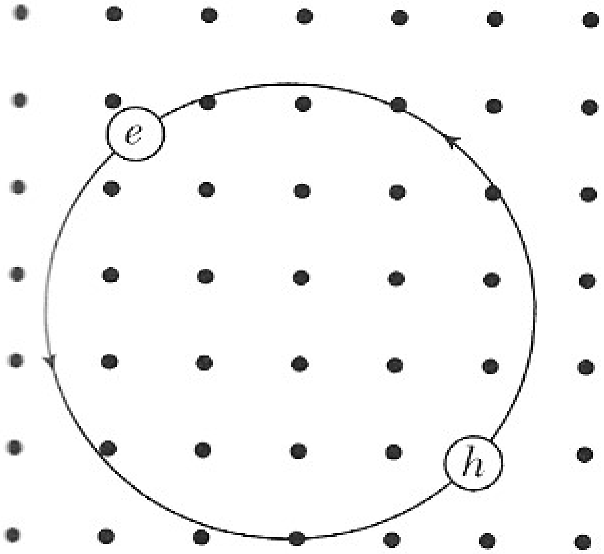
Excitons

Bound state of an electron and a hole in a semiconductor or insulator

Mott Wannier excitons

(like positronium)



Mott-Wannier Excitons

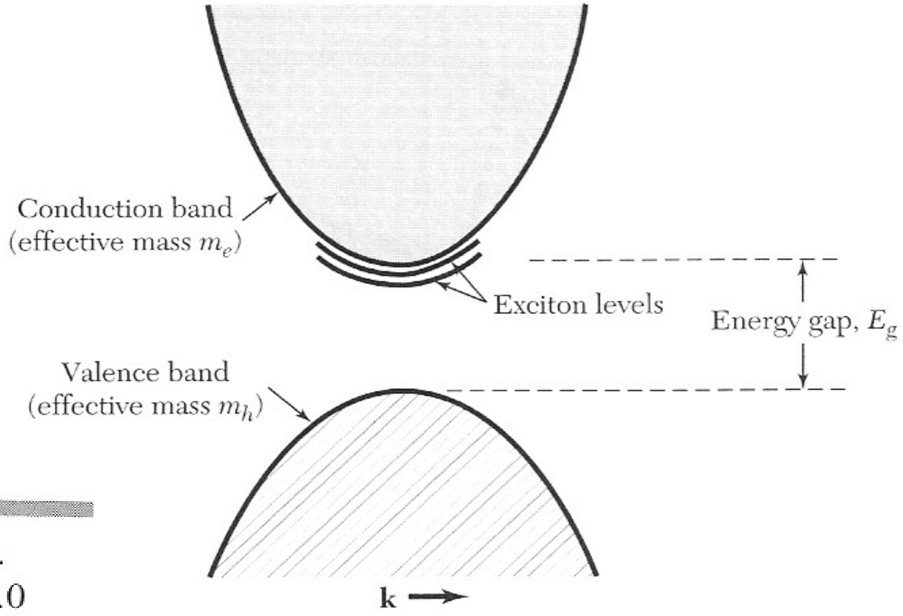
Bound state of an electron and a hole in a semiconductor or insulator (like positronium)

Hydrogenic model

$$E_{n,K} = E_g - \frac{\mu^* e^4}{32\pi^2\hbar^2\varepsilon^2\varepsilon_0^2 n^2} + \frac{\hbar^2 K^2}{2\left(m_h^* + m_e^*\right)}$$

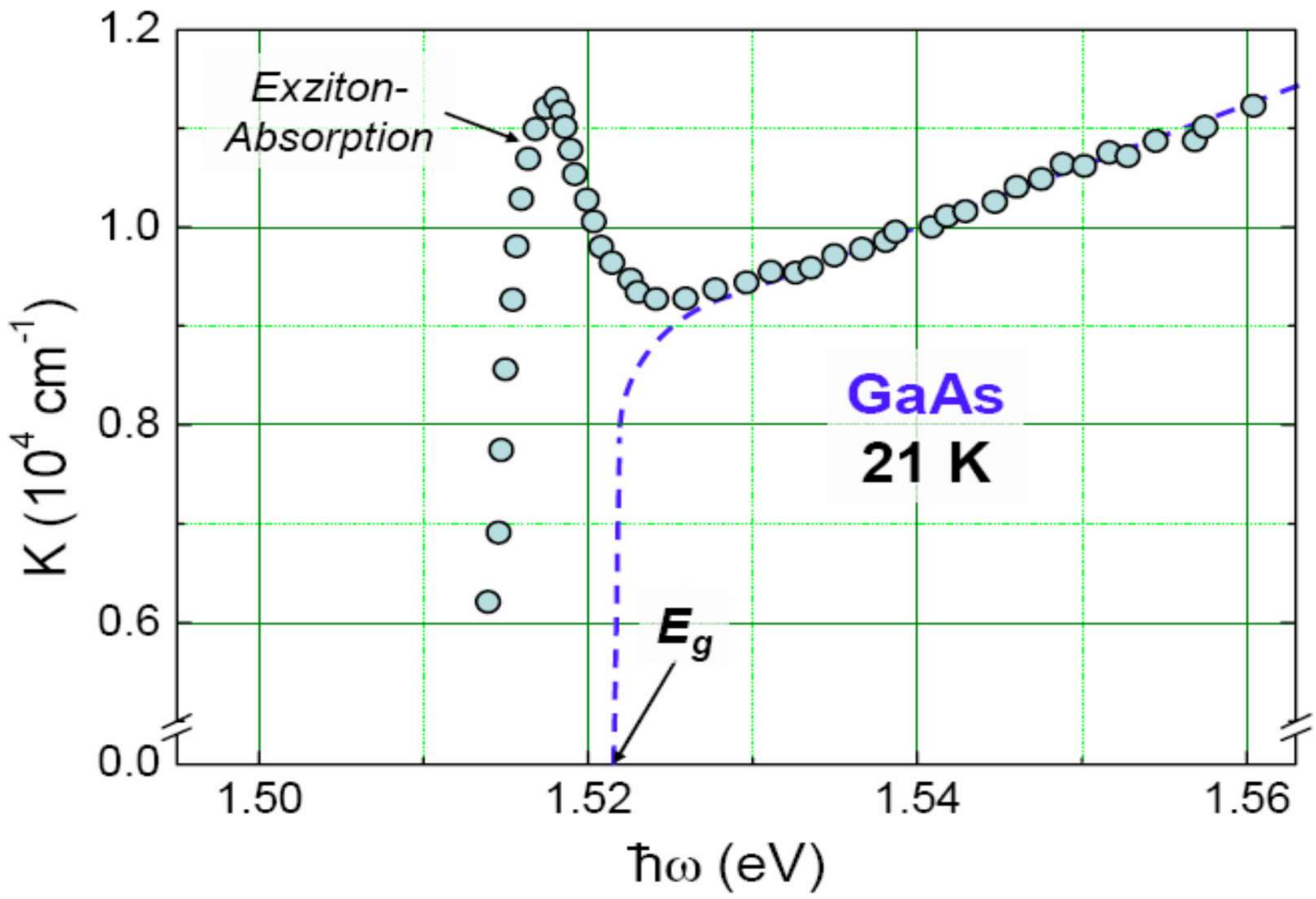
Table 1 Binding energy of excitons, in meV

Si	14.7	BaO	56.
Ge	4.15	InP	4.0
GaAs	4.2	InSb	(0.4)
GaP	3.5	KI	480.
CdS	29.	KCl	400.
CdSe	15.	KBr	400.



Kittel

Excitons



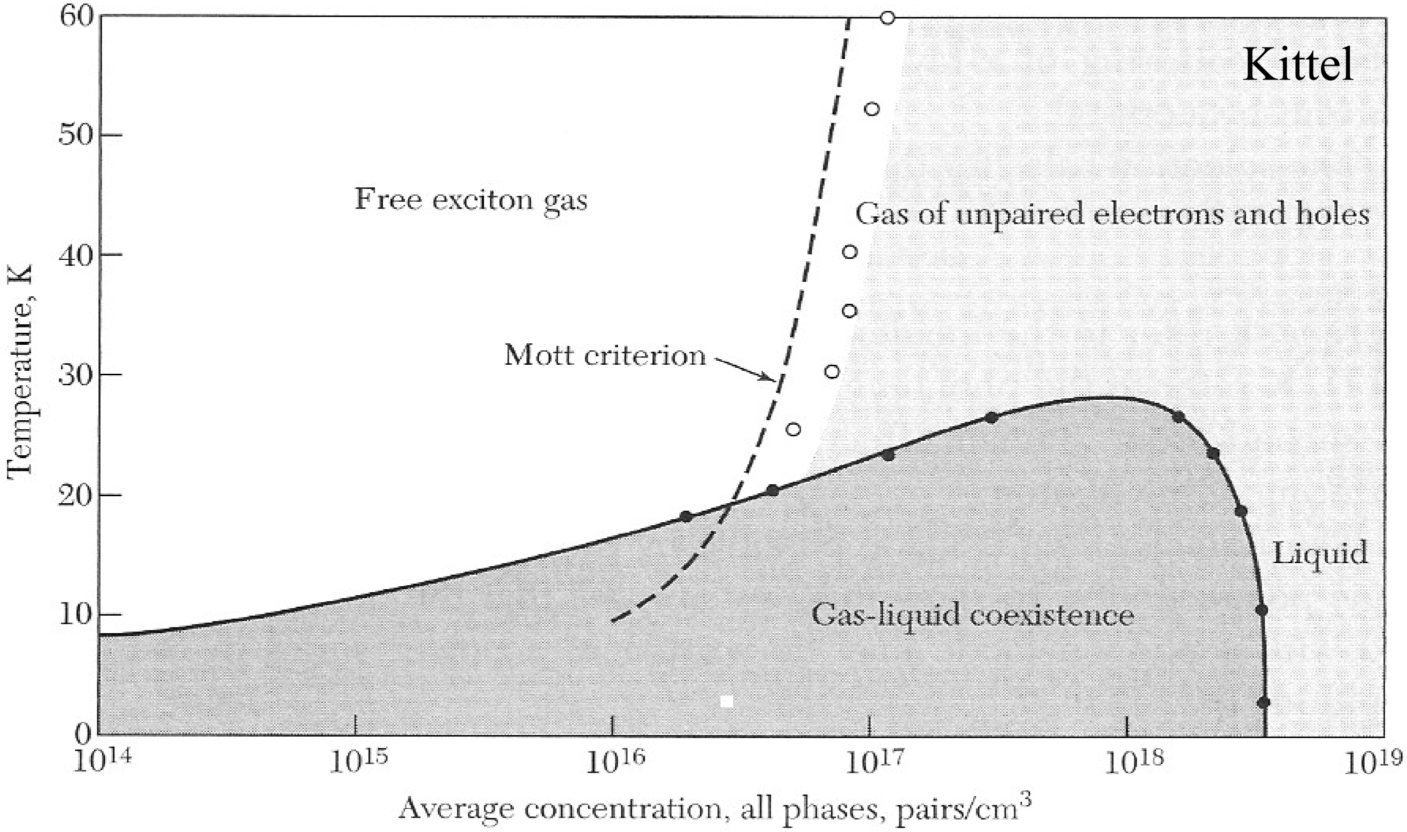
Gross & Marx

Excitons

Biexcitons H_2?

Metallic plasma droplets

Observe with an infrared camera



Phase diagram for photoexcited electrons and holes in unstressed silicon.

See: C. D. Jeffries, Electron-Hole Condensation in Semiconductors, Science 189 p. 955 (1975).

Frenkel Excitons

A Frenkel exciton is localized on an atom or molecule in a crystal.

The band gap of solid krypton is 11.7 eV. Lowest atomic transition in the solid is 10.17 eV.

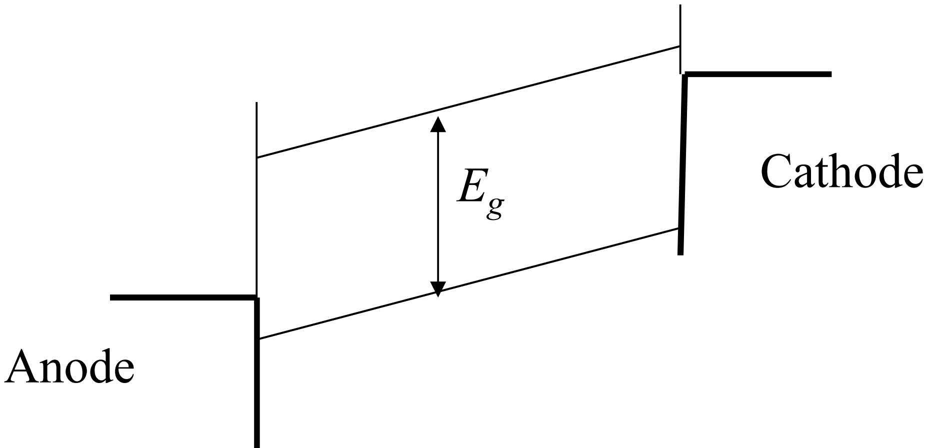
Excitons transport energy but not charge. Frenkel excitons are occur in organic solar cells, organic light emitting diodes, and photosynthesis.

OLEDs

Aluminum cathode
Electron transport layer
Emission layer
Hole transport layer
ITO anode
Glass

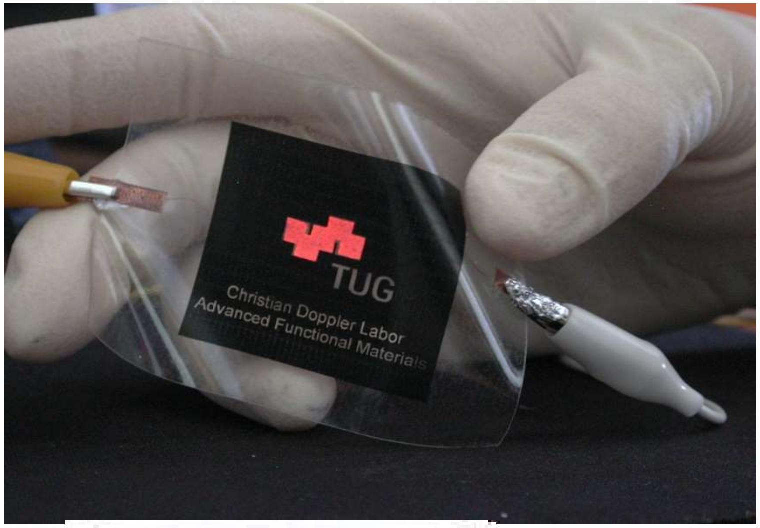
Cathode is typically a low work function material Al, Ca - injects electrons

Anode is typically a high work function material ITO - injects holes



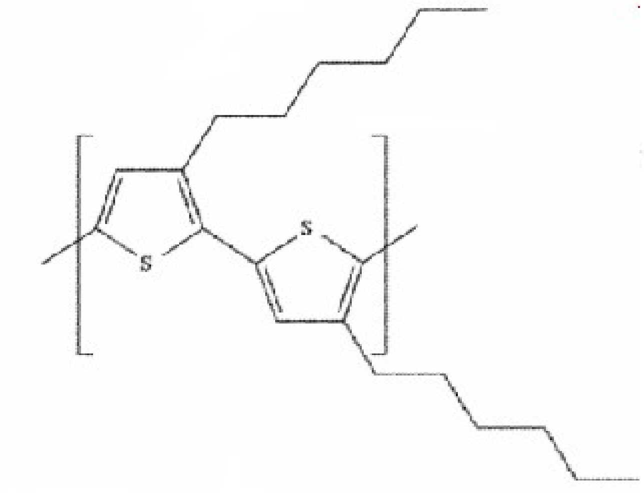
Egbert says you always have an injection barrier. The best you get is about a barrie

OLEDs

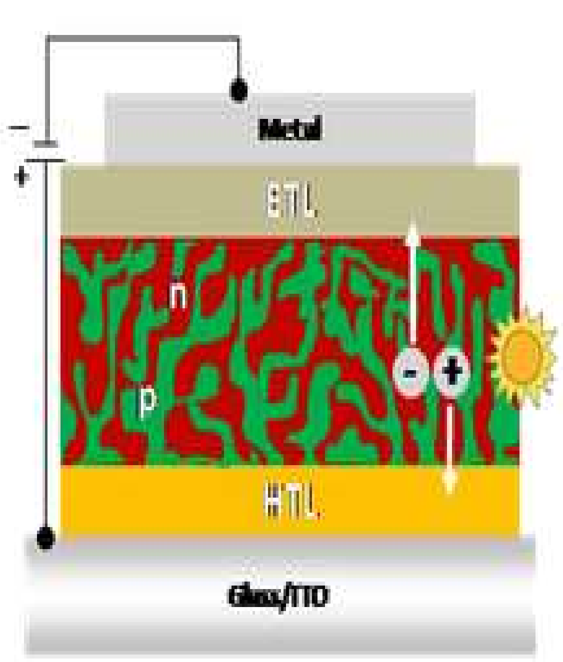


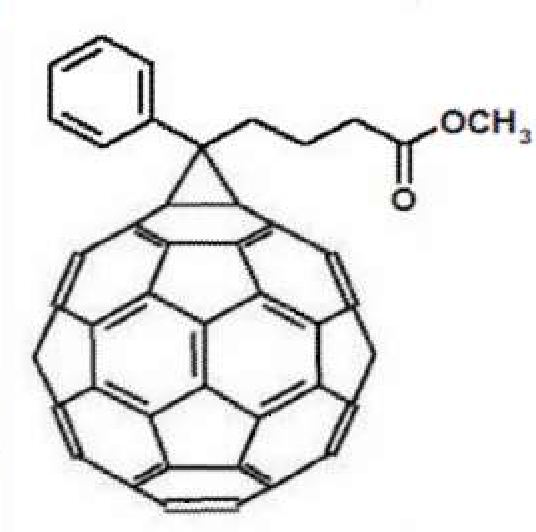
Galaxy Tab

Organic solar cells



P3HT donor





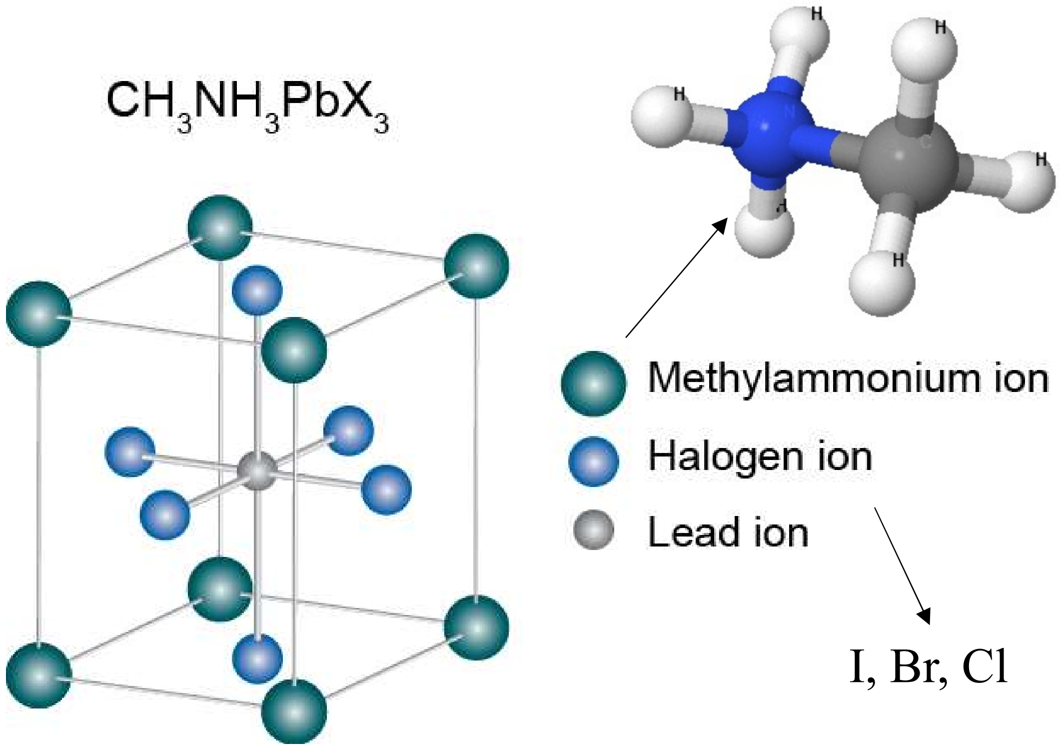
PCBM acceptor

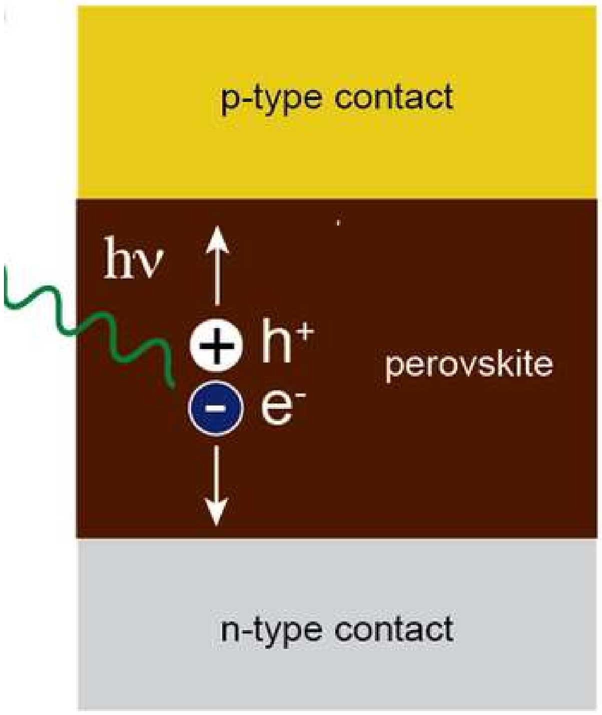
Excitons in polymers: a monomer is in an excited states and this moves down the chain.

https://www.uni-ulm.de/nawi/nawi-oc2/forschung/ag-organische-halbleiter-und-farbstoffe-fuer-die-photovoltaik.html?print=1

Perovskite solar cells

$CH_3NH_3PbX_3$





Efficiency ~ 22%

https://en.wikipedia.org/wiki/Perovskite_solar_cell

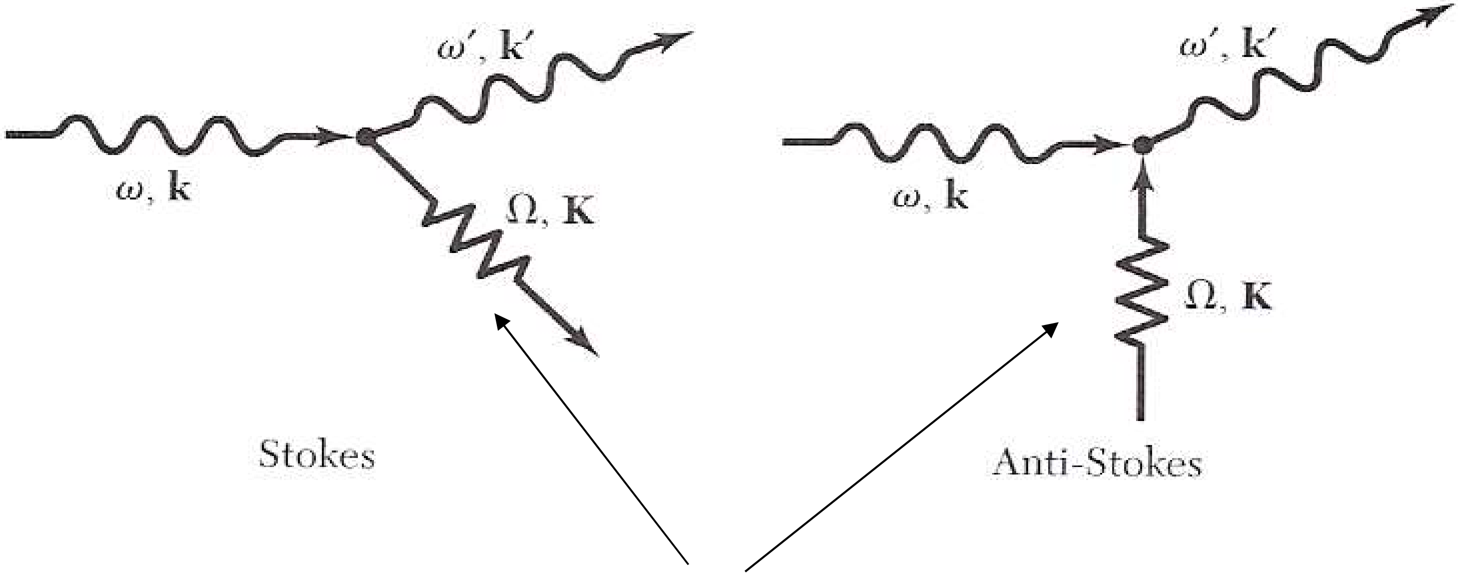
Raman Spectroscopy

C. V. Raman

Inelastic light scattering

$$\omega = \omega' \pm \Omega$$

$$\vec{k} = \vec{k}' \pm \vec{K} \pm \vec{G}$$



Phonons, magnons, plasmons, polaritons, excitons

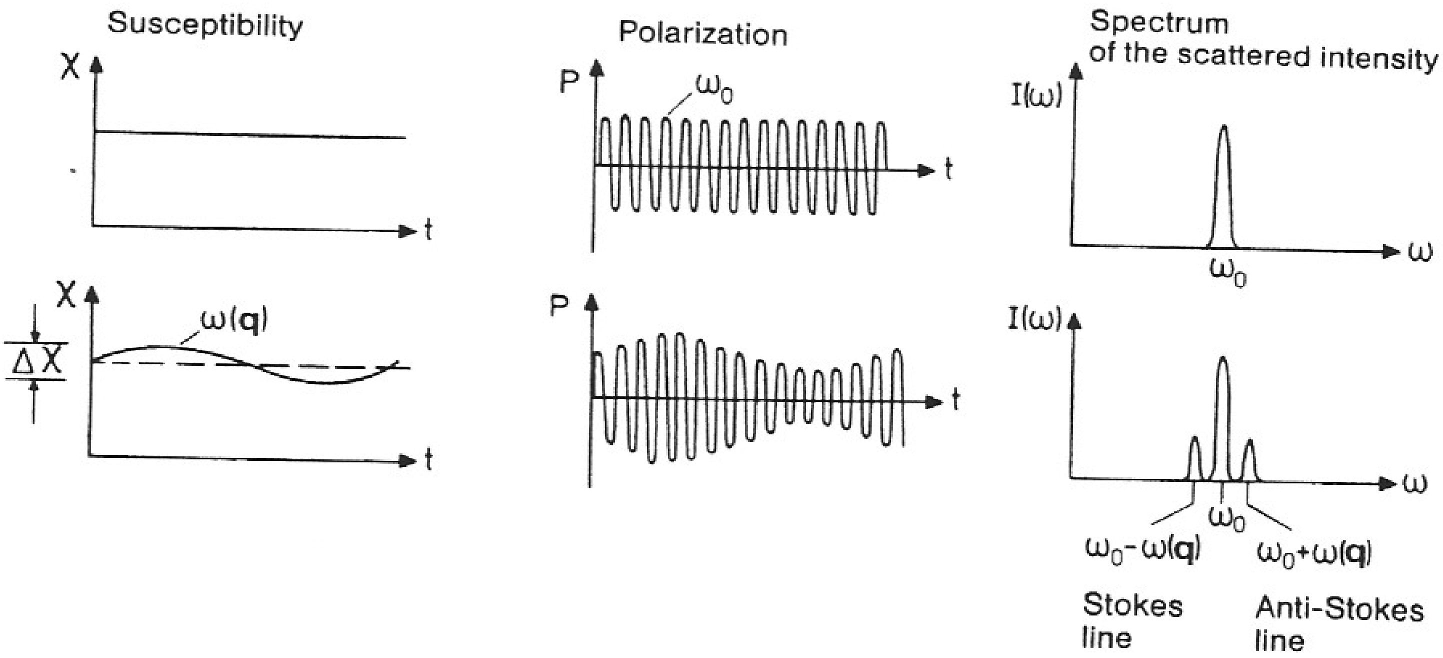
$$\vec{K} \approx 0$$

Raman Spectroscopy

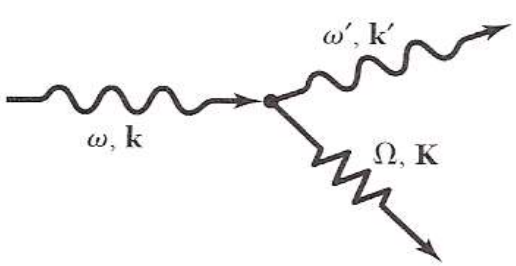
$$\chi = \chi_0 + \frac{\partial \chi}{\partial X} X \cos(\Omega t)$$

$$\vec{P} = \varepsilon_0 \chi \vec{E} \cos(\omega t) + \varepsilon_0 \frac{\partial \chi}{\partial X} X \cos(\Omega t) \vec{E} \cos(\omega t)$$

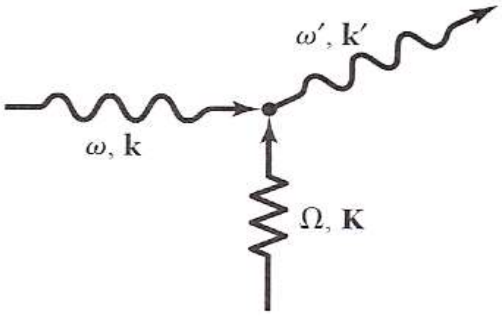
There are components of the polarization that oscillate at $\omega \pm \Omega.$



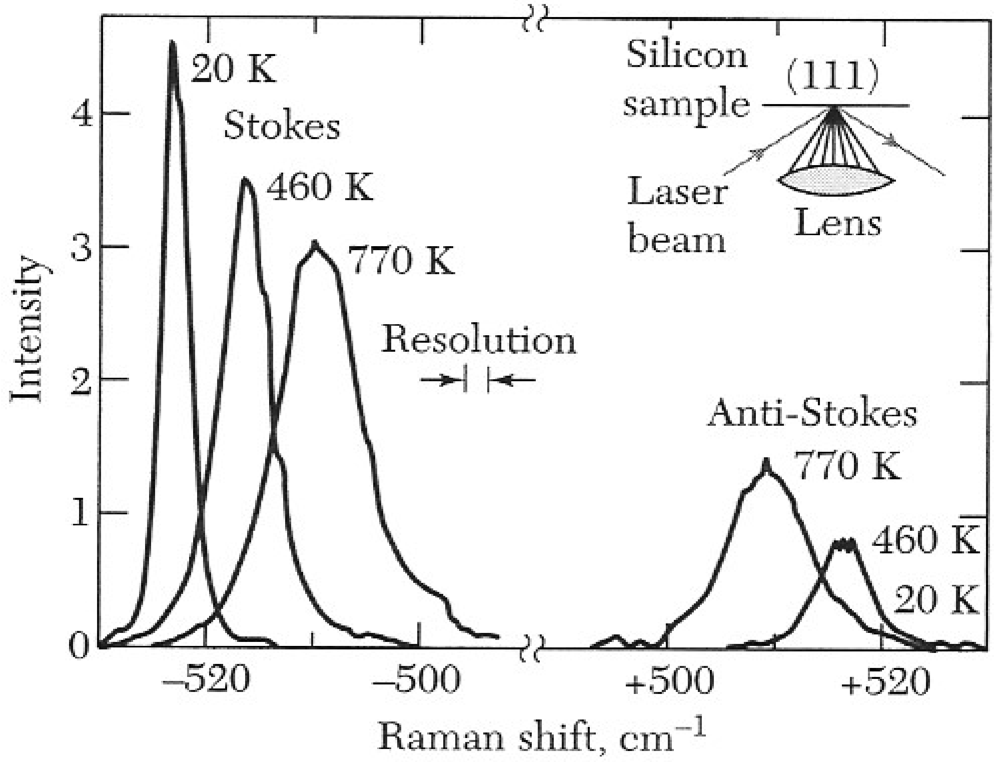
Raman Spectroscopy



Stokes



Anti-Stokes



Stokes:

$$I(\omega-\Omega)\propto n_k+1$$

anti-Stokes:

$$I(\omega+\Omega)\propto n_k$$

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Vacancy-hydrogen defects in silicon studied by Raman spectroscopy

E. V. Lavrov* and J. Weber

Raman spectroscopy

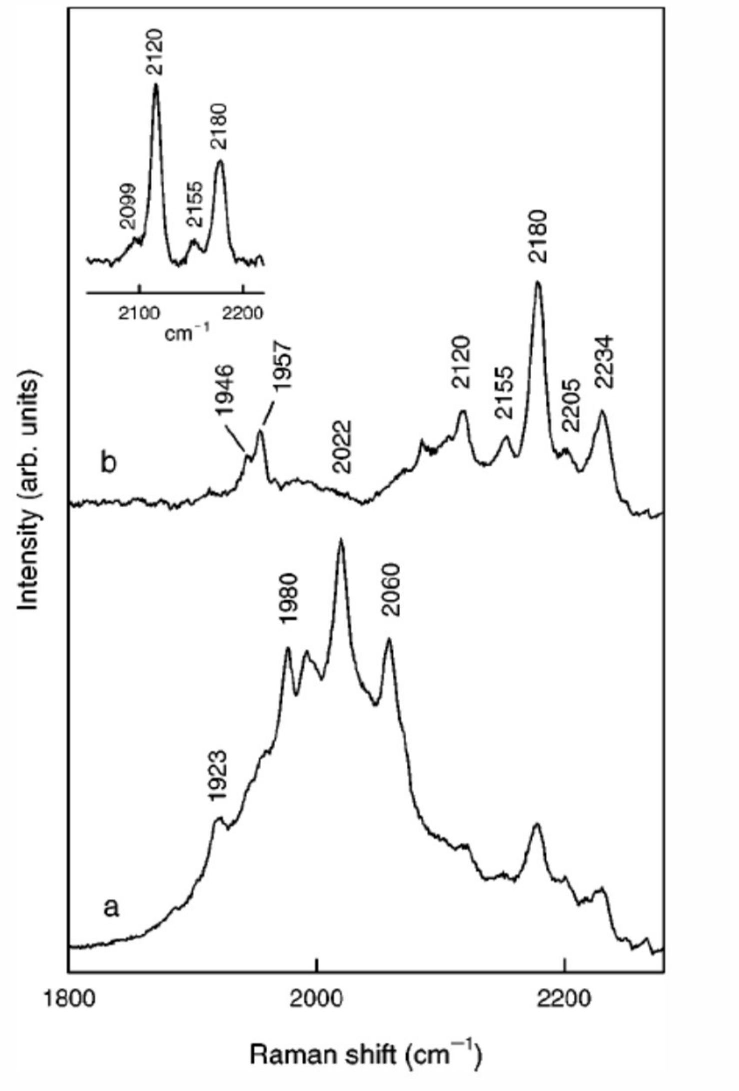
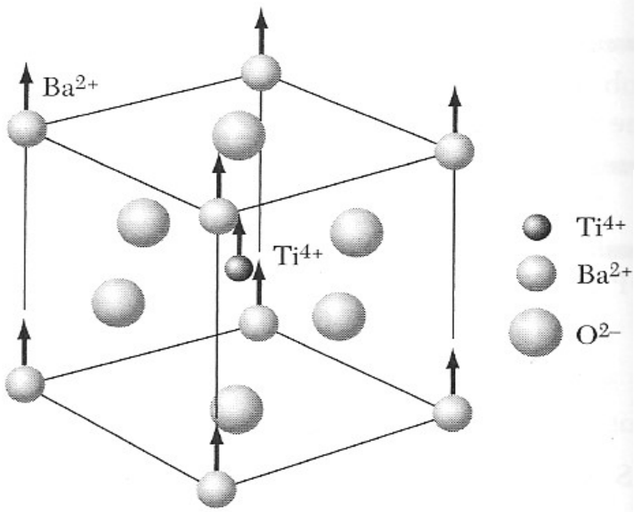


FIG. 1. Raman spectra measured at room temperature on the H_2-implanted sample: (a) as-implanted sample, (b) after annealing at 400 °C for 2 min. Spectra are offset vertically for clarity.

Ferroelectricity

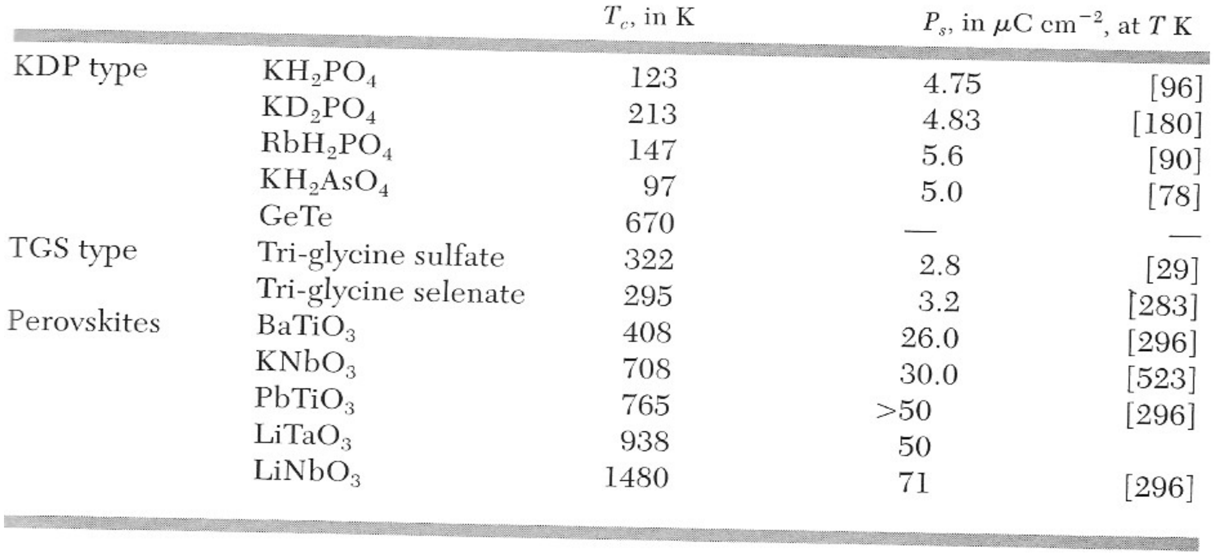
ABX_3

Perovskites



Spontaneous polarization
Analogous to ferromagnetism
Structural phase transition
T_c is transition temperature

Electric field inside the material,
is not conducting



		T_c, in K	P_s, in $\mu C\ cm^{-2}$, at T K	
KDP type	KH_2PO_4	123	4.75	[96]
	KD_2PO_4	213	4.83	[180]
	RbH_2PO_4	147	5.6	[90]
	KH_2AsO_4	97	5.0	[78]
	GeTe	670	—	—
TGS type	Tri-glycine sulfate	322	2.8	[29]
	Tri-glycine selenate	295	3.2	[283]
Perovskites	$BaTiO_3$	408	26.0	[296]
	$KNbO_3$	708	30.0	[523]
	$PbTiO_3$	765	>50	[296]
	$LiTaO_3$	938	50	
	$LiNbO_3$	1480	71	[296]