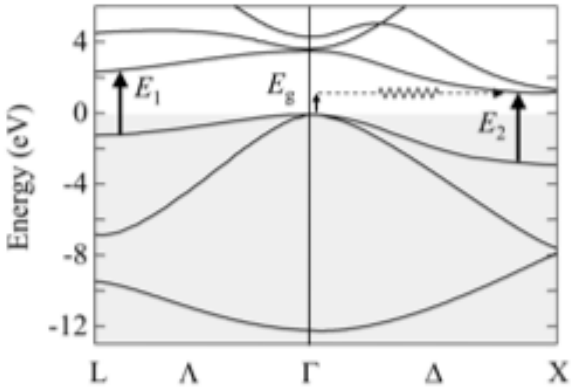
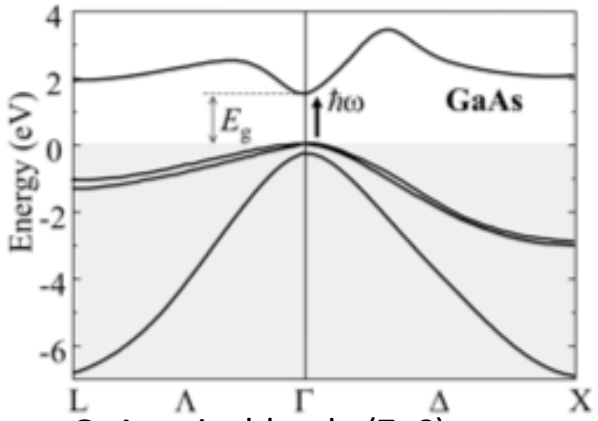
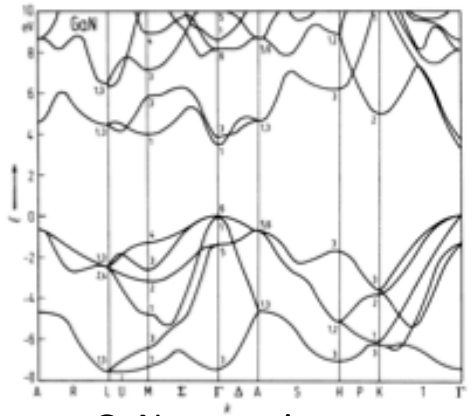
Semiconductors:



Silicon band structure

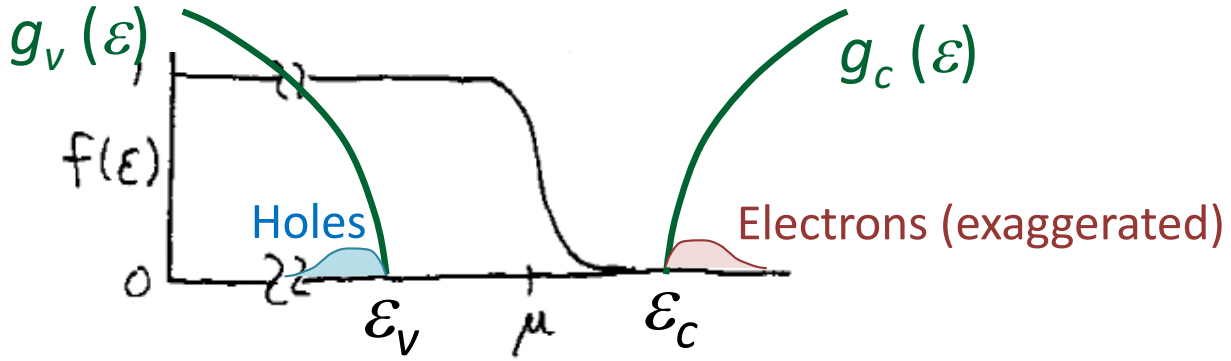


GaAs: zincblende (ZnS)



GaN: wurtzite

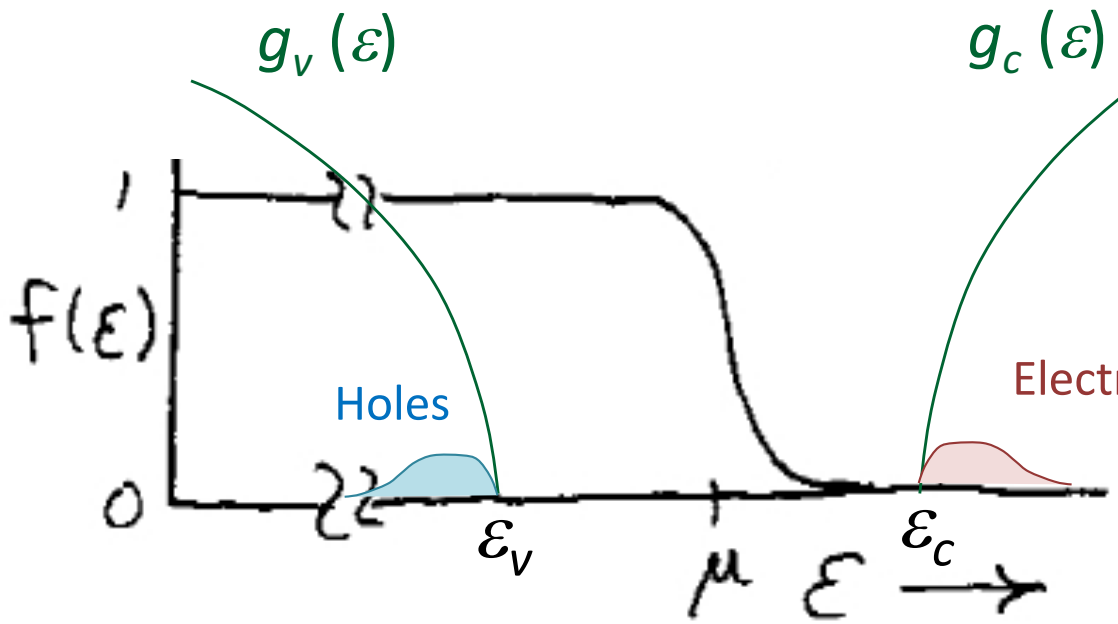
	Group IV			III-V							II-VI	
Material	**Si**	**Ge**	**C**	**AlAs**	**GaAs**	**InAs**	**InP**	**GaSb**	**InSb**	**GaN**	**HgCdTe**	**ZnO**
Bandgap (eV)	1.11	0.67	5.5	2.16	1.43	0.354	1.34	.726	0.17	3.4	0 – 1.47	3.4
Electron mass (or m_l)	0.98	1.64	1.1	0.1	0.063	0.027	0.073	0.042	0.014	0.19	~0	0.27
Electron mass (transverse)	0.19	0.082	0.22	-	-	-	-	-	-	-	-	-
light hole mass	0.16	0.044			0.082	0.026	0.089	0.05	0.015			
heavy hole mass	0.49	0.28	0.25		0.51	0.41	0.6	0.4	0.43	0.8		
Electron Mobility ($cm^2/V.s$)	1350	3900	2800	180	8500	40000	5400	3000	77000	500		
structure	diam	diam	diam	ZnS	ZnS	ZnS	ZnS	ZnS	ZnS	wurtzite	ZnS	wurtzite
Lattice Constant (Å)	5.43	5.66	3.57	5.66	5.65	6.06	5.87	6.09	6.48			



Semiconductor carrier densities:

recall RT
~ .025 eV

- Assume μ is far from band edges, $|\mu - \varepsilon_{c,v}| >> kT$.
- Carriers act as classical gas, occupation function << 1.



$$n = \int g(\epsilon) f(\epsilon) d\epsilon$$

$$g(\epsilon) = \left[\frac{N_m \sqrt{2 m_1^* m_2^* m_3^*}}{\hbar^3 \pi^2} \right] \sqrt{\epsilon - \epsilon_c} \qquad f(\varepsilon) = \left[\exp \frac{\varepsilon - \mu}{k_B T} + 1 \right]^{-1} \approx \exp\left(- \frac{\varepsilon - \mu}{k_B T} \right)$$

Semiconductors

$$f(\varepsilon) \approx \exp\left(-\frac{\varepsilon-\mu}{k_B T}\right) \qquad g(\epsilon) = \left[\frac{N_m \sqrt{2m_1^* m_2^* m_3^*}}{\hbar^3 \pi^2}\right] \sqrt{\epsilon - \epsilon_c}$$

minima

integrate ⇨

$$n = \left[\frac{N_m \sqrt{m_1^* m_2^* m_3^* (k_B T)^3}}{\sqrt{2}\hbar^3 \pi^{3/2}}\right] e^{-(\varepsilon_c - \mu)/kT} = N_c(T) e^{-(\varepsilon_c - \mu)/kT}$$

e.g. Si, at RT 2.8×10^{19} cm^{-3}

similar for holes:

$$p = \left[\frac{\sqrt{m_1^* m_2^* m_3^* (k_B T)^3}}{\sqrt{2}\hbar^3 \pi^{3/2}}\right] e^{-(\mu - \varepsilon_v)/kT} = P_v(T) e^{-(\mu - \varepsilon_v)/kT}$$

Si, at RT 1.0×10^{19} cm^{-3}

---

gives $\sigma = \frac{ne^2\tau}{m_c^*} + \frac{pe^2\tau}{m_v^*}$ etc.

Intrinsic densities:

product is independent of μ

$$n = N_c(T)e^{-(\varepsilon_c - \mu)/kT}$$

$$p = P_v(T)e^{-(\mu - \varepsilon_v)/kT}$$

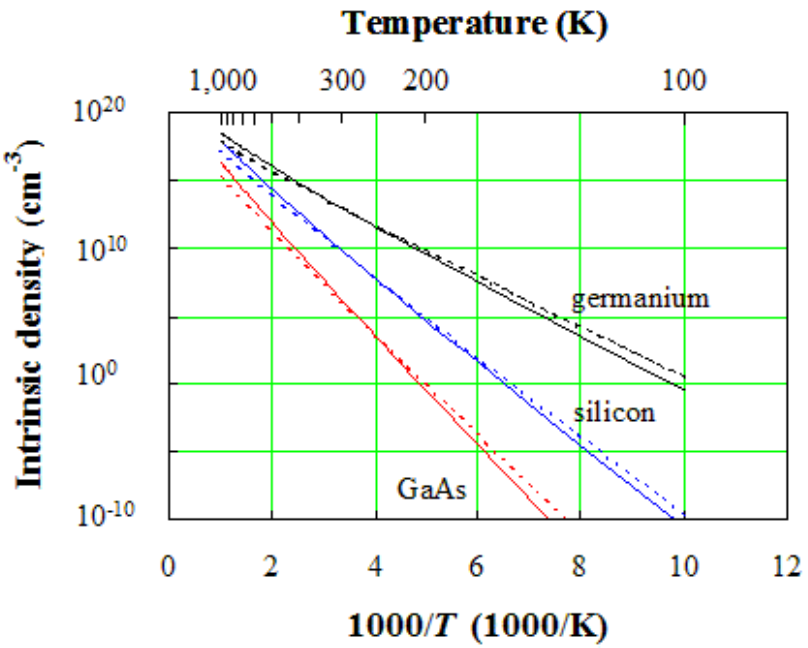
$$\Rightarrow \quad np = N_c(T)P_v(T)e^{-(\varepsilon_g)/kT}$$

Silicon, RT $N_c P_v = (2.8 \times 1.0) \times 10^{38}$ cm^{-6}

- Intrinsic: ultra-pure (no impurities, or field effects)
- $n = p$ by charge conservation.
- μ near mid-gap position.

$$n_i = \sqrt{N_c(T)P_v(T)}e^{-(\varepsilon_g)/2kT}$$

Silicon, RT $n_i = 1.5 \times 10^{10}$ cm^{-3}



Law of mass action:

Independent of μ

$$np = N_c(T)P_v(T)e^{-(\varepsilon_g)/kT} \equiv n_i^2$$

Silicon, RT $n_i = 1.5 \times 10^{10}$ cm^{-3}

So, e.g. if $n = 1.5 \times 10^{15}$ cm^{-3} ("*n*-type" for example by impurities) then $p = 1.5 \times 10^{5}$ cm^{-3}