PHY404- Solid State Physics II

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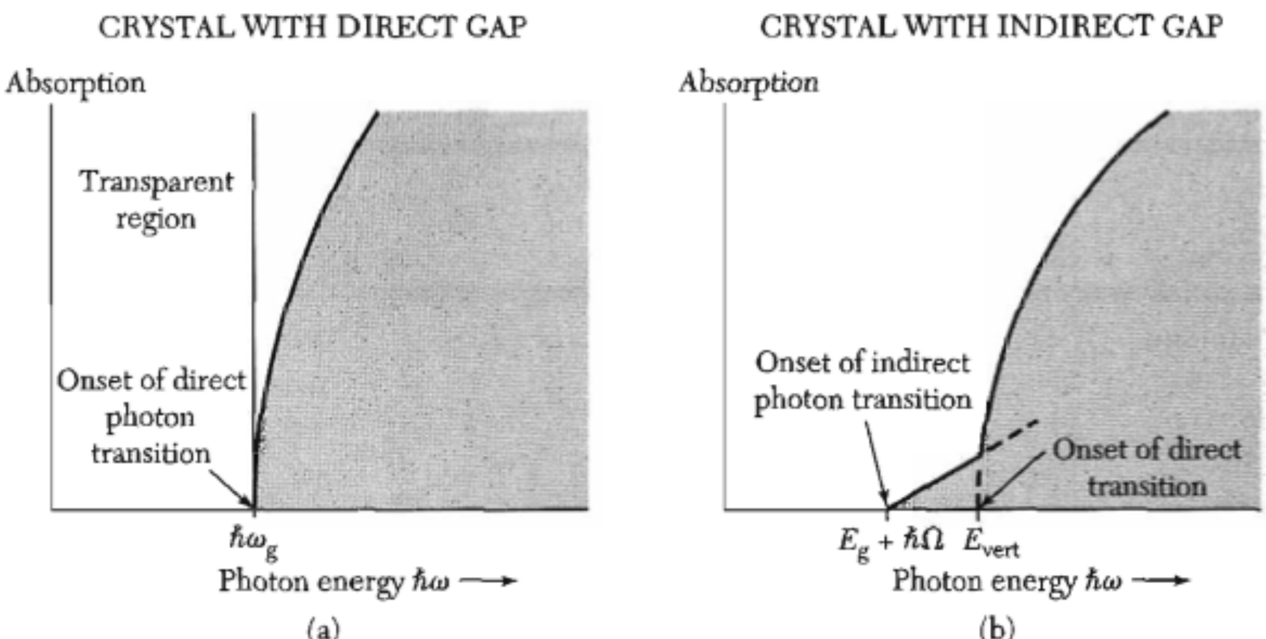
Energy gap between valence and conduction bands

		E_g, eV				E_g, eV	
Crystal	Gap	0 K	300 K	Crystal	Gap	0 K	300 K
Diamond	*i*	5.4		SiC(hex)	*i*	3.0	—
Si	*i*	1.17	1.11	Te	*d*	0.33	—
Ge	*i*	0.744	0.66	HgTe[a]	*d*	−0.30	
αSn	*d*	0.00	0.00	PbS	*d*	0.286	0.34–0.37
InSb	*d*	0.23	0.17	PbSe	*i*	0.165	0.27
InAs	*d*	0.43	0.36	PbTe	*i*	0.190	0.29
InP	*d*	1.42	1.27	CdS	*d*	2.582	2.42
GaP	*i*	2.32	2.25	CdSe	*d*	1.840	1.74
GaAs	*d*	1.52	1.43	CdTe	*d*	1.607	1.44
GaSb	*d*	0.81	0.68	SnTe	*d*	0.3	0.18
AlSb	*i*	1.65	1.6	Cu_2O	*d*	2.172	—

i: indirect gap, d: direct gap

(The table is used from Introduction to Solid State Physics, C. Kittel)

Optical Adsorption in Pure Insulators



In (a) The threshold determines the energy gap, optical absorption is weaker near the threshold.

In (b) the energy ***E,*** marks the threshold for the creation of a free electron and a free hole, with no phonon involved.

Such a transition is called vertical; it is similar to the direct transition in (a).

(The figuree is used from Introduction to Solid State Physics, C. Kittel)

In a direct adsorption process the threshold of continuous optical adsorption at frequency w_g measures the band gap. A photon is adsorbed by the crystal with the creation of an electron and a hole.

In the indirect absorption process the minimum energy gap of the band structure involves electrons and holes seperated by a substantial wavevector **k**.

- Optical measurements determines whether the gap is direct or indirect.

Ex: The band edges in Ge and in Si are connected by indirect transitions, the band edges in InSb and GaAs are connected by a direct transition.

- HgTe and HgSe are semimetals and have negative gaps- the conduction and valence bands overlap.

EQUATIONS OF MOTION

- We derive the equation of motion of an electron in an energy band.
- We look at the notion of a wave packet in an applied electric field.
- Suppose that the wave packet is made up of wavefunctions assembled near a particular wavevector ***k***

EQUATIONS OF MOTION

The frequency associated with a wavefunction of energy;

$$v_g = \hbar^{-1} d\epsilon/dk \qquad \text{or} \qquad \mathbf{v} = \hbar^{-1} \nabla_{\mathbf{k}} \epsilon(\mathbf{k})$$

$$v_g = d\omega/dk$$ *The group velocity*

The work done on the electron by the electric field **E** in the time interval is:

$$\delta\epsilon = -eEv_g\,\delta t$$

External force **F** is: $$\boxed{\hbar \frac{d\mathbf{k}}{dt} = \mathbf{F}\ .}$$

EQUATIONS OF MOTION

We examine the transfer of momentum between the electron and the lattice when the state $\mathbf{k}$ of the electron is changed to $\mathbf{k} + \Delta\mathbf{k}$ by the application of an external force. We imagine an insulating crystal electrostatically neutral except for a single electron in the state $\mathbf{k}$ of an otherwise empty band.

We suppose that a weak external force is applied for a time interval such that the total impulse given to the entire crystal system is $\mathbf{J} = \int \mathbf{F}\, dt$. If the conduction electron were free ($m^* = m$), the total momentum imparted to the crystal system by the impulse would appear in the change of momentum of the conduction electron:

$$\mathbf{J} = \Delta\mathbf{p}_{tot} = \Delta\mathbf{p}_{el} = \hbar\Delta\mathbf{k}$$