Effective Mass in 2D

Electrons in some 2D material satisfy the E-k relation:

$$E = E_C + \frac{\hbar^2 k_x^2}{2m_1} + \frac{\hbar^2 k_y^2}{2m_2}$$

The effective mass tensor, defined as

$$\mathbf{M}^{-1} = \begin{bmatrix} 1/m_{xx} & 1/m_{xy} \\ 1/m_{yx} & 1/m_{yy} \end{bmatrix}$$

is given by:

$$\frac{1}{m_{ij}^*} = \frac{1}{\hbar^2}\frac{\partial^2 E}{\partial k_i \partial k_j},\ i, j = x, y$$

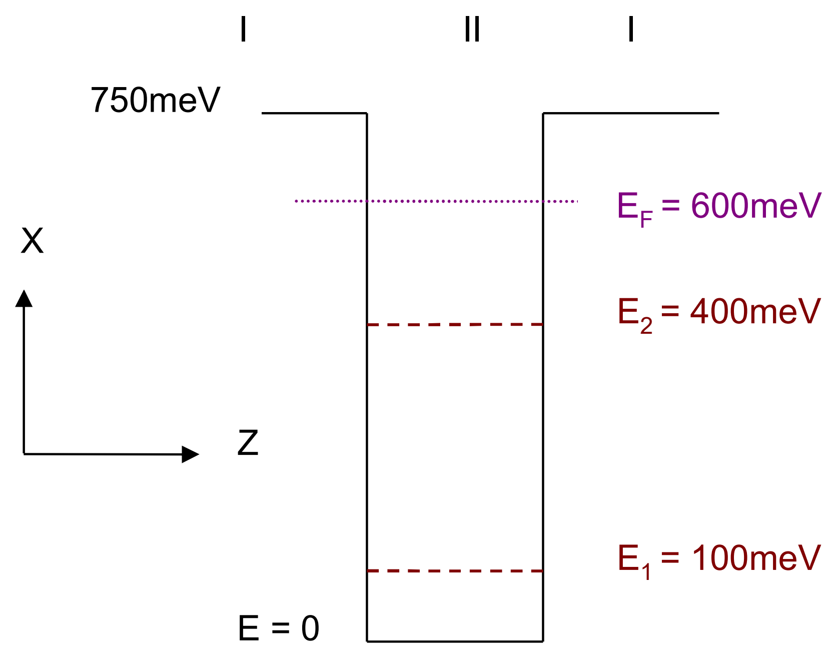
$$\begin{bmatrix} m_1^{-1} & 0 \\ 0 & m_2^{-1} \end{bmatrix}$$

Carrier Density in 2D

The DOS for free electrons in 2D is: $g_{2D} = \frac{m_0}{\pi\hbar^2} \simeq 4.2 \times 10^{14} cm^{-2} eV^{-1}$

Consider now the quantum well in the heterostructure formed between semiconductors I and II, a quasi-2D system.

Assume spherical effective mass $m^* = m_0$ everywhere.



The 2D electron density at cryogenic temperature is:

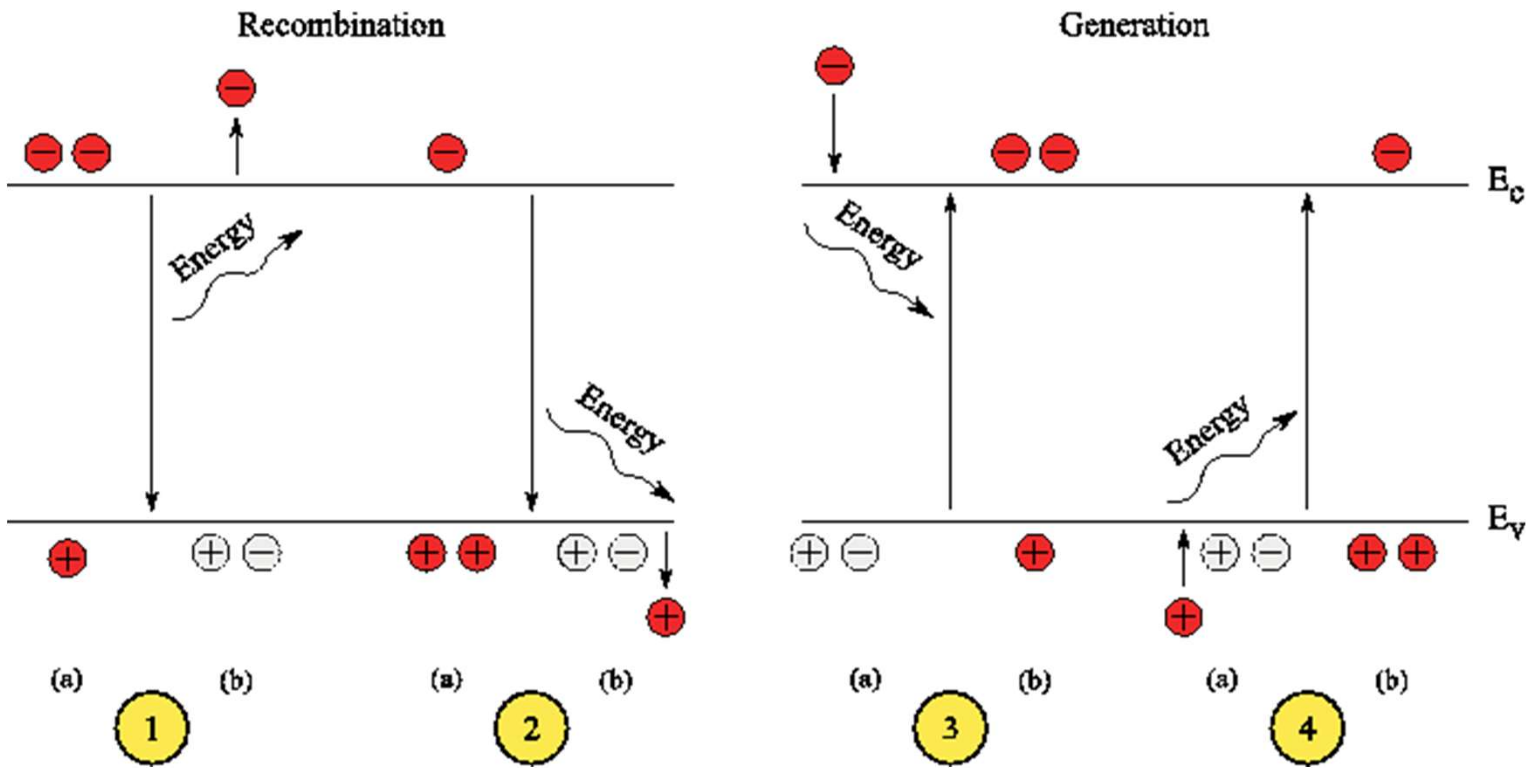
a. No idea

b. $g_{2D} \times 0.4eV$

c. $g_{2D} \times 0.6eV$

d. $g_{2D} \times 0.7eV$

Auger Recombination

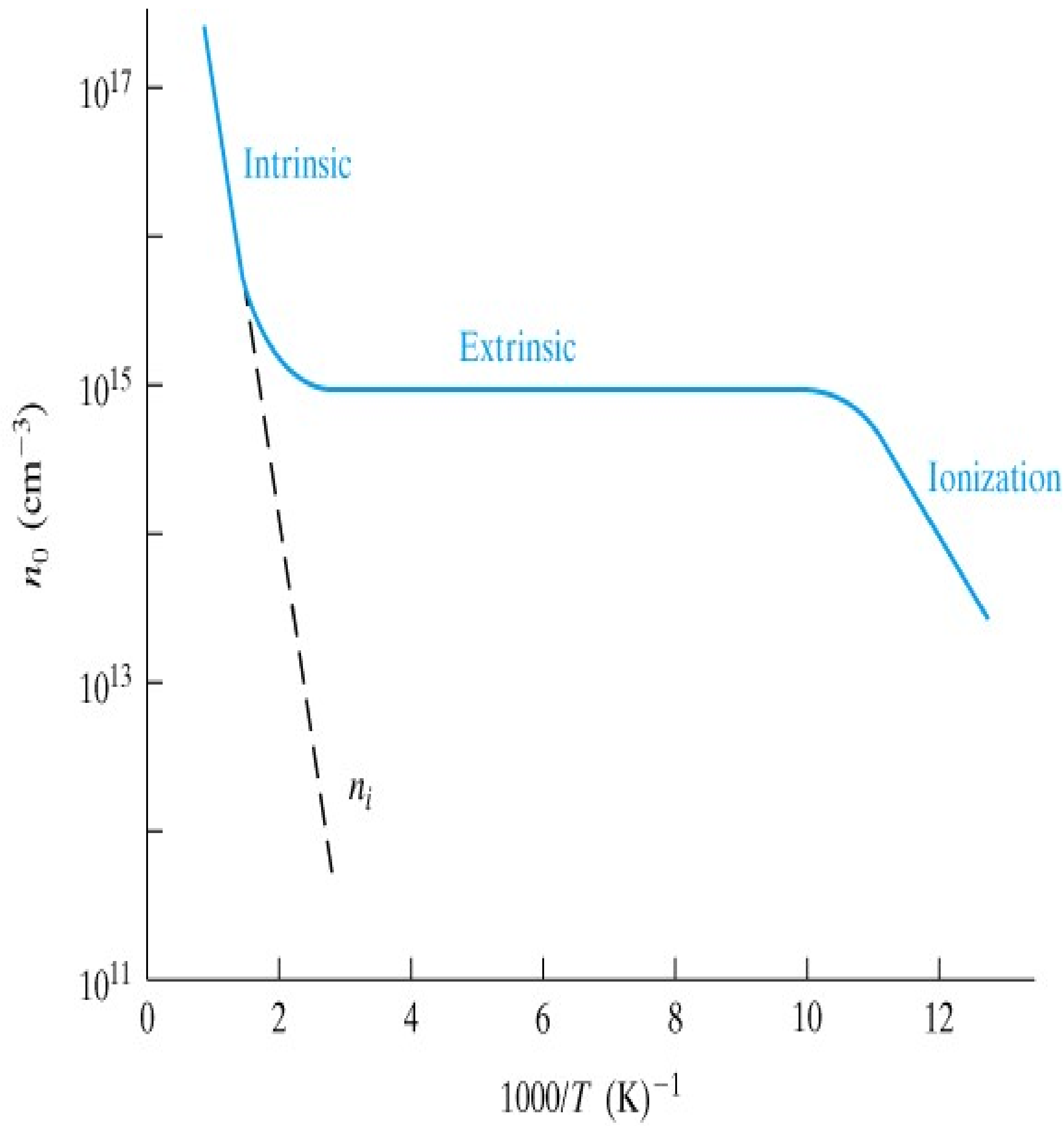


$$R = a_n\left(n^2 p - n_i^2 n\right) + a_p\left(np^2 - n_i^2 p\right)$$

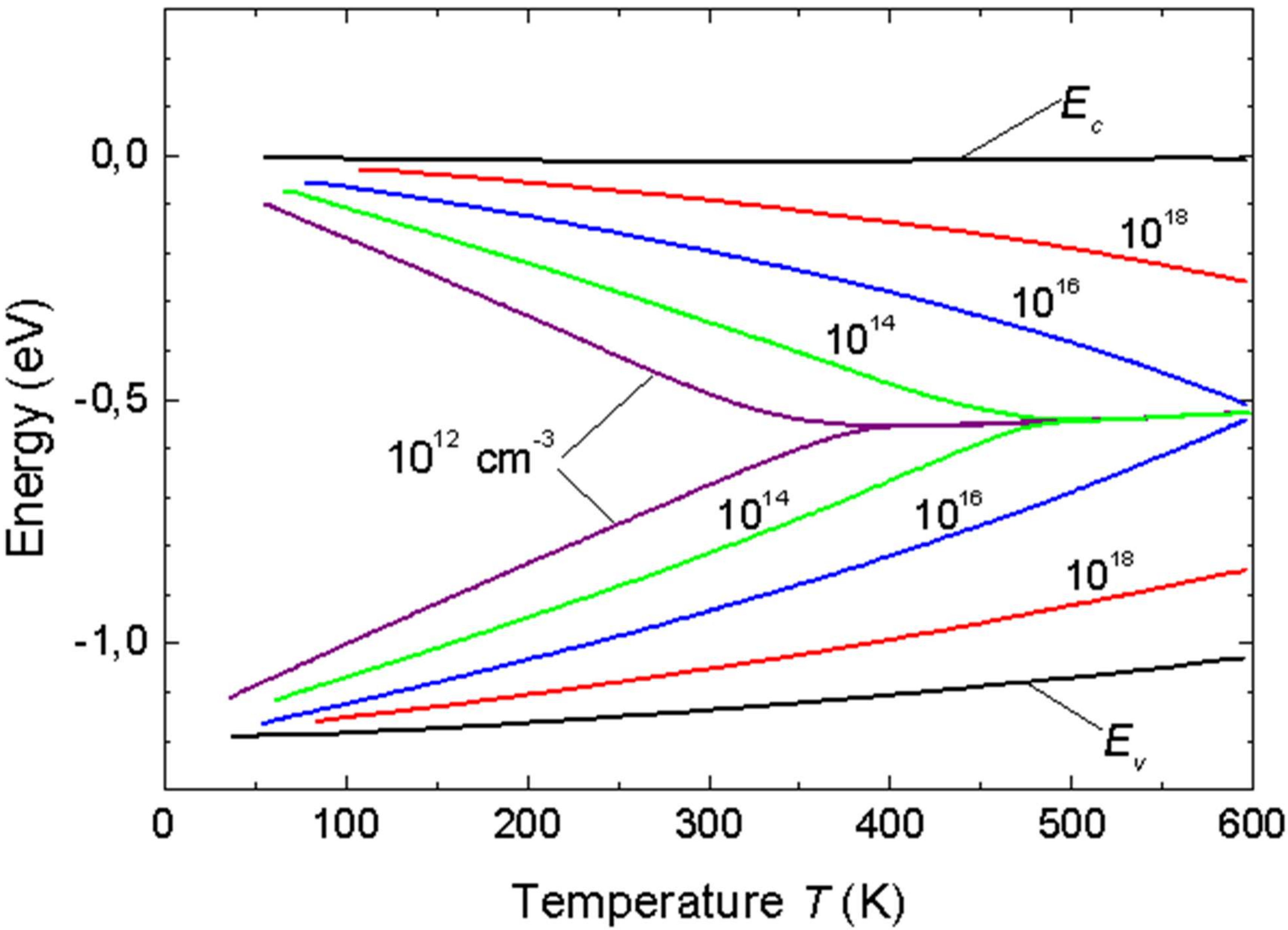
$2e^- + 1h^+$ $1e^- + 2h^+$

Inverse (generation) process is impact ionization (?).

Density vs. Temp



E_F vs. Temp



Energy (eV)
0,0
-0,5
-1,0
E_c
E_v
10^{18}
10^{16}
10^{14}
10^{12} cm^{-3}
10^{14}
10^{16}
10^{18}
0
100
200
300
400
500
600
Temperature T (K)

SRH Recombination

$$R = \frac{\left(np - n_i^2\right)}{\tau_p\left(n + n_i e^{(E_t - E_i)/kT}\right) + \tau_n\left(p + n_i e^{(E_i - E_t)/kT}\right)}$$

Consider the SRH formula for the low-level injection case. Assume nearly equal lifetimes for electrons and holes. The most effective trap levels will have:

a. $E_t \approx E_v$

b. $E_t \approx E_i$

c. $E_t \approx E_c$

d. No idea

Quasi-Fermi Levels

The equilibrium and steady state conditions before and after illumination of a semiconductor are characterized by the energy band diagrams shown in figure below. If the resistivity before illumination is 4.8 Ω-cm, and $\mu_n=\mu_p$, then the resistivity (in Ω-cm) after illumination will be:

a) 4.8 b) 3.2 c) 2.4 d) 1.6