Exciton Recombination Mechanisms in General

Advanced

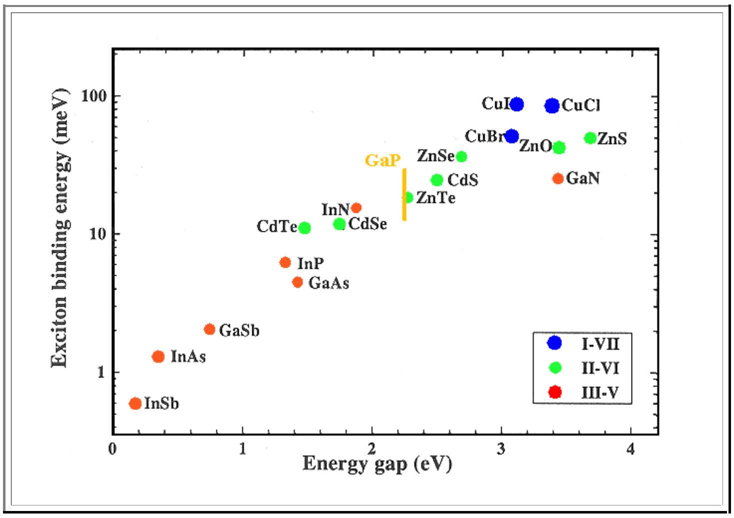
- In chapter 5.1.3 several questions concerning exciton recombination mechanisms were asked:
  - Why GaP? How about other **III-V** compound semiconductors?
  - How about more exotic semiconductors? The **II-VI** system, organic semiconductors?
  - Anything similar for elemental semiconductors? Afer all, putting **Ge** into **Si** also changes the potential locally.
  - How about other defects, not necessarily isoelectronic ones? For example, ionized donors and acceptors also attract and possibly "bind" freee electrons or holes, respectively?
- Lets see about some answers. But first some more data to excitons in general

Excitons in Semiconductors

- First lets look at the binding energy of free excitons in various semiconductors
  - The values for the effective masses, m^*_e and m^*_h (in units of the free electron mass) are included (compare with the values given before to see how literature values can differ).
  - For completeness, we also give the numbers for ϵ_r and the nominal exciton Bohr radius r_X at which the particles would circle each other.
  - We have $\mathbf{k}T_{\mathbf{room}} \approx$ **25 meV**; only exciton energies **> 20 meV** are usable; those are colored blue.

Material	m^*_e	m^*_h	ϵ_r	E_b [meV]	r_X [nm]
BN	0.752	0.38	5.1	131	1.1
GaN	0.20	0.80	9.3	25.2	3.1
GaAs	0.063	0.50	13.2	4.4	12.5
InP	0.079	0.60	12.6	6.0	9.5
GaSb	0.041	0.28	15.7	2.0	23.2
GaP					
InAs	0.024	0.41	15.2	1.3	35.5
InSb	0.014	0.42	17.3	0.6	67.5
ZnS	0.34	1.76	8.9	49.0	1.7
ZnO	0.28	0.59	7.8	42.5	2.2
ZnSe	0.16	0.78	7.1	35.9	2.8
CdS	0.21	0.68	9.4	24.7	3.1
ZnTe	0.12	0.6	8.7	18.0	4.6
CdSe	0.11	0.45	10.2	11.6	6.1
CdTe	0.096	0.63	10.2	10.9	6.5
HgTe	0.031	0.32	21.0	0.87	39.3
Si				7.5	

- There is a definite correlation of the binding energy E_b with the bandgap as shown in the following figure. Since **GaP** was not contained in the origial data, an indication of its probable position is included.



How About Bound Excitons in Other III-V Semiconductors?

There are a couple of other semiconductors where isoelectronic "dopant" atoms play some role:

- **Bi** replacing **P** in **InP**
- **N**, or **N-N** pairs, replacing **P** or **As** in $\mathbf{GaAs_{1-x}P_x}$

Anything Similar for Elemental Semiconductors?

Yes – at low temperatures!

- In **Si**, the radiative part of the recombination proceeds to about **85 %** via (free) excitons at **85 K**, and at **20 K** it is close to **100 %**.
- Recombination due to excitons bound to $\mathbf{As^+}$ donors have been obseved, too. The binding energy is about **6.5 meV**.
- However, non-radiative recombination is still the major channel, so even at low tempertures **Si** is not a good emitter of light.