How is electricity generated in PV panels?

To answer this question, we need to revisit some physics concepts:

1.1 Energy Band Model

According to Niels Bohr (1885), an atom consists of a core of protons and neutrons, circled by electrons in distinct orbits which are determined by a specific energy balance. Each atom contains the same number of negatively charged electrons as positively charged protons (neutrons have zero charge). When energy is applied, an electron can jump to an orbit further away from the core. If the energy is not sufficient to reach the next orbit, the electron will fall back to its original orbit. The energy level increases with increasing distance from the core.

The orbits of electrons, in a solid, interact with each other and form certain energy bands. Each energy band has a maximum capacity to take on electrons. The highest complete energy band is called the valence band, the next energy band is the conduction band which might be empty or partially filled. The space between those two bands is called the forbidden zone: electrons are not able to stay here.

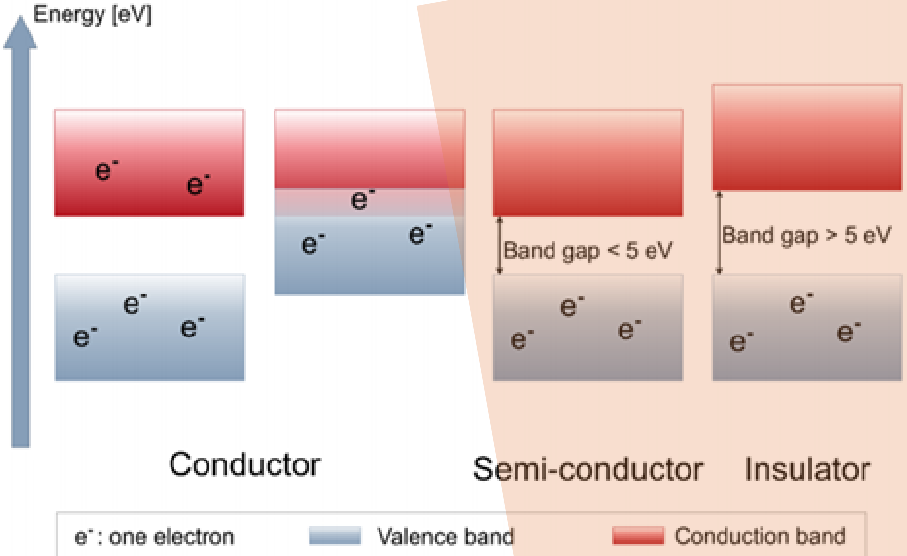
The distance between these two bands is the band gap.

Different materials have different band gaps, and this determines the conductivity of the material:

• Conductor: either there are electrons in the conduction band or conduction band and valence band overlap (i.e., there is no band gap)

• Semiconductor: there are no electrons in the conduction band and the band gap is smaller than 5 eV.

• Insulator: there are no electrons in the conduction band and the band gap is larger than 5 eV, thus it is very difficult to lift electrons into the conduction band



Energy bands and band gap

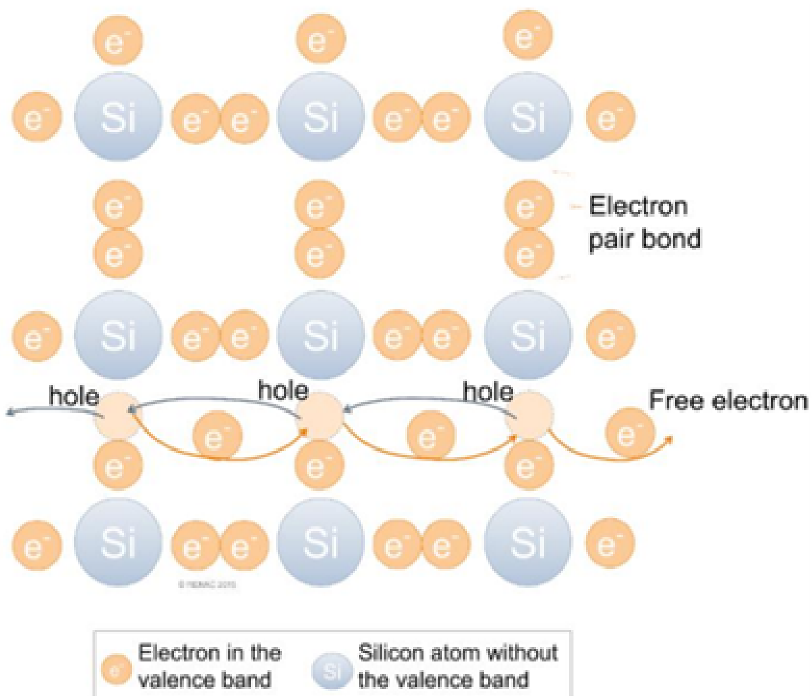
2.2 Photovoltaic Effect

A material that has the ability to act as either a conductor or an insulator is called a semiconductor. The electrical conductivity of the material, or its capacity to conduct electricity, can be regulated by changing the material's properties or by applying external influences, such as sunlight. PV cells are manufactured from a variety of semiconductor materials, creating various PV technologies. Silicon metal, for example, is a semiconductor, and is the most common material used to make PV cells.
When semiconductor materials are exposed to sunlight, energy-carrying photons strike the material.

Since the energy of photons in the sunlight spectrum varies, a variety of interactions can happen:

1. Some of the photons will be reflected off the surface of the PV cell.
2. Some will be absorbed in the outer coating layers protecting the PV cell.
3. Some of the low-energy photons (long wavelength infrared) will pass directly through the PV cell without transferring energy.
4. A large proportion of the photons will be absorbed into the material itself.

Electrons in the atomic structure of the PV cell material absorb some of the energy from this last group of photons. The additional energy input causes the electrons to excite from the valence band of their atoms to the conduction band. This increased energy level frees the energised electrons, and enables them to move around the atomic lattice of the material ('conduction'). As an electron becomes mobilised or 'free', it breaks away from its parent atom, leaving a so-called 'hole' behind. These holes are also mobile, passing from atom to atom as the free electrons pass in the opposite directionz

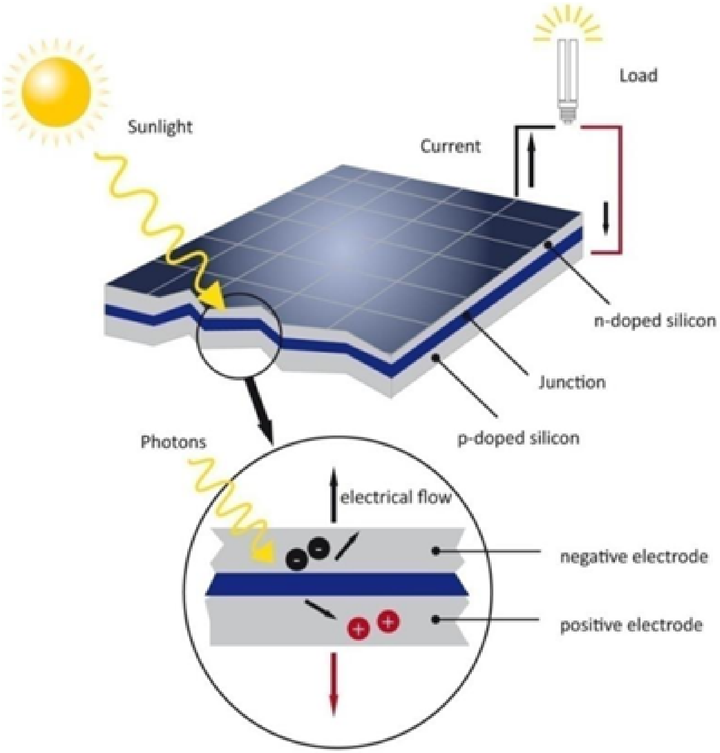


Movement of free electrons and holes in the silicon crystal structure

2.3 The P-N Junction

By doping the semiconductor, i.e., adding tiny amounts of other elements like boron or phosphorus to the crystalline structure of the silicon, p- or n-type semiconductors are formed, respectively. Excess electrons and holes are thereby made available in the material, increasing its conductivity. Semiconductors with a p-type doping have more holes available (and therefore, the absence of an electron creates the effect of a positive charge), and semiconductors with an n-type doping have more electrons available (and therefore, these electrons are free to move around and allow an electric current to flow through the silicon). By bringing the n-type doping and p-type doping materials together, a p-n junction is formed, and an electric field is created within the semiconductor. This electric field serves to forcefully separate mobile electrons in the n-type material and holes in the p- type material in a region called "depletion

region", which allows for the directional channeling of the photocurrent produced in the PV cell. This DC electricity is routed to the metal electrodes on either side of the PV cell and delivered to the output contacts, where it can be consumed in an electrical load.
Some electron-hole pairs recombine before arriving at the contacts, causing the PV cell to heat up.



Silicon PV cell working principle

In the upcoming whitepapers we will discuss more about different types of photovoltaic cells an modules. Don't hesitate to contact us for any further information:

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