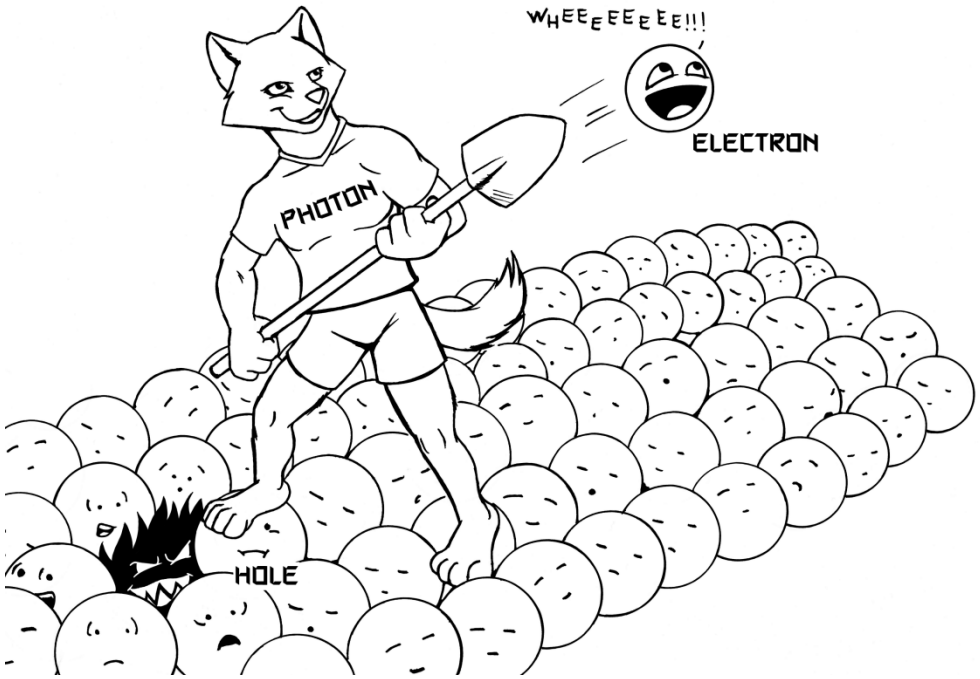
Building Better Solar Cells

by Deuce =^.^=.

(art by Hiker – http://hiker.avbrand.com)

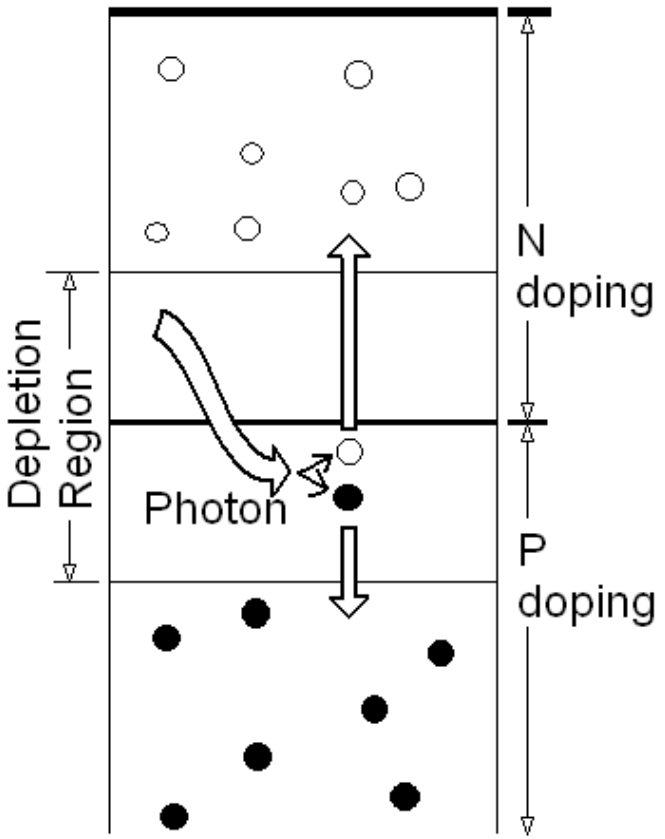
How Solar Cells Work



- Semiconductor crystal has an ordered lattice of “valence” electrons.
- Light particle (“photon”) knocks one free; now it can move around.
- Leaves behind a “hole”, which can also move around.

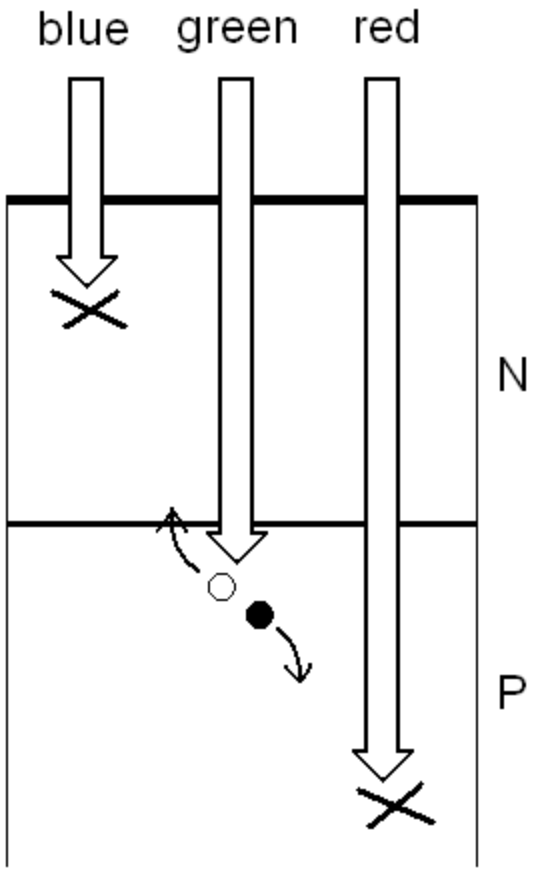
How Solar Cells Work

- A solar cell has “N” type region, “P” type region, and “depletion” region.
- Light makes electrons and holes in the “depletion” region. These wander to N and P terminals, respectively.
- Resulting “photo-current” produces power!

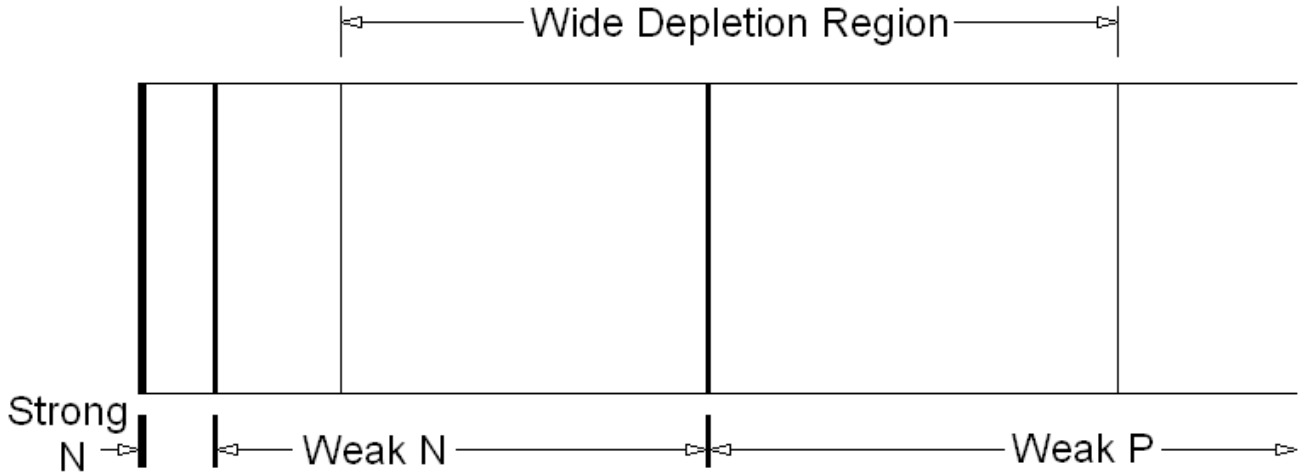


Early Silicon Cells: Problems

- Light travels to different depths in silicon depending on color.
- Too deep: carriers recombine before reaching junction.
- Too shallow: surface defects trap the carriers.



Early Silicon Cells: Solutions

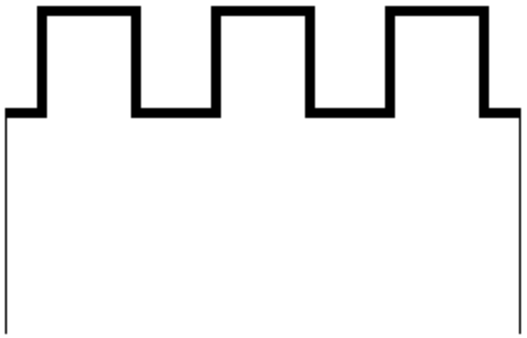


- Fab process specifically for solar cells.
- Weak doping near junction means a large “depletion region” where carriers can wander.
- Strong doping near surface keeps carriers away.

Modern Silicon Cells

- Internal “quantum efficiency” is 60%, but still have to get light into the cell.

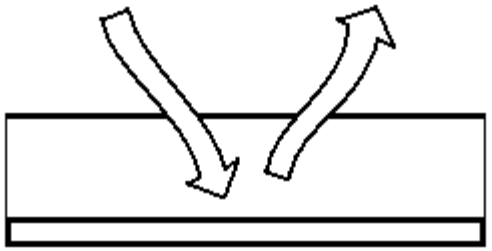
- Approach: Anti-reflection coating.



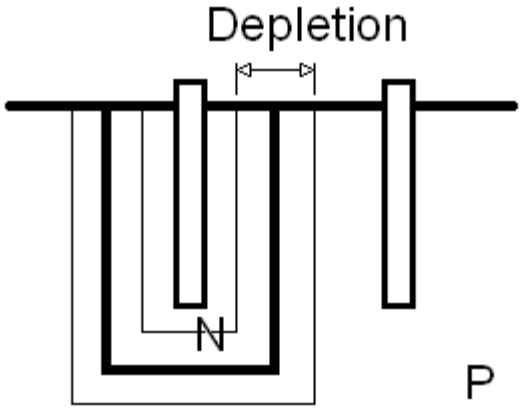
- Approach: Texture.

Modern Silicon Cells

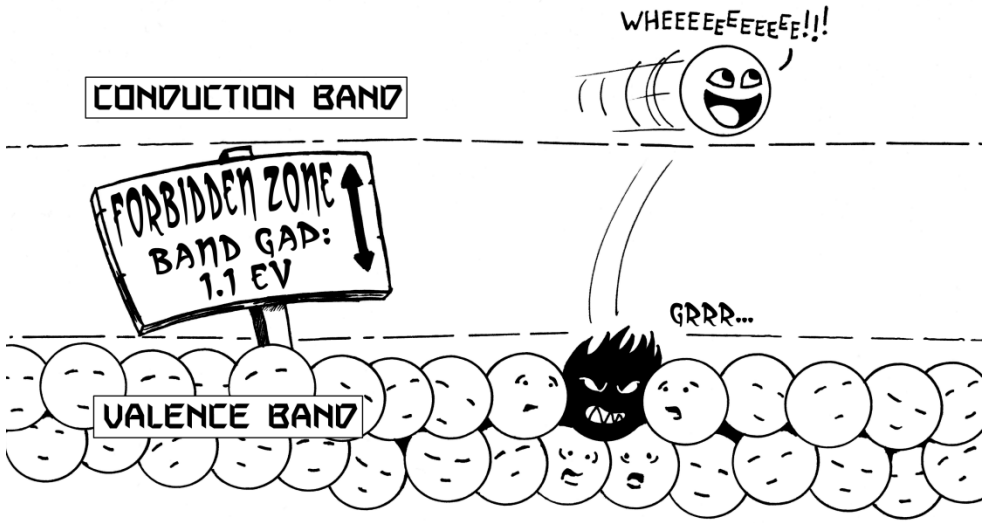
- Can also improve efficiency by increasing chance of capture.



- Approach: Back reflector.
- Approach: Vertical junction.



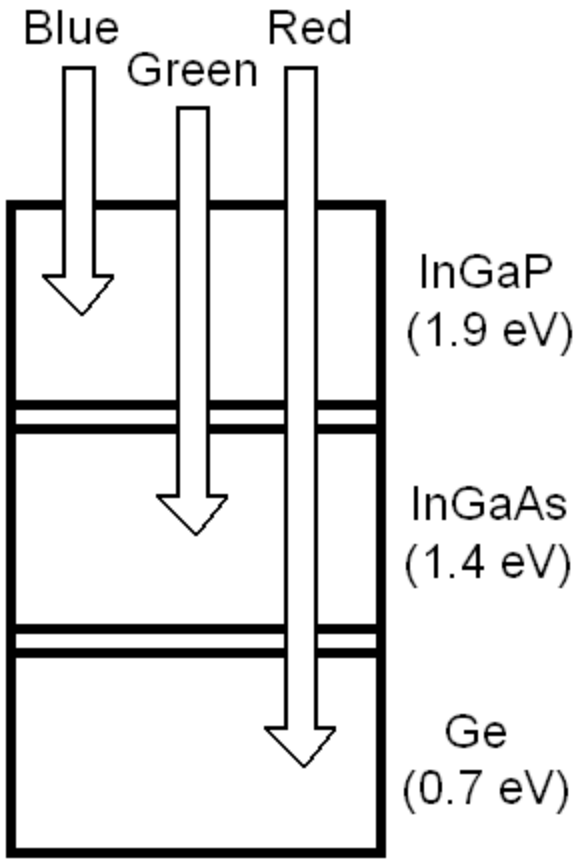
Better than Silicon



- Fundamental problem: “band gap”.
- 1V band gap + 2eV photon means wasted energy.
- 1V band gap + 0.5 eV photon means photon not absorbed.

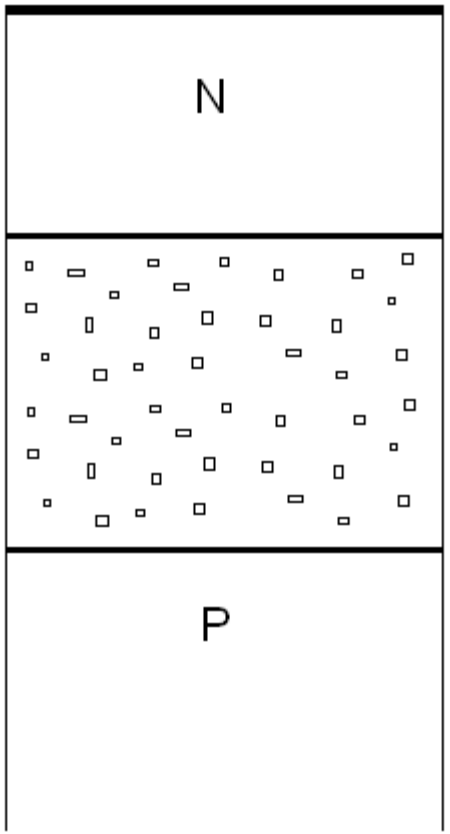
Better than Silicon

- Solution: Multi-junction cell.
- Wide band gap materials on top, narrow band gap materials below.
- Light penetrates until it reaches the layer that best absorbs it.
- Downsides: toxic, expensive, hard to manufacture.



Better that Silicon

- Solution: Nanocrystals.
- Made as tiny silicon crystals inside insulating layer. Acts like a semiconductor.
- Band gap of nanocrystal depends on size. Different sizes gives a tunable band gap.



Cheaper than Crystal Silicon

- Crystalline silicon is expensive.
- Cheaper option: vapor-deposit an amorphous silicon film.
- Problems: Low efficiency, degrades over time.

Looking Forward

- Solar niche: Distributed small-scale power. Big plants use heat engines (more efficient and lower $/watt).

- Key enabling technology will be cells that are cheap and made of mostly-safe materials. Efficiency is secondary.

- My best guess: mature silicon thin-film technology will do it.