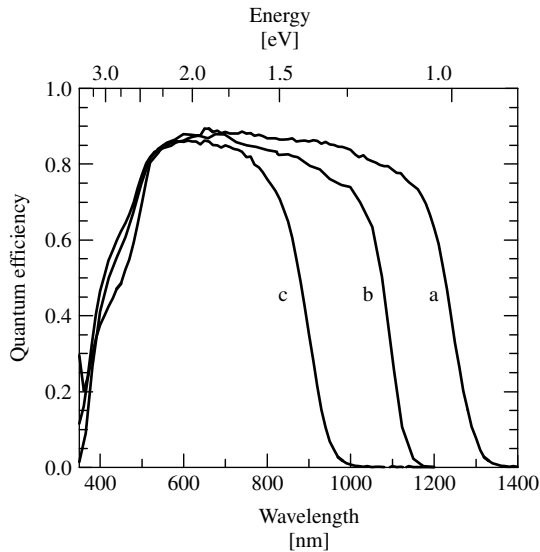


**Figure 13.16** Current–voltage curves for Cu(InGa)Se<sub>2</sub>/CdS solar cells with different relative Ga content giving (a)  $E_g = 1.02$ , (b) 1.16, and (c) 1.4 eV



**Figure 13.17** Quantum efficiency curves for the devices shown in Figure 13.16

To understand the specific diode behavior of Cu(InGa)Se<sub>2</sub>/CdS solar cells, it is instructive to look at the effect of the Cu(InGa)Se<sub>2</sub> band gap, varied by changing  $x \equiv \text{Ga}/(\text{In} + \text{Ga})$ , and temperature. Figures 13.16 and 13.17 show  $J$ – $V$  and  $QE$  curves for 3 devices with  $x = 0, 0.24$ , and  $0.61$ , corresponding to  $E_g = 1.02, 1.16$ , and  $1.40$  eV, respectively.  $V_{OC}$  increases and the position of the long-wavelength  $QE$  edge shifts to greater energy as  $E_g$  increases. Figure 13.18 shows the temperature dependence of  $V_{OC}$  for these devices. In each case, as  $T \rightarrow 0$ ,  $V_{OC} \rightarrow E_g/q$ . Thus, combining equations (13.7)