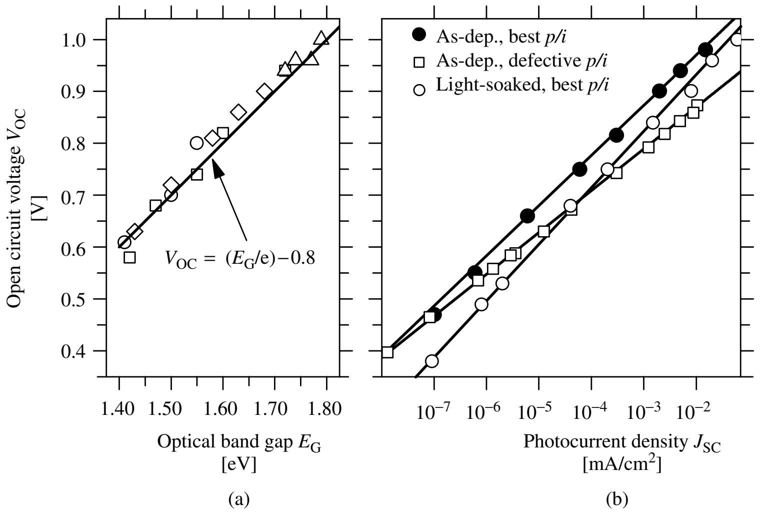

Figure 12.18 (a) Open-circuit voltages for a-Si:H-based solar cells as a function of optical band gap [129]. The band gap variation is mostly due to germanium incorporation. The measurements are from several laboratories; consult the reference for details. (b) Open-circuit voltage V_{OC} versus short-circuit photocurrent density J_{SC} for *nip* solar cells as reported by Pearce *et al.* [130]. The short-circuit current density is proportional to the intensity of the illumination, which had a "white" spectrum similar to solar illumination

larger than 0.95 eV per photon – so over 60% of the absorbed energy must, alas, be lost in such a cell.

The simplicity of the dependence of V_{OC} upon band gap in Figure 12.18 is only possible because open-circuit voltages depend only weakly on (1) the thickness of a-Si:H solar cells and (2) the intensity of illumination. As a result, most details about the cells and measurement conditions are unimportant. For example, in the calculations of Figure 12.17, the open-circuit voltage changed about 10% (from 0.9–1.0 V), while the output power varied from 1 to over 20 mW/cm^2.

Still another simplification applies to many cells. Most workers think that the very best open-circuit voltages in a-Si:H-based cells have reached their "intrinsic limit." This means that these best values are not limited by the details of the *p*- and *n*-type electrode layers [130], but are a fundamental property of the intrinsic layer.

We now give a short argument to explain how V_{OC} is related to the energy profile of Figure 12.14 and why V_{OC} depends only weakly on thickness. The lower panel of Figure 12.14 presents calculated open-circuit profiles of the bandedge levels E_C and E_V of a cell with uniformly absorbed illumination. No Fermi energy is shown in this lower panel because the cell is not in thermal equilibrium – it is exposed to light. Instead, electron and hole quasi-Fermi energies E_{Fe} and E_{Fh} are illustrated, which we will define shortly. Notice that these quasi-Fermi energies merge together at the left edge of the *p*-layer and again at the right edge of the *n*-layer; this merging means that an ordinary Fermi energy can be defined at these edges despite the presence of light. The product eV_{OC} is the difference between these two Fermi levels, as illustrated in the figure. The illuminated