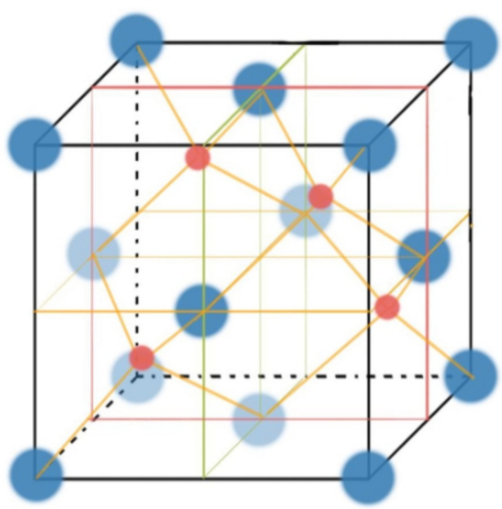
9.2 Compound Semiconductors and Mixed Bonding

By Professor Jun Nogami

Column IV of the periodic table has as its first three elements C, Si, and Ge. All three have the diamond cubic crystal structure and exhibit covalent bonding (although of course C can also have other crystal structures). Diamonds are insulators, whereas Si and Ge are semiconductors.

However, there is another class of semiconductors that is extremely important: the compound semiconductors.

Consider the crystal structure of GaAs. It crystallizes in the zincblende structure, which is a variant of the diamond structure in which Si atoms are replaced by alternating pairs of Ga and As atoms.



The zincblende crystal structure.

The elements Ga and As lie on either side of Ge, and this type of semiconductor is called a III-V compound semiconductor. There is some degree of charge transfer from the As to the Ga, making their average valence close to four, which accommodates the tetrahedral bonding in this structure. This type of bonding is called mixed bonding, and it has characteristics between ionic and covalent bonding.

It is also possible to have II-VI compound semiconductors. An example is CdTe which also has the zincblende structure. However, beyond that, a I-VII atom pair would result in an ionic material.

Compound semiconductors have the important property that they can emit as well as absorb light. The emitted light has the photon energy that is equal to the bandgap of the semiconductor. This is the basis for light emitting diode (LED) technology.

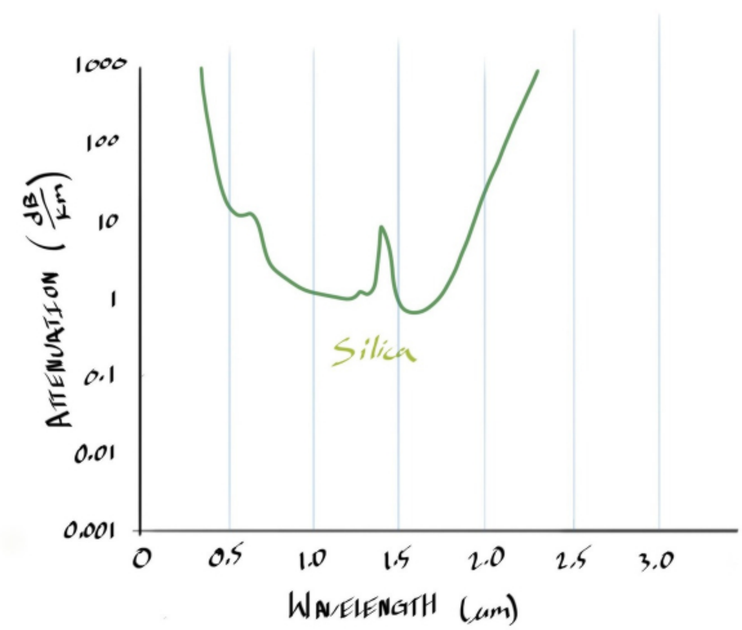
In the case of GaAs, the band gap is 1.4 eV, which is in the infrared. Aluminum arsenide has a larger band gap, and one can construct a semiconductor alloy of the form

$$Ga_x Al_{1-x} As$$

Where the As content is constant at 50%, but the group III site in the zincblende structure is occupied by 100x % Ga and 100(1-x) % Al, with 0<x<1. In this manner, one can create an alloy that emits a photon at a chosen energy that is between the bandgaps of the two materials. This system was responsible for the first generation of LEDs which were red, and then orange.

Why is it important to create an LED of a very specific colour?

The optical transparency of the special glass used in optical fibre communication looks like this:



Silica signal attenuation versus wavelength

So if you can hit a wavelength of just above 1.5 microns, then the signal in your transoceanic optical fiber will be stronger.

Over the years many more compound semiconductors have been developed and put into devices. Some of the most important are based on GaN, which has a band gap that is large enough that it emits in the blue end of the spectrum. With the advent of these larger band gap materials, it has been possible to make all colours of LEDs.

How do white LEDs work?

There are two ways in which to make white LEDs. The more expensive but more efficient way is to have a combination of single colour LEDs, similar to the red green blue (RGB) technologies underlying all colour displays. However, there is a cheaper way to do it: to have an LED in the blue end of the spectrum that excites a phosphor material that converts some of the light energy to lower wavelengths simulating white light. This is the basis for those cheap LED Christmas lights.

9.ex2.1

Review

Mark as: None

GaAs has a bandgap of 1.4 eV and AlAs has a bandgap of 3.14 eV. Assume that the bandgap of Ga_xAl_(1-x)As varies linearly with x. If you want to make an orange LED that emits at wavelength 600 nm, what is the value of x that you should use?

Type your numeric answer and submit

Correct Answer:

✓ 0.6

Show Submitted Answer

Hide Correct Answer

Check My Answer