

Optoelectronics (광전자공학)

Lecture 5. Absorption/Luminescence

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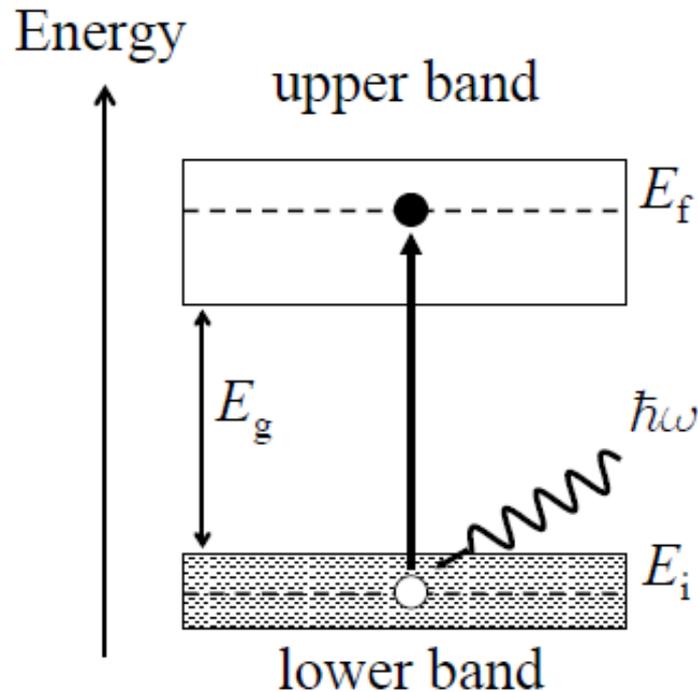
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Interband absorption

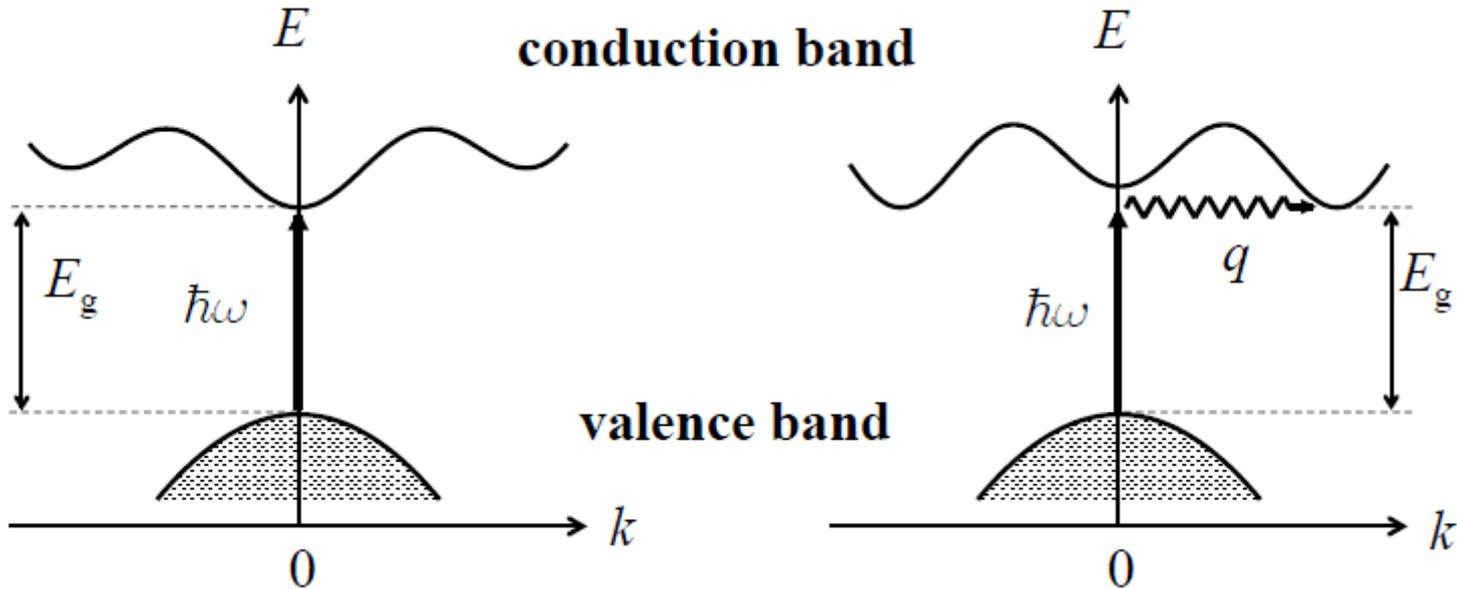


Photon excites electron from filled valence to empty conduction band

Fundamental absorption edge at E_g

Process creates an electron-hole pair

Direct and indirect absorption



- Transitions appear as vertical lines on E-k diagrams.
- Phonon needed to conserve momentum for indirect gap materials.
- Indirect absorption 2nd order process, therefore low probability.

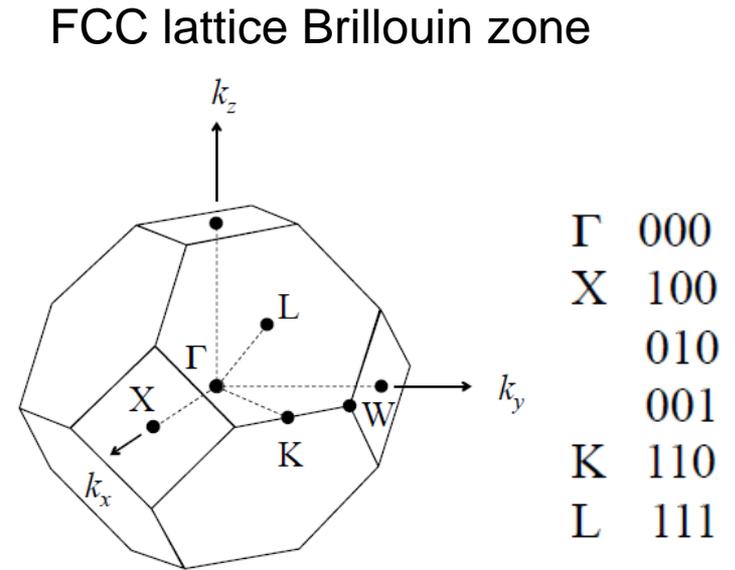
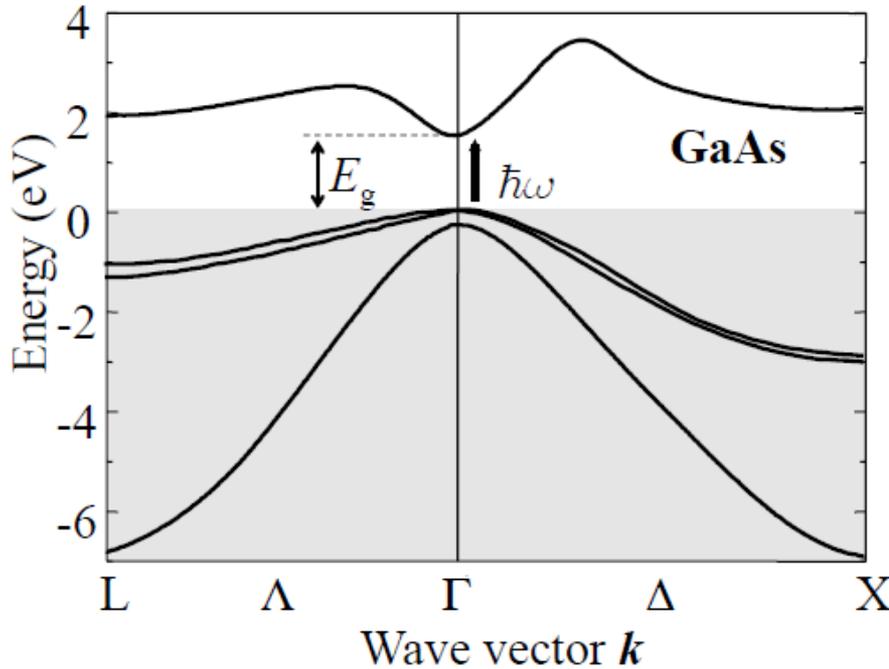
Transition rate for direct absorption

- The optical absorption coefficient is determined by the quantum mechanical transition rate W for exciting an electron in an initial quantum state to a final state by absorption of a photon of angular frequency.
- The transition rate is given by Fermi's golden rule:

Transition rate for direct absorption

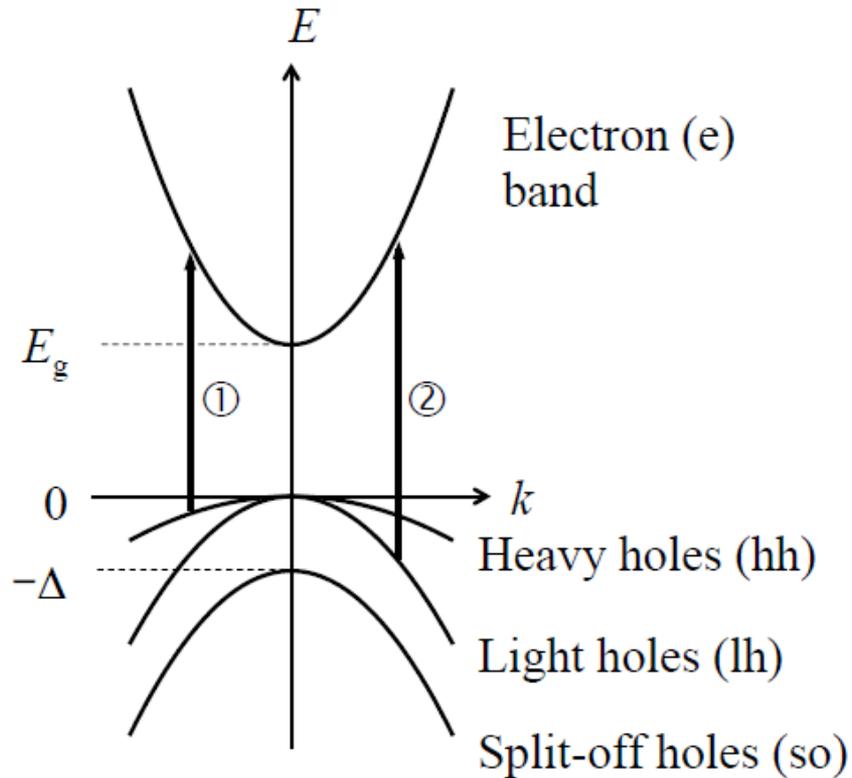
- The electron states in a crystalline solid are described by Bloch functions. This allow us to write the wave functions as a product of a plane wave and an envelope function that has the periodicity of the crystal lattice.

GaAs band structure



- Direct gap at 1.5 eV
- Very important optoelectronic material
- Strong absorption

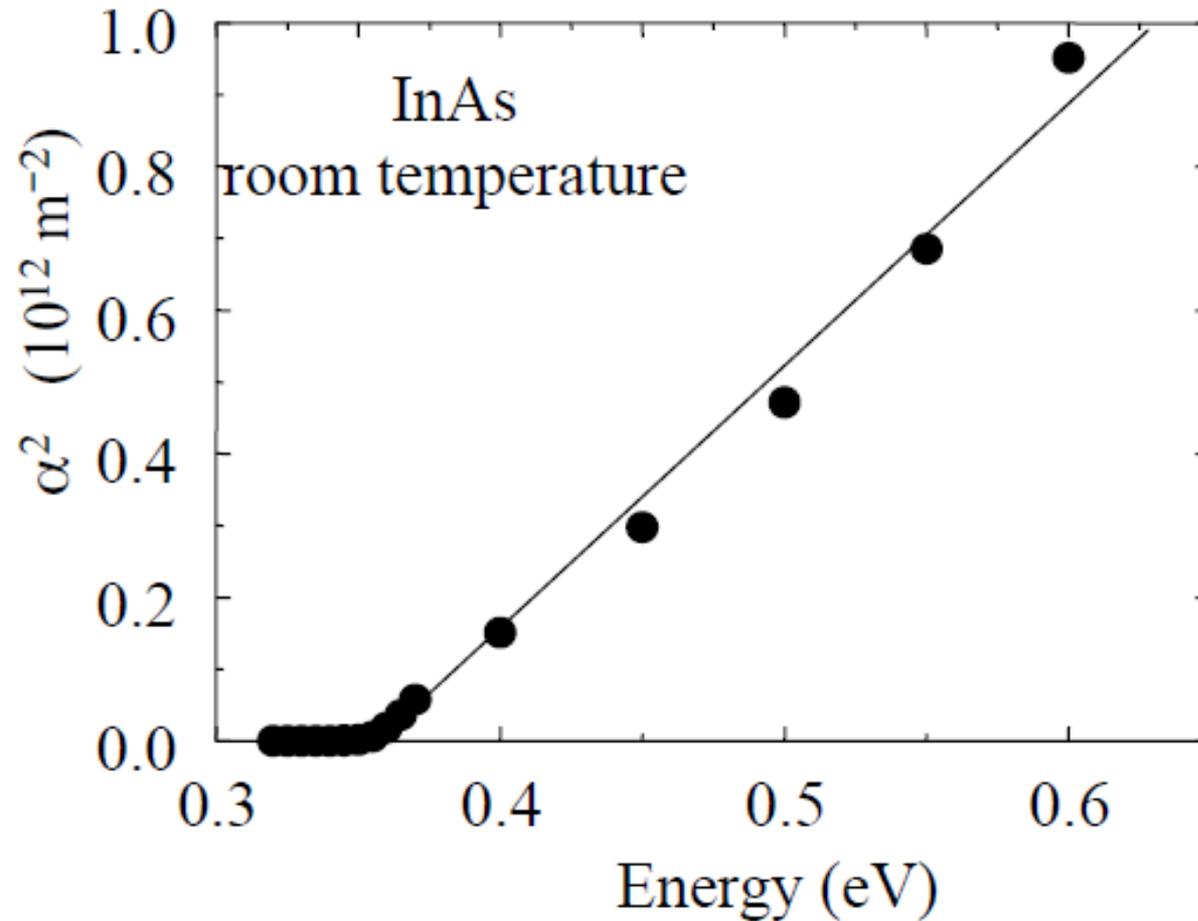
Four-band model



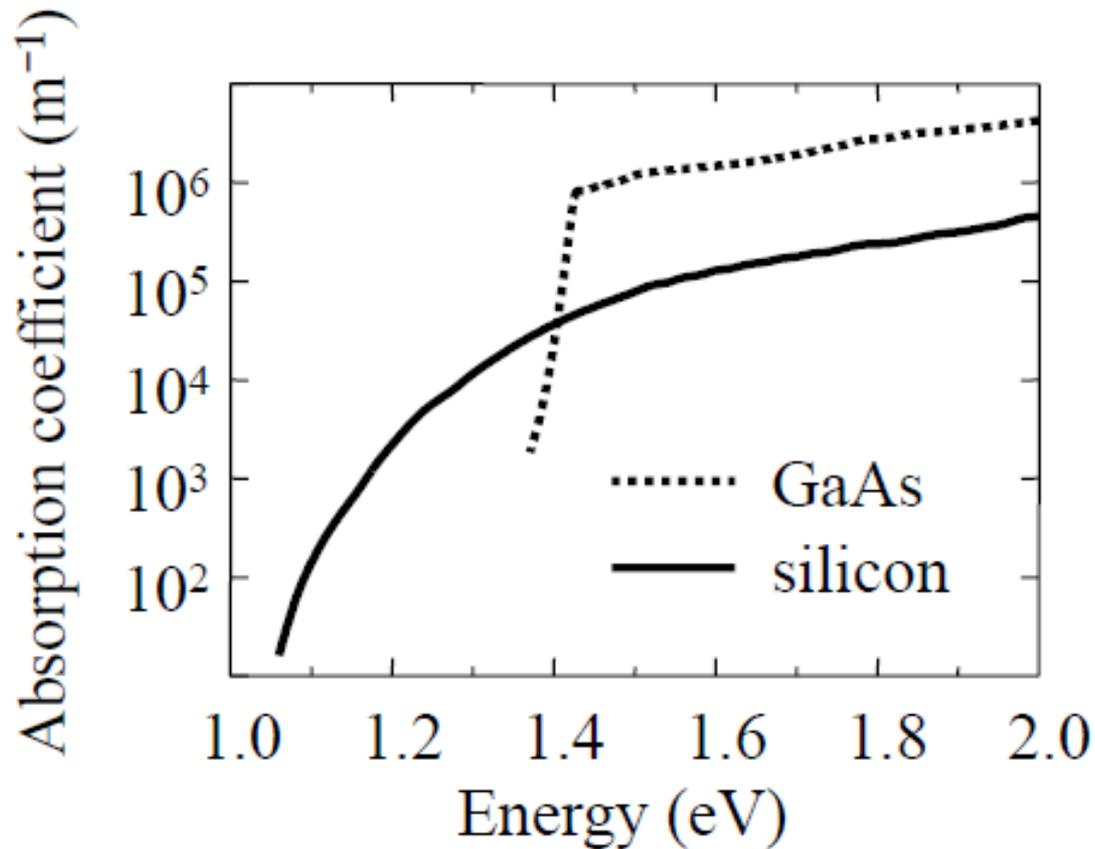
- Simplified band structure first proposed by Kane (1957)
- Valid near $k = 0$
- (1) Heavy hole transition
- (2) Light hole transition

Joint density of states

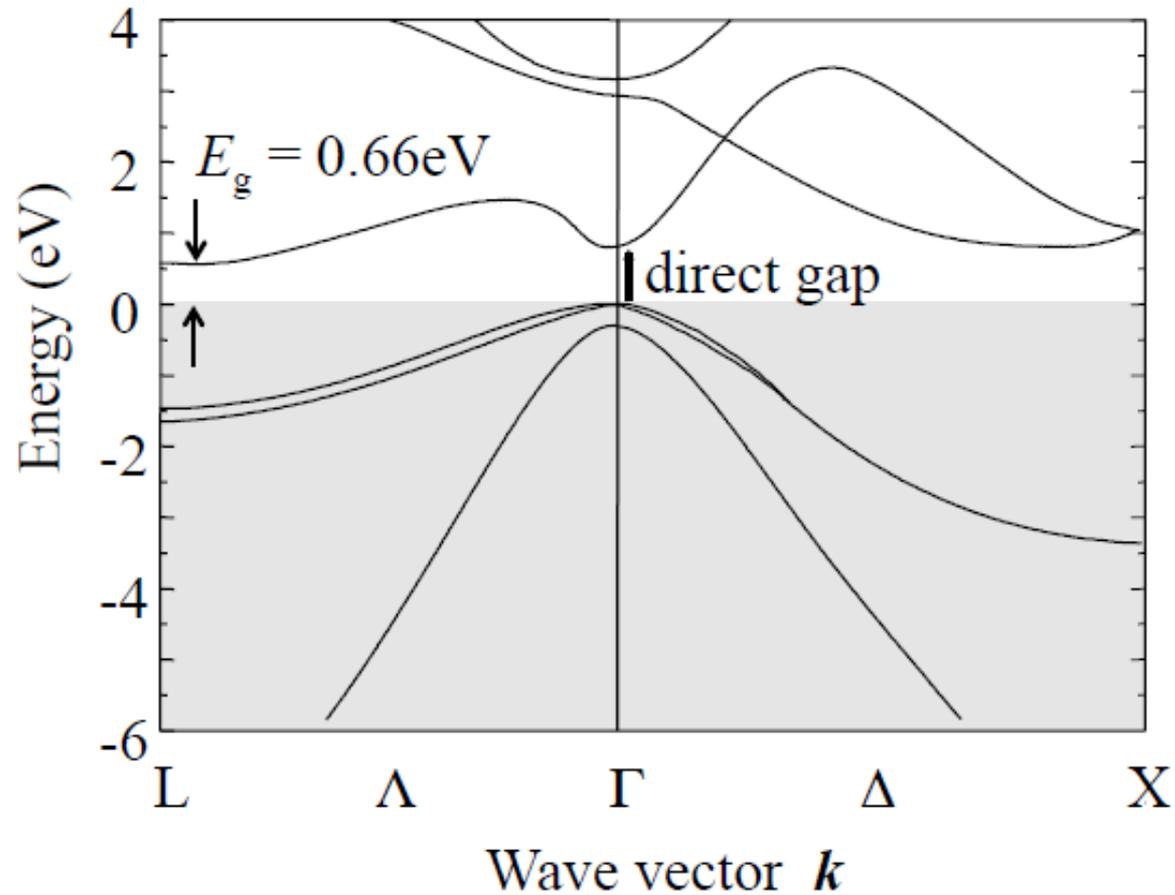
InAs band edge absorption



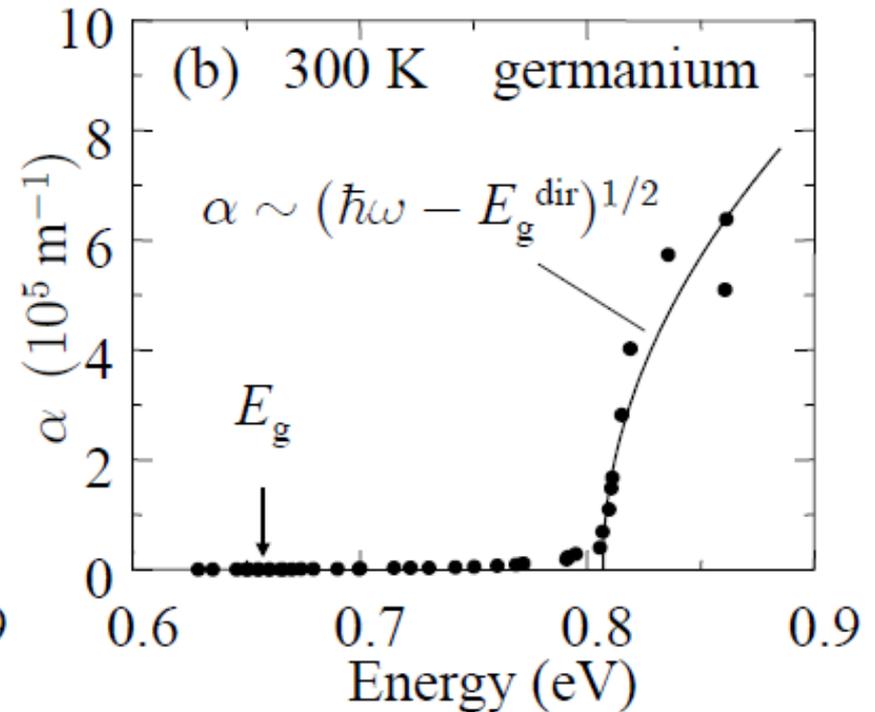
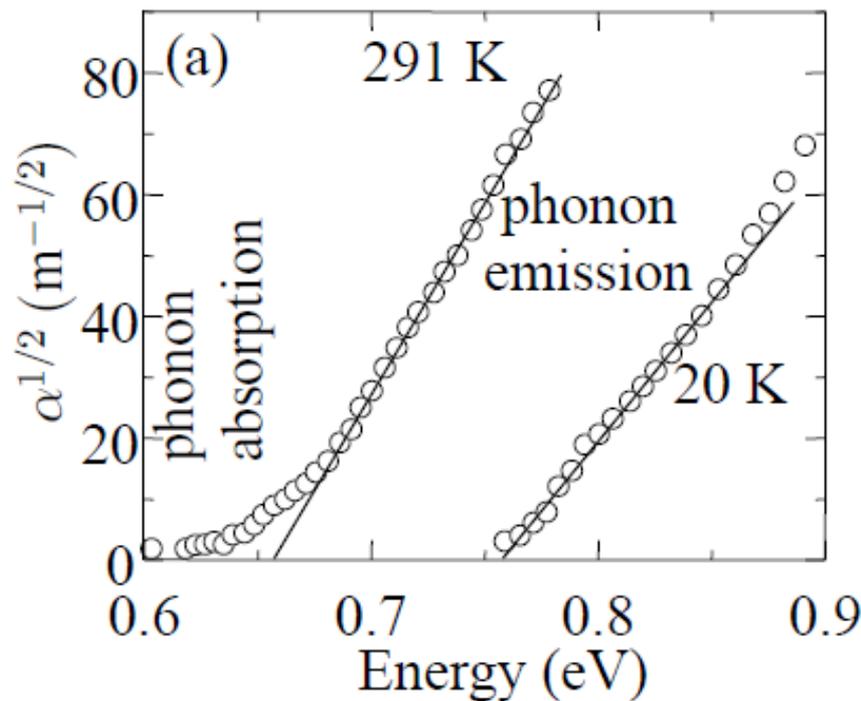
Direct versus indirect absorption



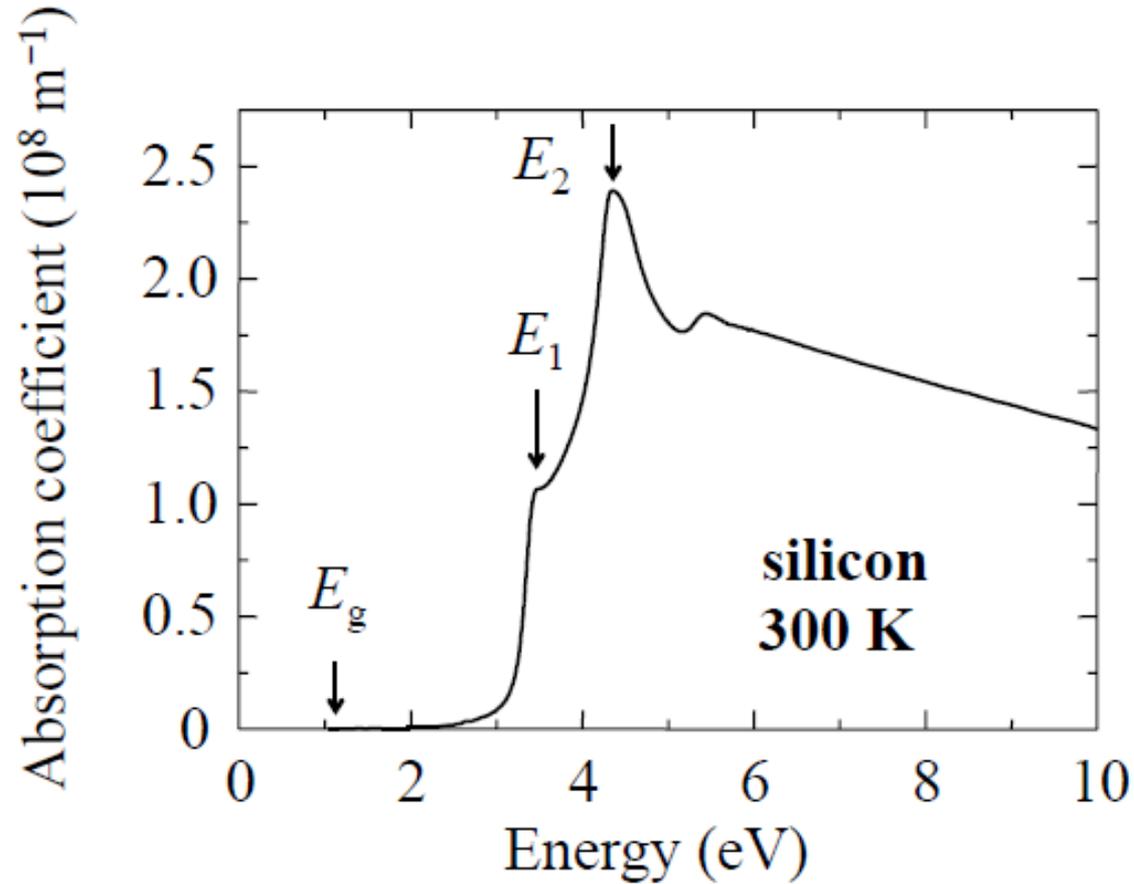
Germanium band structure



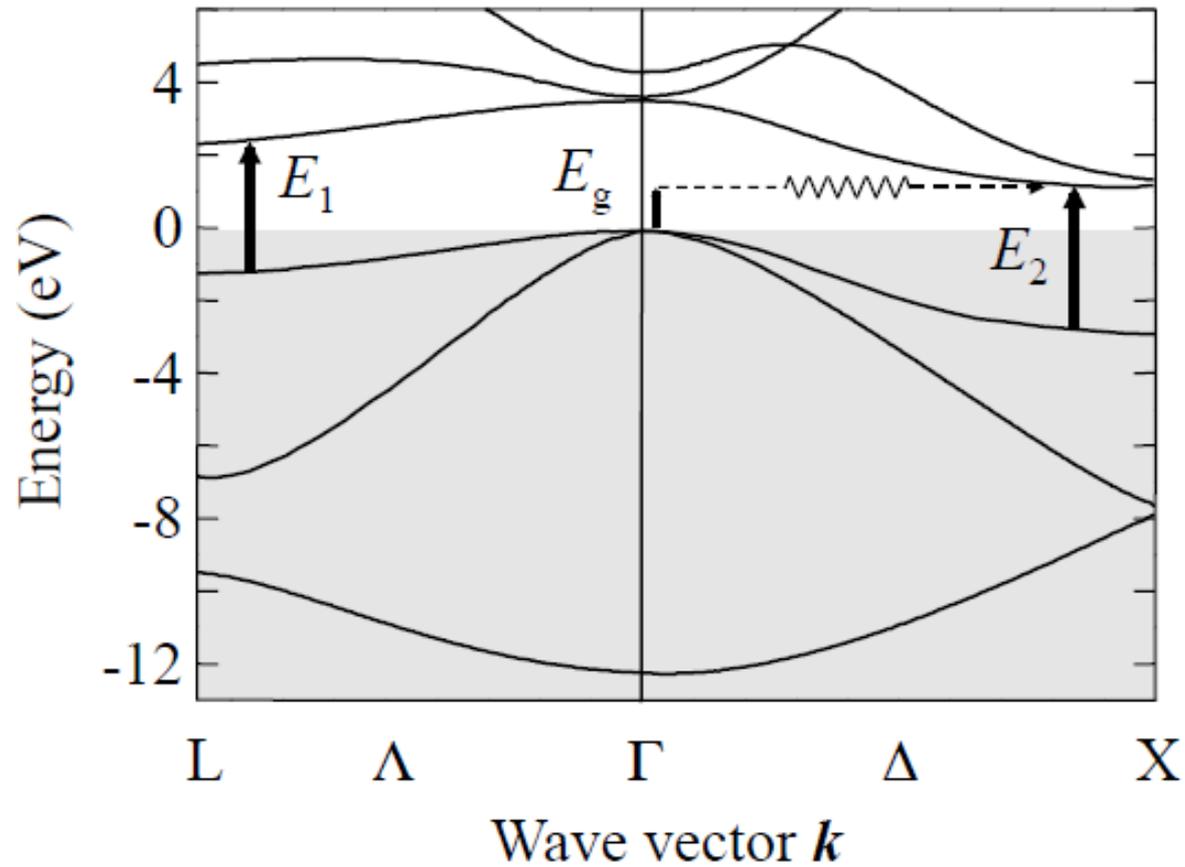
Germanium band edge absorption



Silicon absorption



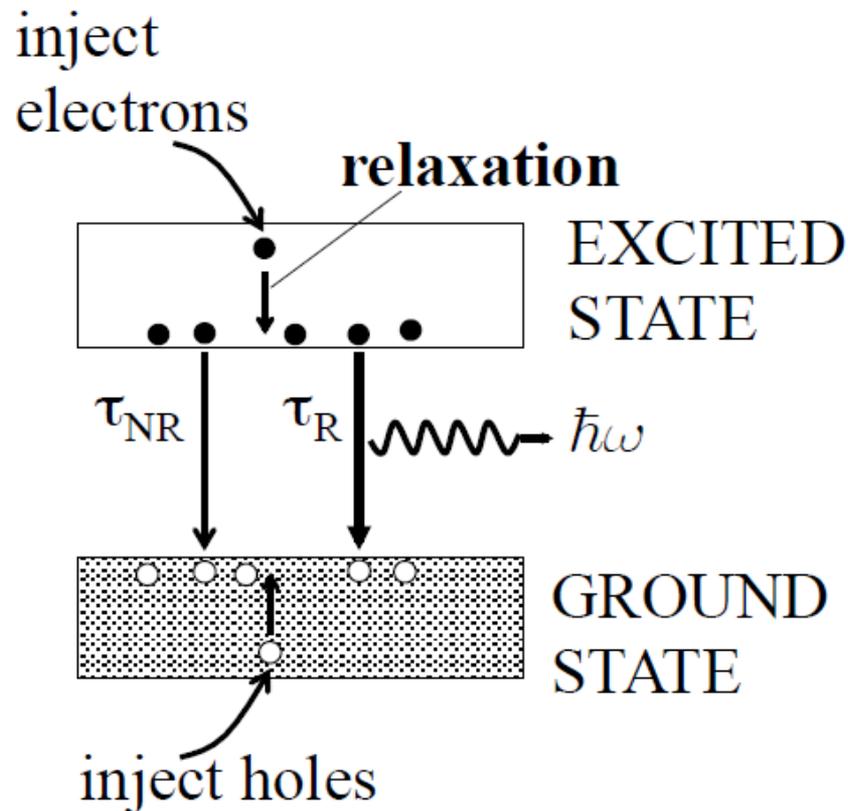
Silicon band structure



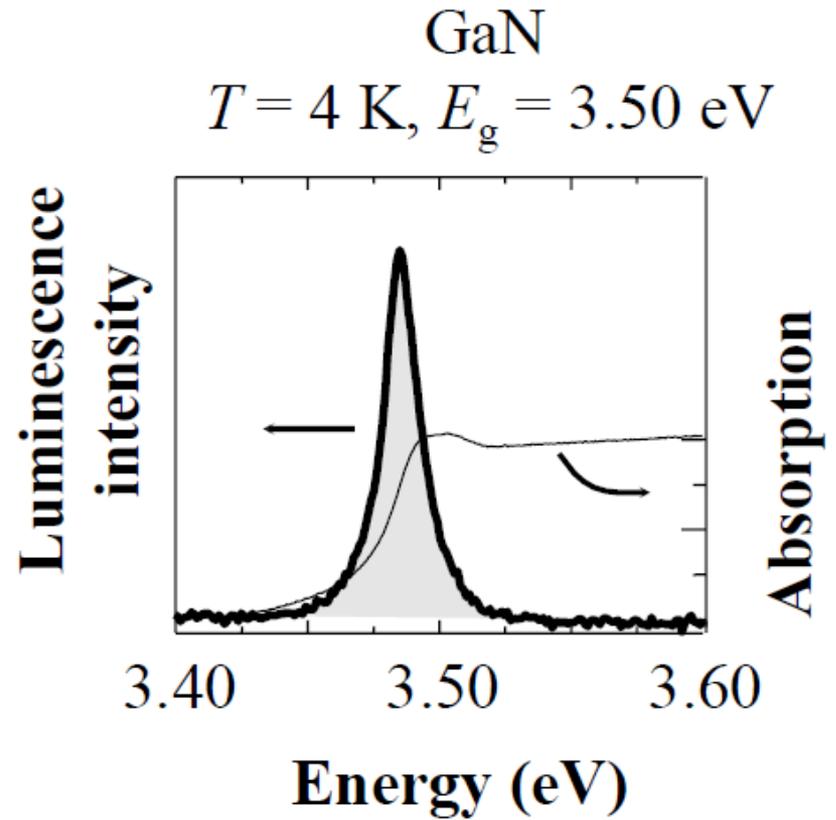
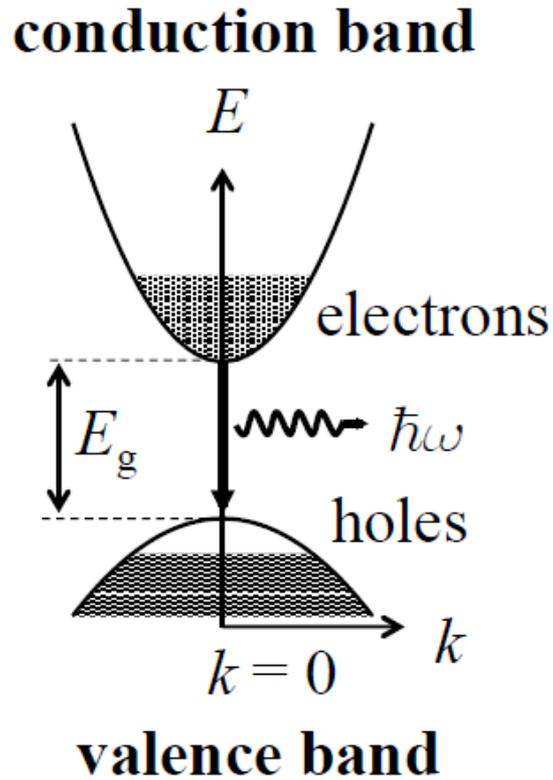
Luminescence

- Luminescence : Spontaneous emission in solids
- Fluorescence : Fast luminescence
electric-dipole allowed
- Phosphorescence : Slow luminescence
electric-dipole forbidden
- Electroluminescence : electrical excitation
- Photoluminescence : optical excitation
- Cathodoluminescence : cathode ray (e-beam) excitation

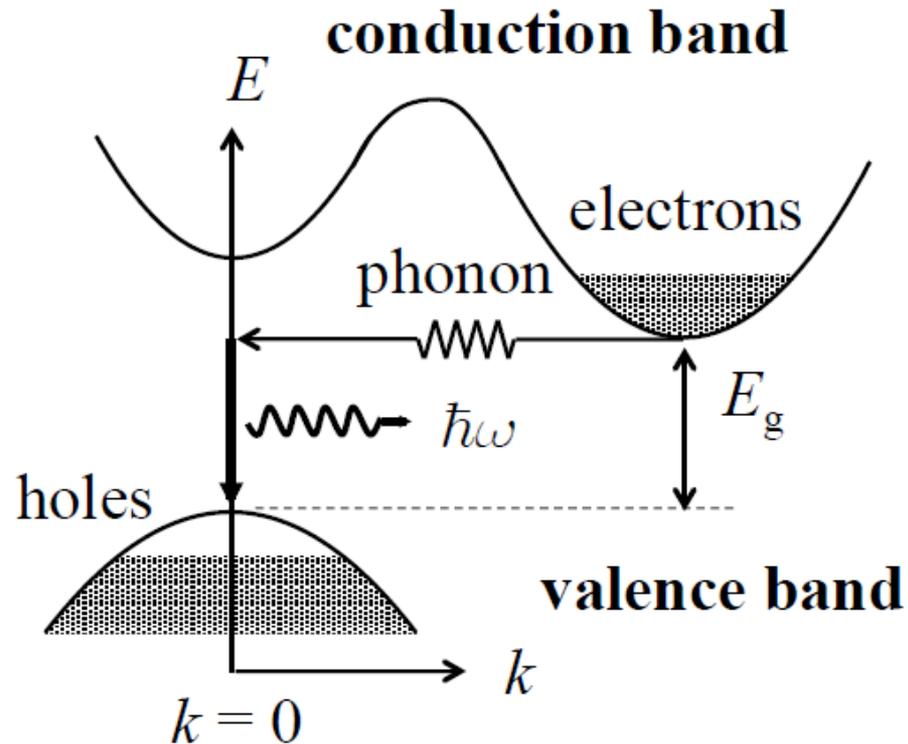
Luminescence



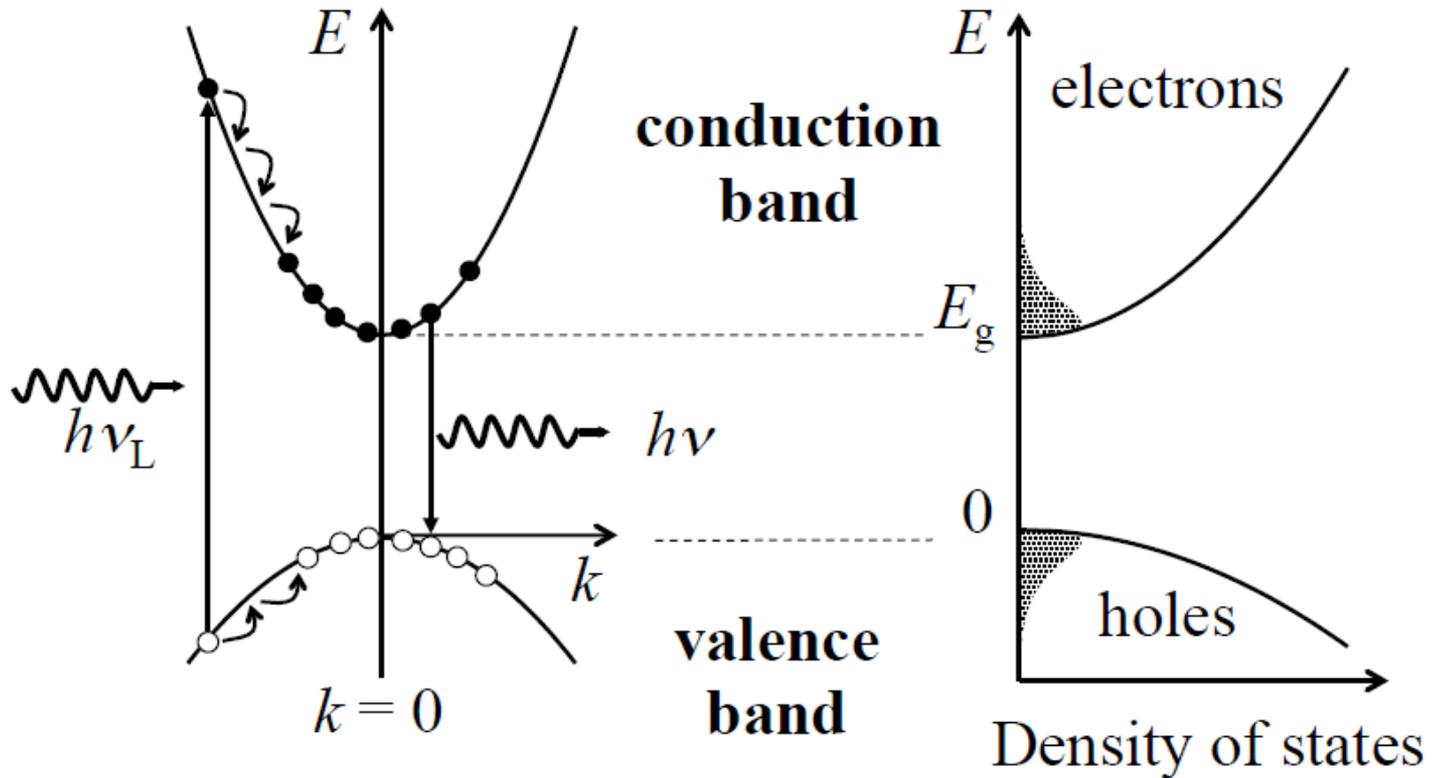
Direct gap materials



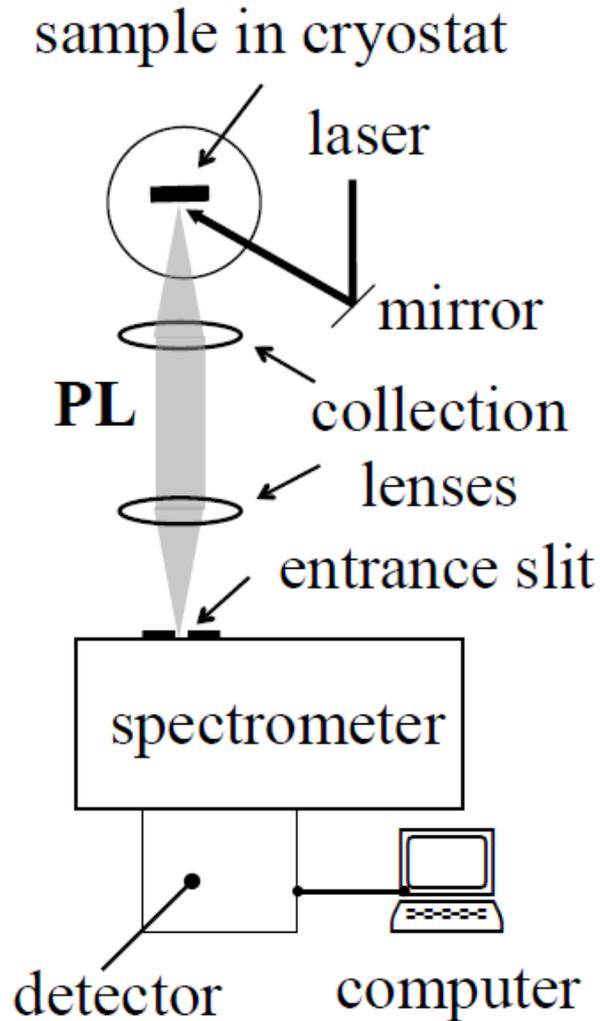
Indirect gap materials



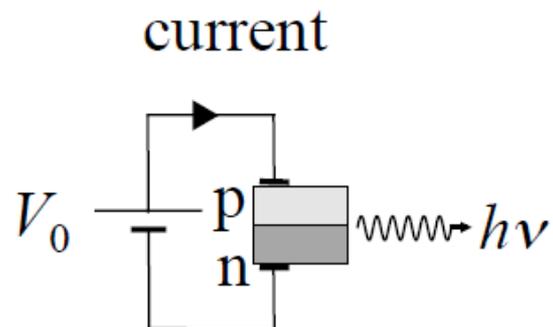
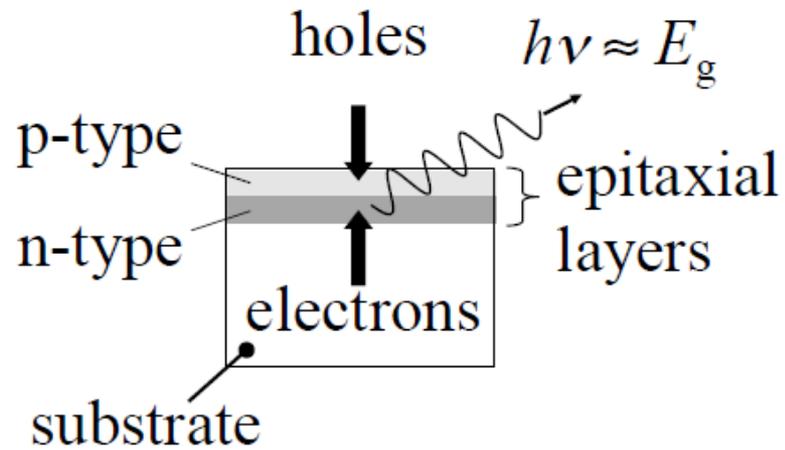
Photoluminescence



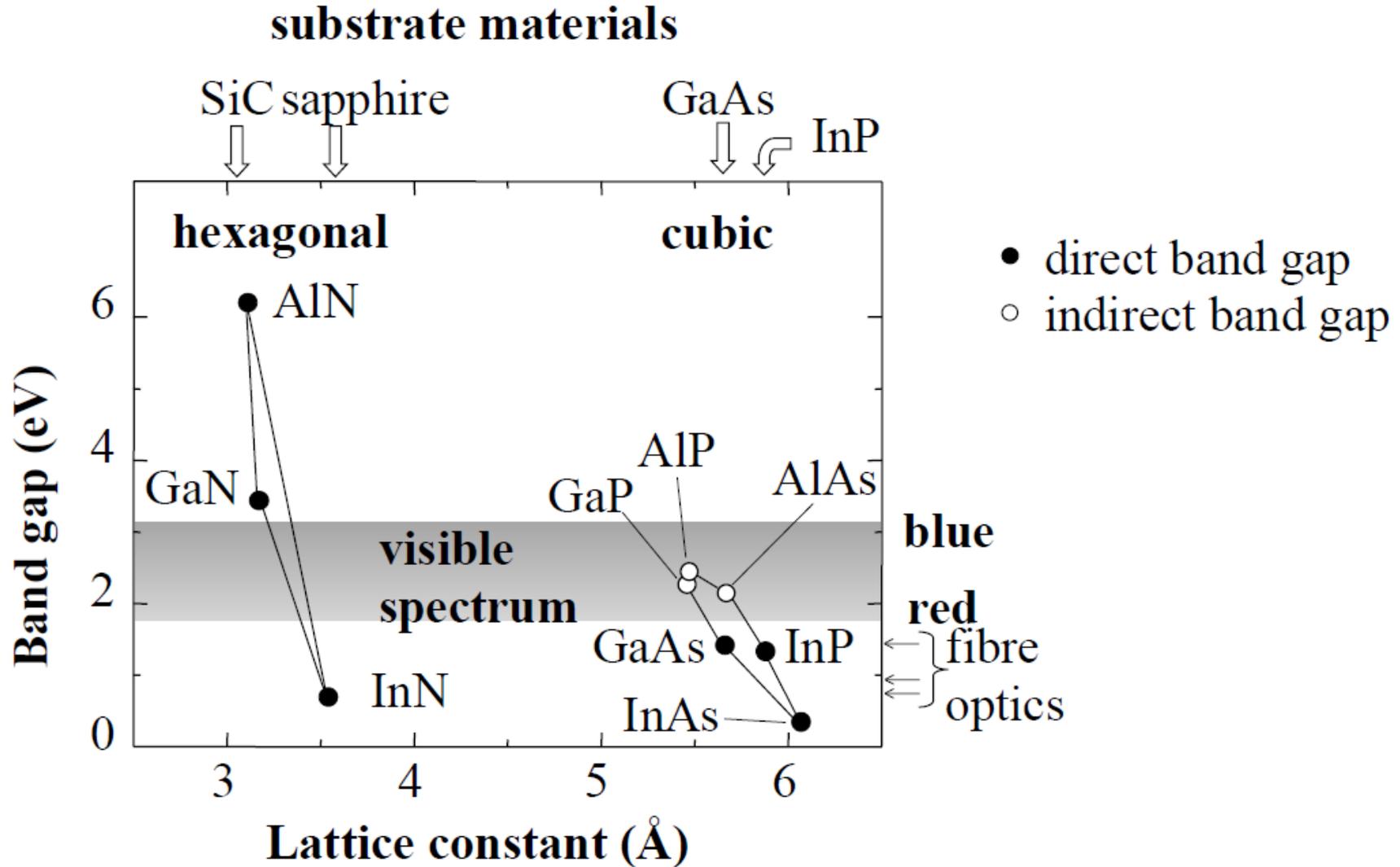
Photoluminescence spectroscopy



Electroluminescence



Lattice matching



Question or Comment?