Crystals and the Absorption of Photons

When billions and billions of atoms, such as silicon (Si), come together to form a crystal, the available energy levels for the electrons are still quantized, but now there are a great many closely-spaced levels. The values of the electron energies separate into two bands separated by a band gap energy E_g. The low energy band is called the valence band, and the electrons occupying these states provide the basic chemical bonds which hold the whole crystal together. The higher energy band is called the conduction band, and electrons occupying states within this band are free to move throughout the crystal. A perfect crystal with band gap energy this large has no electrons in the conduction band at room temperature.

A photon can provide the energy to "move" an electron from the valence band to the conduction band. Here, "move" is used in the energetic sense. The energy of the electron is increased when a photon is absorbed. But the photon must have an energy greater than the band gap. When an electron is excited from the valence band to the conduction band a hole is created in the valence band Both the photo-generated electron and hole are free to move in three dimensions through the crystal.

Pictured below is a crystal with $E_g = 3eV$. The green ($3eV$) and violet ($5eV$) photons have sufficient energy to generate a conduction band electron, indicated by $-$, and a vacancy or hole in the valence band, indicated by $+$. The orange photon ($2eV$) cannot be absorbed because there is no energy level available for an electron between the valence and conduction bands.

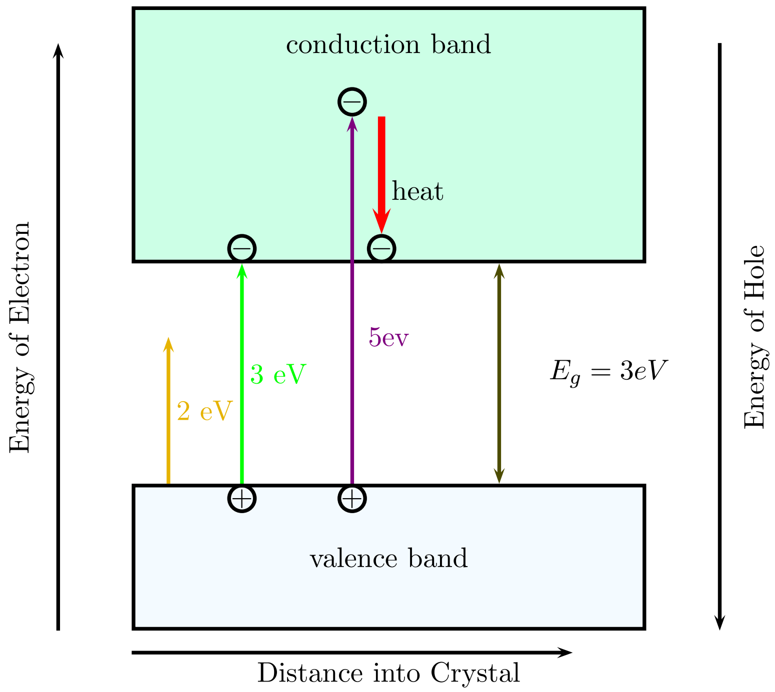

Figure 1: The energy bands of a crystal and the effects of absorption of photons.

When the energy of the absorbed photon is greater than the band gap energy, the electron has the full energy of the photon for only a brief period of time, less than 10^{-12} second. The electron rapidly loses the extra energy above the band gap as heat to the crystal. After that, the electron will recombine with the hole to emit a $3eV$ photon or transfer its energy as heat to the crystal.

The energy of the excited electron-hole pair cannot be tapped for electrical work. There are no preferred directions in which the electrons and holes move. Therefore, there are no points at which to attach wires to draw current through an external circuit.