Excitons and solar energy

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1 Why we need solar energy

Nowadays world need more and more energy. We have lots of troubles in using traditional energy: We spend lots of money on oil which will be used out in about 50 years. The nuclear energy always causes conflicts between different countries. Hydroelectric energy can not provide stable power due to the period of seasons and the rain. Build big am will also cause small earthquakes and damage to the upper area's environment. Coal power caused too much green house effect and air pollution.

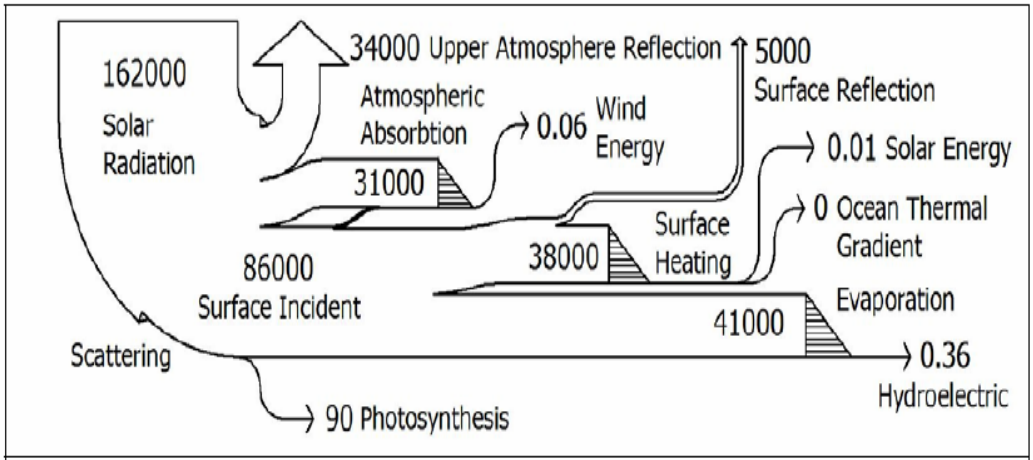


Fig. 2. Solar radiation exergy flow diagram (units in TW) [6]. Shaded surfaces represent natural exergy destruction; arrows represent human use for energy services.

Why not directly get energy from the sun? Remember sun is a independent fusion reactor from which we can safely get energy! Let's look at the picture above. It is really interesting that the hydroelectric energy, wind energy all come from the sun!

Now, what we want to do is directly get energy from the huge amount of energy of solar radiation.

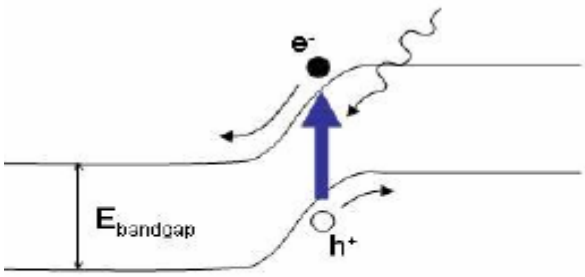
2 Silicon wafer and exciton

Basing on energy band theory, people only consider one electron approximation for one atom, but neglect the interaction between different electrons. In experiment, people find fine structures in the band in the scattering spectrum. Then people introduce the concept of exciton.

Exciton is a bound state of an electron and an imaginary particle (holes) in an insulator or semiconductor, and such is a coulomb-correlated electron-hole pair. It is an elementary excitation, or a quasiparticle of a solid.

The binding energy of exciton lowered the band energy. And the energy levels of exciton are very similar as Hydrogen atoms due to the model have the same style of coulomb attractive potential.

Silicon wafer is the first generation photovoltaic. This kind of semi conductor can absorb photons from the sun. The physics process for the silicon semiconductor is to gain energy from photon: When a photon hits a piece of silicon , the photon can be absorbed by the silicon when the photon energy is higher than the silicon band gap. When a photon is absorbed, its energy is given to an electron in the lattice and make it jump to conduction band. The electron can move freely in conduction band. The place the electron used to stay now is a hole. Since electron in the valence band can full the hole, we can have a equivalent view that the hole is moving in opposite direction. The free moving electron and the hole form a “particle-hole” or an exciton. Since one photon can only excite one electron up to conduction band in semiconductor, only one exciton can be created after absorbing an photon.



n-type *p*-type

In p-n junction, due to the inside electric field, the electron and hole will move in opposite directions and finally be separated. This is the way silicon semiconductor generate current under sun light.

3 The shortcoming of Silicon wafer

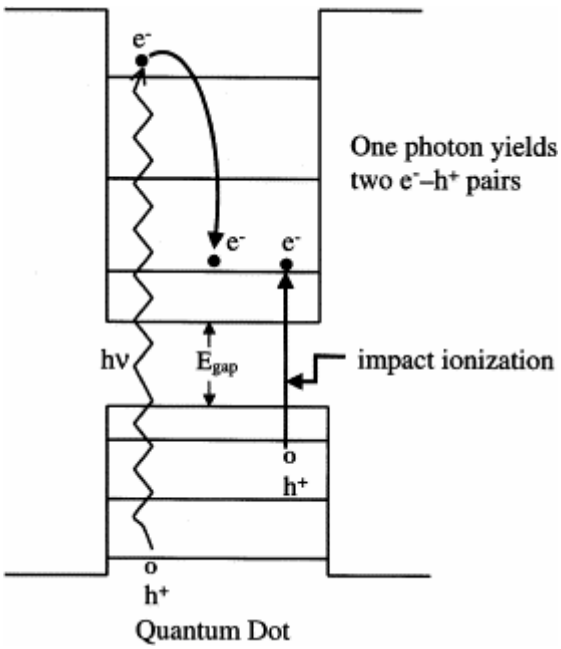
When the exciton be separated and form current in p-n junction, the energy which can be get is equal to the band gap. It means, if the rest energy of photon will be wasted by the excited electron. The additional energy will change into vibration of lattice and finally change into heat energy. As we know, silicon wafer can only use the visible light which only contains small percent of total energy of solar radiation.

The second point is. One photon can only form one exciton. It limits the efficiency of silicon wafer.

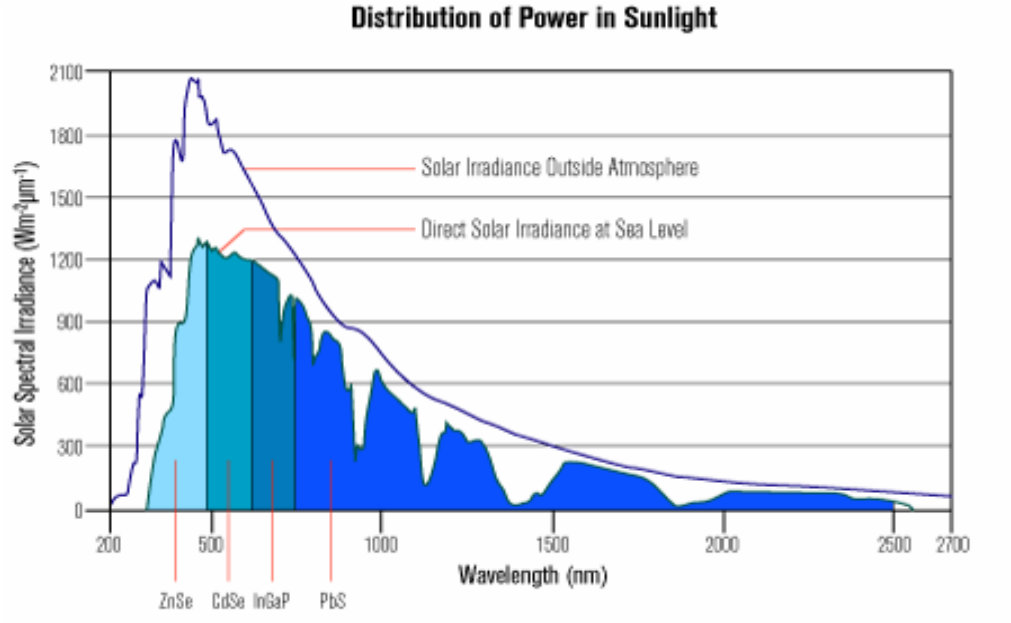
4. Quantum Dot Solar Cells

The third generation photovoltaic cells is Quantum dot solar cells. Quantum dot is kind of small spot made of two layers of different material. Looks like a egg. It means the cover have high potential which make it a “square well” (you can understand in this way). Then there will have bound states and energy levels in the “egg”.

The Quantum dot cells have much higher efficiency than normal silicon cell. It is because there are several excited energy level for excited electrons to stay. So even though the photon is energy is much larger than the gap. The electron can jump to much higher level. Then it can transport the additional energy to other electrons which located in valence band. In this case, if there have enough energy, the first electron can excited multiple ones to the conduction band. It means there have multiple excitons. Compare to silicon cell which can only form one exciton per photon, Quantum Dot use solar energy much more effectively.



Another very important feature is that, technically, Quantum dot’ s band gap is easily to be set. It means we can choose the light with which kind of wavelength we want to choose. Different kinds of Quantum dots cell span almost all solar energy spectrum.



Multiple quantum dot material systems span the entire solar energy spectrum

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