures without a significant drop-off in efficiency. Typical solar cells, with their electrical characteristics, appear in Fig. 20.46.

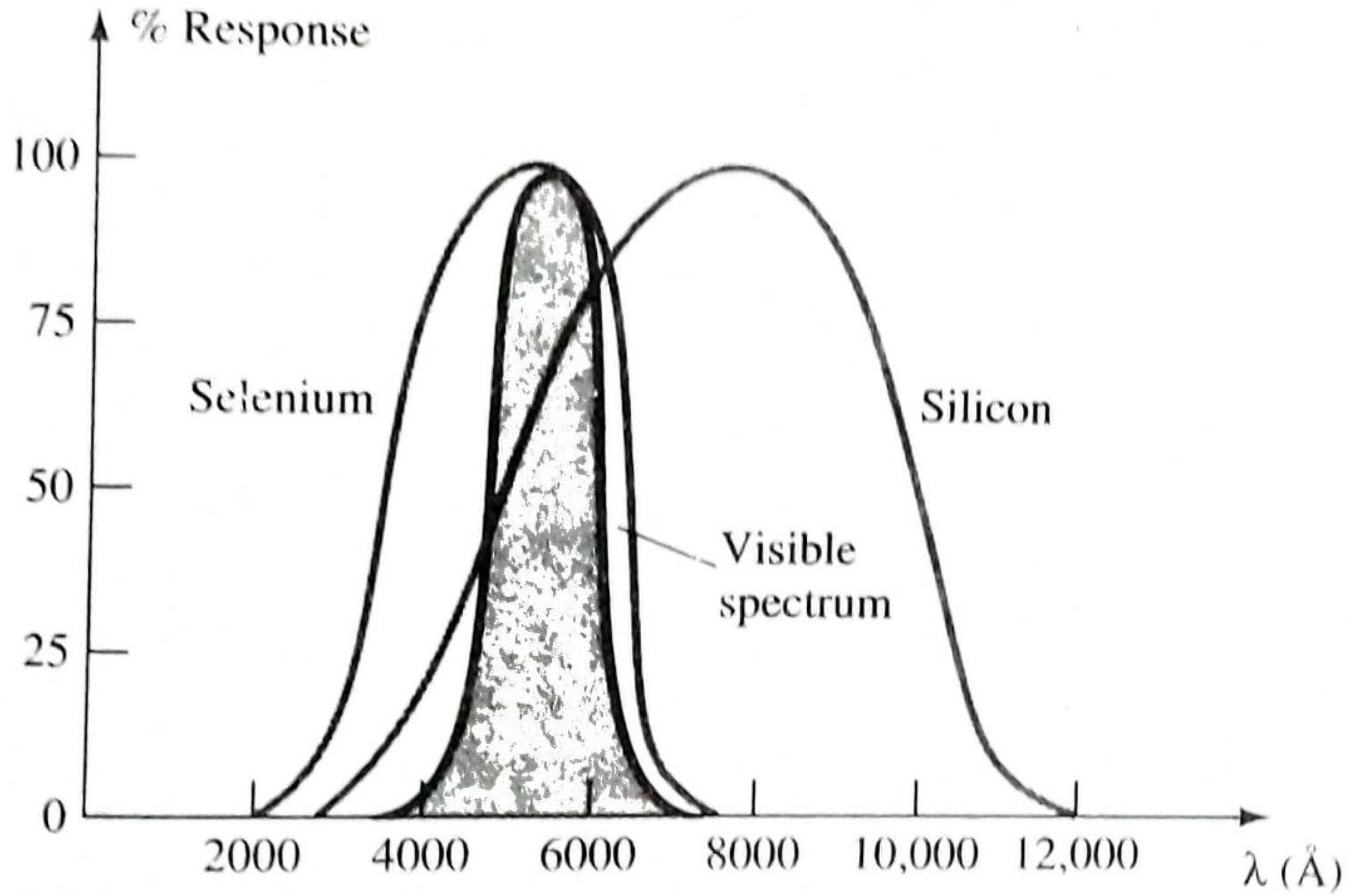

Figure 20.45 Spectral response of Se, Si, and the naked eye.