3.15
Photoconductors, Photovoltaics and Photodetectors
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Reference: Pierret, chapter 9.2 and 9.3

Photoconductors – conductivity a function of light
Photovoltaics – generate power from light
Photodetectors – use a pn junction to detect light

<u>Photoconducting materials:</u>
CdS, ZnS for camera lightmeters, amorphous As,Se,Te for photocopiers

<u>Photodiode and Photovoltaic (PV):</u>
Carriers created within L_n or L_p of junction contribute to reverse current:

$$I = I_o + I_G$$

Photodiode operates in reverse bias. A PIN diode has a wide depletion region; operates much faster than a pn junction photodetector because it doesn not rely on diffusion.

A PV operates in the fourth quadrant (positive V, negative I). When connected to a load (e.g. a battery charger or a lightbulb) with resistance R_L,

$$V = I\,(R_{PV} + R_L)$$

also $\quad I = I_o\,(\exp(eV/kT) - 1) + I_G$

these two relations define the voltage and current that the PV produces.

$$\text{Power} = IV$$

Solar Cells: the PV must respond to the visible spectrum (400 – 700 nm, or 2 – 3 eV; note that λ (μm) = 1.24/E (eV))
Ideally we would use a bandgap of about 1.2 eV, but Si does not absorb light well because it has an indirect band gap.

<u>Direct and indirect gap</u>

On an E-k plot: $\quad m^* = \hbar^2 (\partial^2 E / \partial k^2)^{-1}$

Momentum of an electron typically $\pi/a \sim 10^{10}$ m^{-1}

Momentum of a photon $= 2\pi/\lambda \sim 10^{7}$ m^{-1}

If the band gap is indirect, a phonon plus a photon are eeded to make an e-h pair, so light absorption (and emission) is less efficient.
Amorphous Si: uncertainly principle $\quad \Delta x \Delta p \geq \hbar$
-the localization of carriers gives them an uncertain momentum, so direct absorption of light can occur. Use PIN design because mobility is low.

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Please See "This Month in Physics History, October 22, 1938: Invention of Xerography." *APS News* 12 (2003): 2.

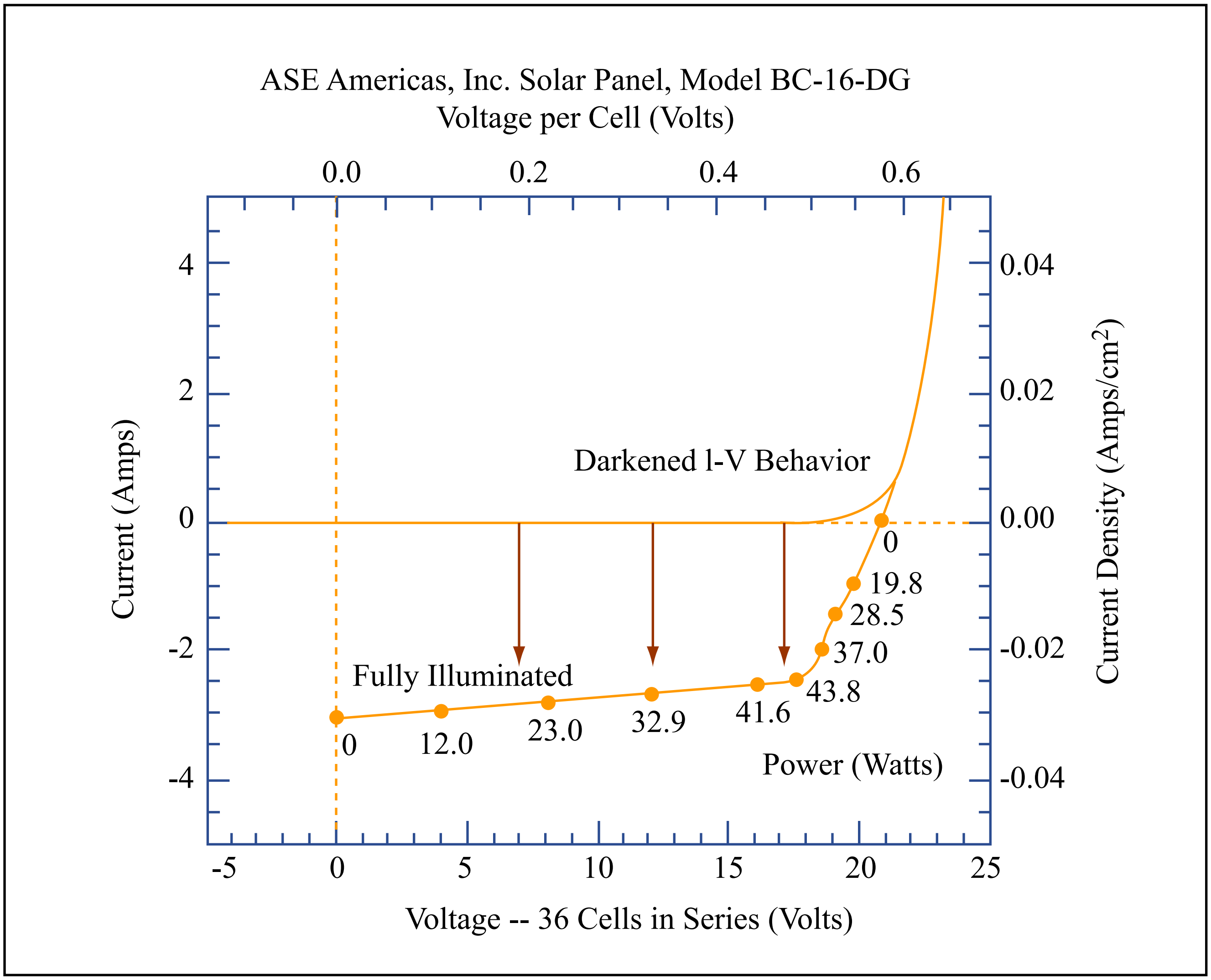

Figure by MIT OCW.