Next Generation Solar Cells

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What are solar cells?

Solar cells utilise the energy from the sun. They are a form of renewable energy and will soon take over the roles of fossil fuels in our current society. The need for alternative energies is growing with the severity of the climate crisis and with a small percentile of our world currently running on solar (~2%), we need to focus on improving the materials that they are composed of.

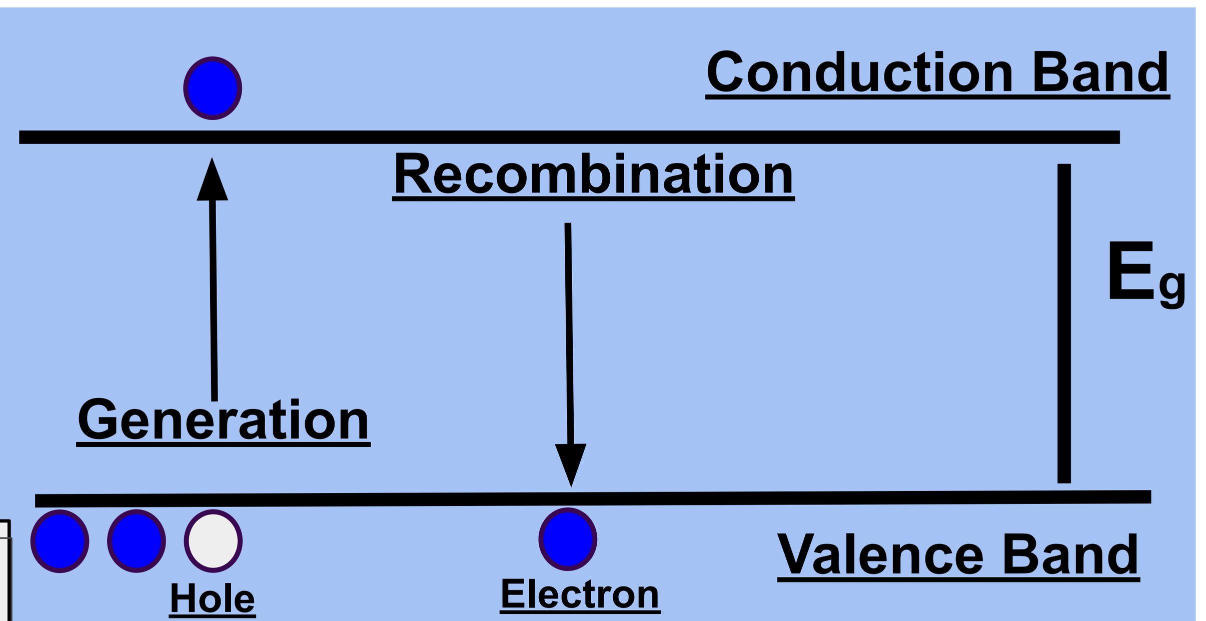
Sourcing non-toxic, sustainably sourced and abundant materials will make the new generation of solar cells to be more efficient, cheap to set up and cut back on harmful greenhouse gases.

How do Solar Cells work?

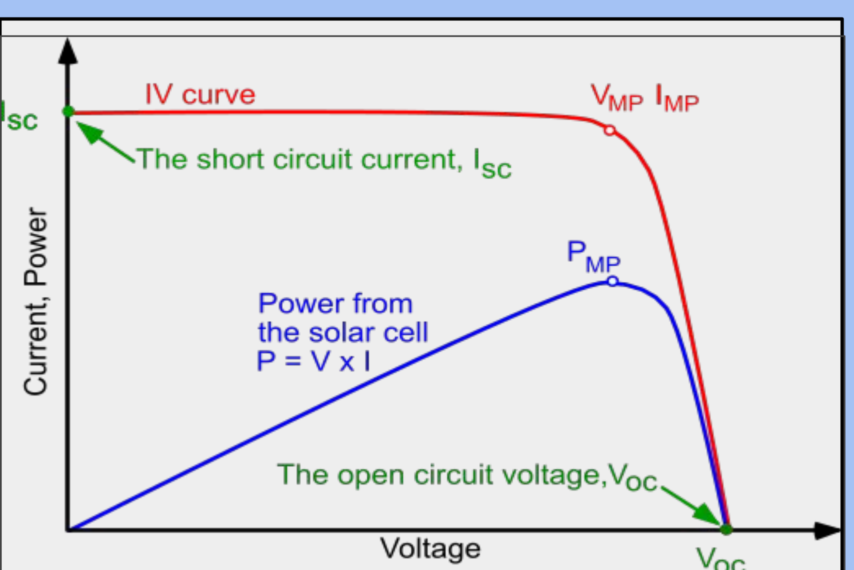
Generation- An electron leaves the valence band(where previously accompanied with the nucleus). The increase in energy now places the electron at the conduction band. A 'hole' replaces the previous position of the electron. An electron-hole pair is created.

Recombination- The opposite to generation. The electron re-occupies the energy state of the hole, 'de-excitation', emitting a photon. This returns to valence band level. The photon energy (E=hf) must be larger than the band gap. A potential difference is generated causing the electron to shift left, and the whole right.

Eg- this is the maximum energy band gap between the conduction band and valence band. Only in the case of a ferroelectric can this be exceeded due to the fact a p-n junction is not required.



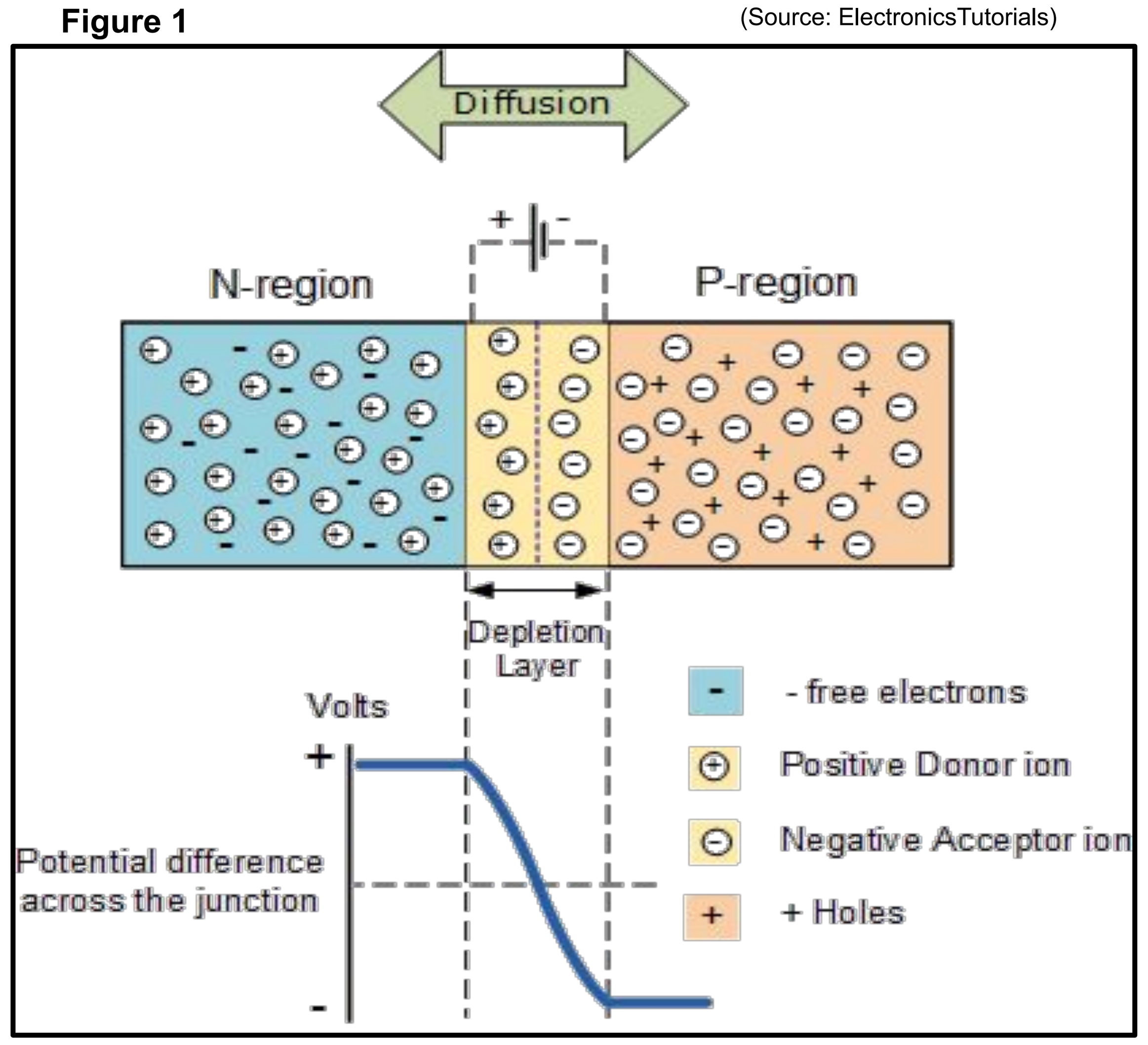
(Figure 2- Solar Cell Process)



Current voltage(IV) of a solar cell. To get maximum power output of a solar cell it needs to operate at the maximum power point, P_{mp}.[5]

- Short circuit current- the voltage passing through the cell will be zero here.
- Open circuit voltage- the current passing through the cell will be zero here.
- Efficiency- ratio of initial input energy to output energy from the solar cell.
- Currently used silicon solar cells have around a 25% efficiency, thin film material having around 20%.
- Fill Factor describes the square likeness of a curve, with the most efficient being most square.
- Absorption coefficient- how well the material absorbs incoming light, how far a photon can penetrate a material, units cm^{-1}.

Figure 1 (Source: ElectronicsTutorials)



References:
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[3] Keith T. Butler, Jarvist M. Frost and Aron Walsh (2014), 'Ferroelectric materials for solar energy conversion: photoferroics revisited', *Energy & Environmental Science,* Royal Society of Chemistry, 8, 838-848, (Accessed on 17 February 2021)
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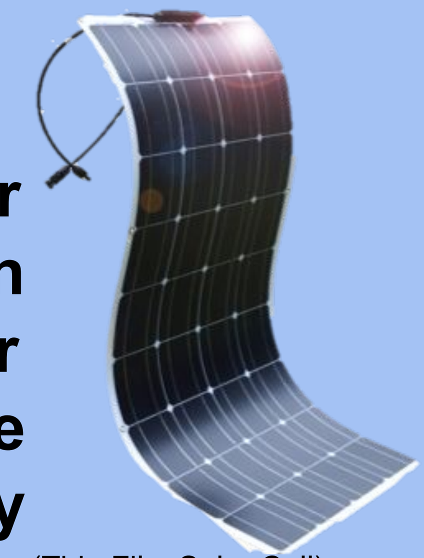
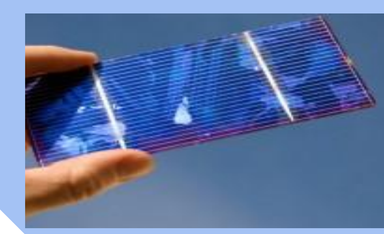
[5] C.B. Honsberg, S.G. Bowden (2019), *IV Curve,* Available at: www.pveducation.org, (Accessed on 18 February 2021)
[6] Oliver Rigby (2021), *Next Generation Materials for Solar Cells: Ferroelectric Photovoltaics,* (Accessed on 16 February 2021)

Current Materials

Currently, around 90% of the material used in solar cells is silicon and around 10% is a mix of 'thin film' technologies. However, the future of solar cells requires new and better materials, which are earth abundant, non-toxic, cheap and sustainably sourced.



(Thin Film Solar Cell)



(Silicon Solar Cell)

Though silicon is very cheap and abundant, the process of making silica into silicon is energy intensive and the energy band gap is outside the optimal range. Thin films have their energy gaps within the range and have good conductivities but have limitations such as difficult installation, shorter lifetime and higher space requirement.[1]

Ferroelectric (FE) Photovoltaics

Ferroelectric materials (FE) have spontaneous polarisation[2] as an electron dipole naturally exists. This means that an electric field is around the entirety of the material due to the the existence of the electric dipole. Another special quality is that these materials have a "memory" of their past net polarisation.[4]

As photovoltaic materials, the naturally occuring net field helps separate the photo-generated charges. This is more effective than semiconductors. Another thing is that FE materials are able to produce a photovoltage greater than the E_g.

Bournonite ($CuPbSbS_3$) is stable as it naturally occurs in the Earth. It has a direct E_g of ~1.3 eV which is ideal for solar cells. The predicted absorption coefficient (for wavelengths between 300nm to 900nm) is $10cm^4$, which is higher than silicon ($\sim 10cm^3$).

Conclusion

Over the past decade, the cost of solar energy has significantly decreased and new research gives hope for increased efficiency and even lower costs. As mentioned above, ferroelectrics are a large subject of research but, only one research group has published a working bournonite solar cell. Hence, research continues as development of solar energy becomes increasingly more important. [6]