What Is Energy Band Model?

Complete the following text with the missing terms: *(a)Pauli exclusion, (b)moving around, (c)insulators, (d) interactions, (e)closer, (f)split again, (g)conduction band, (h)far enough, (i)valence band, (l)forbidden region, (m)lowest possible, (n)distance, (o)electron (p) energy band, (q)almost completely, (r)crystalline silicon, (s)chemical reactions, (t)unoccupied*

In this video we will discuss the energy levels in semiconductors. This (1) …………model can be used for all solid materials, not just semiconductors. At the end, we will use this model to explain the electrical conductivity difference between (2)……………….., metals and semiconductors.

In an isolated silicon atom, its energy levels are quantized. The electronic energy states within a group of silicon atoms are all identical – as long as these atoms are (3)………………..apart so that they do not interact.

But when two silicon atoms are brought close together, the quantized energy levels get mixed up and split into two different levels because of the mutual (4)………………….. Keep in mind though, we are only talking about valence electrons here since all lower level electrons are tightly bound to the nucleus and typically don't involve in (5)…………………….or atom-to-atom interactions.

More generally, when N atoms are moved (6)…………………, the energy levels split into N levels. These N levels are very close to each other. If N is large, which is the case in a crystal, they eventually form a continuous energy band.

This figure shows the formation of the bands as a function of the inter-atomic (7)………………… (Lattice Constant d).

When the lattice constant d gets even smaller and finally at the equilibrium inter-atomic distance, the band (8)……………….... But now there are 4 quantum states per atom in the upper band and 4 quantum states per atom in the lower band. The upper band is called the (9)……………………………., and the lower band is called the (10)……………………… 4 times N is 4N, so in total there are 4N conduction band states and 4N valence band states.

The lowest energy level of the conduction band is denoted as EC and the highest energy level of the valence band is denoted as EV and we also get the relationship Eg=EC-EV. The band gap energy Eg is the energy levels that electrons cannot occupy. This (11)………………………is called the gap and its width Eg is a characteristic of the material.

The conduction band CB and valence band VB represent the energies of the states that could potentially be occupied by electrons. But, pay close attention here, they do not provide any information about the ACTUAL occupation of the energy states by electrons.

In filling the allowed energy band states, electrons tend to fill the (12)……………….energies. Each allowed state can only be occupied by one electron, this is called the (13)……………principle. So that the 4N valence band states can just accommodate what were formerly 4N valence electrons, we typically find that the valence band is (14)……………….full with electrons and the conduction band is all but devoid of electrons. At absolute zero temperature 0°K, the valence band is completely filled and the conduction band completely empty.

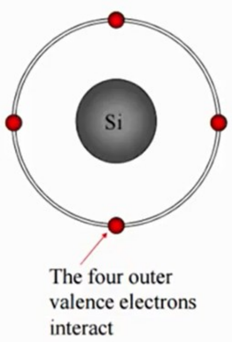
Here is one big concept that we should memorize. Unlike the valence electrons in an isolated atom, these band electrons in (15)………………..are not tied to any one particular atom. On the average, we typically find four electrons being shared between any given silicon atom and its four nearest neighbors. However, the identity of the shared electrons changes as a function of time, with the electrons (16)…………………from point to point in the crystal. In other words, the allowed electronic states are no longer atomic states but are associated with the crystal as a whole.

Once we know the band structure of a given material we still need to find out which energy levels are occupied and whether specific bands are empty, partially filled or completely filled.

Empty bands do not contain electrons. Therefore, they do not contribute to the electrical conductivity of the material.

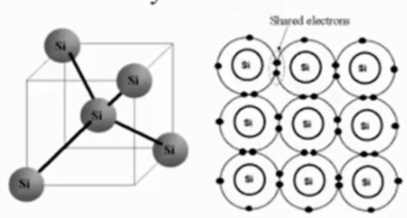
Partially filled bands do contain electrons as well as available energy levels at slightly higher energies. These (17)………………energy levels enable electrons to gain energy when moving in an applied electric field. Electrons in a partially filled band therefore do contribute to the electrical conductivity of the material.

Completely filled bands do contain plenty of electrons but do NOT contribute to the conductivity of the material. This is because the electrons cannot gain energy since all energy levels are already filled.

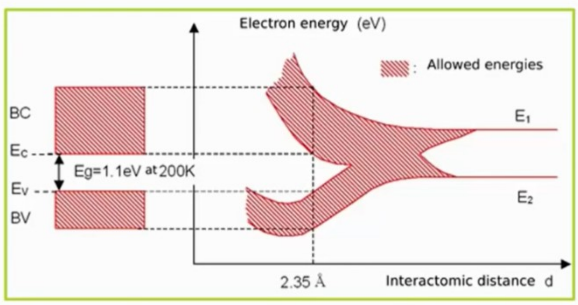


Isolated Silicon Atom

Crystal Structure of Single Crystal Silicon



Crystalline Silicon



Energy Levels vs. Inter-Atomic Distance