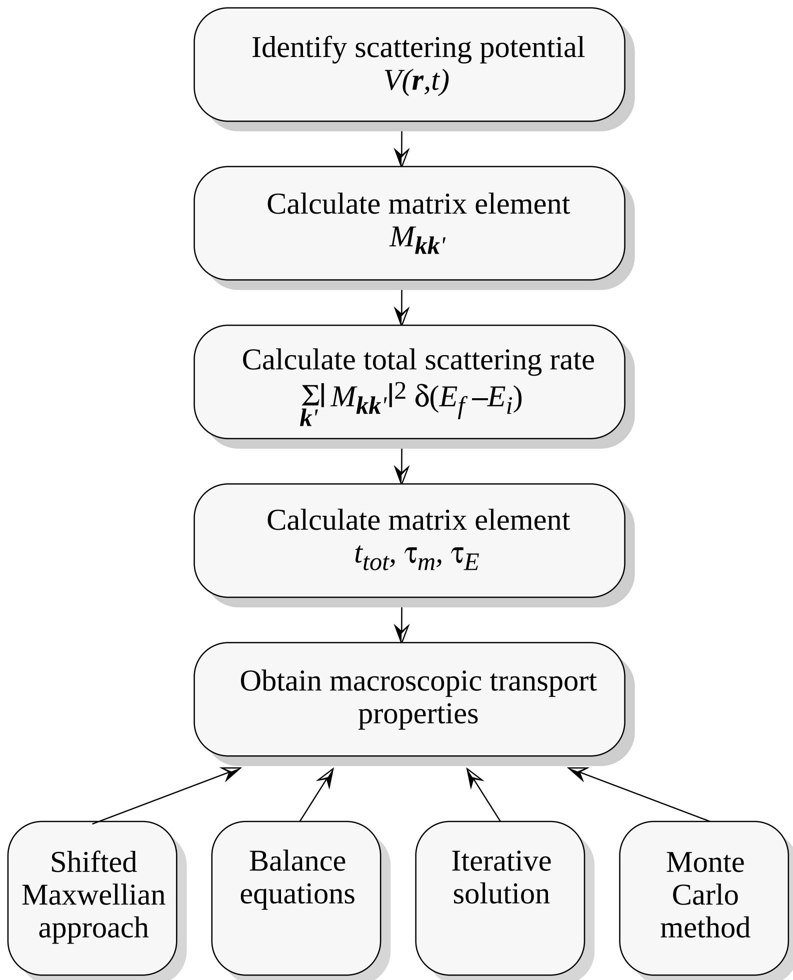
Chapter 5

DEFECT AND CARRIER-CARRIER SCATTERING

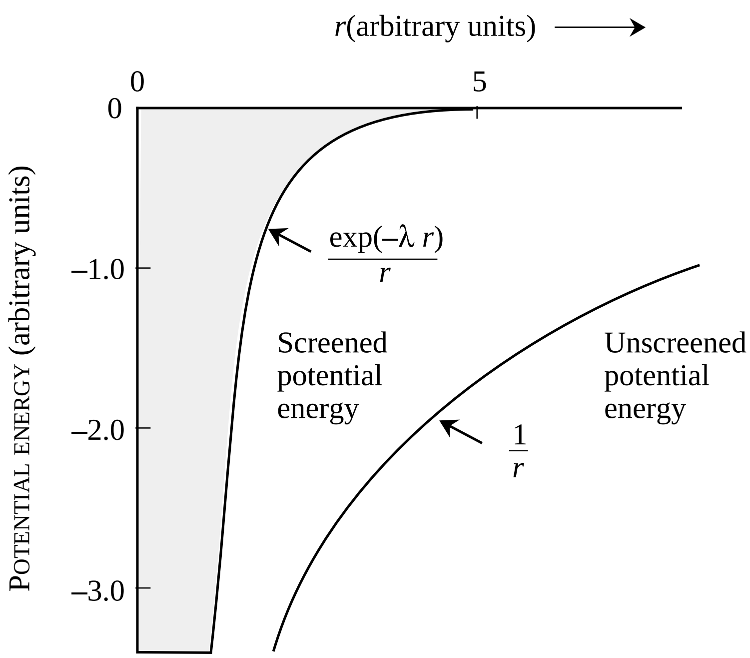
GENERAL APPROACH TO SCATTERING DOMINATED TRANSPORT



IONIZED IMPURITY SCATTERING

Base scattering potential: Charge = Ze

$$U(r) = \frac{Ze^2}{4\pi\epsilon} \frac{1}{r}$$



Comparison of screened and unscreened Coulomb potentials of a unit positive charge as seen by an electron. The screening length is λ^{-1}.

Screened Coulombic potential:

$$U(r) = \frac{Ze^2}{4\pi\epsilon} \frac{e^{-\lambda r}}{r}$$

Low free carrier density (n_0):

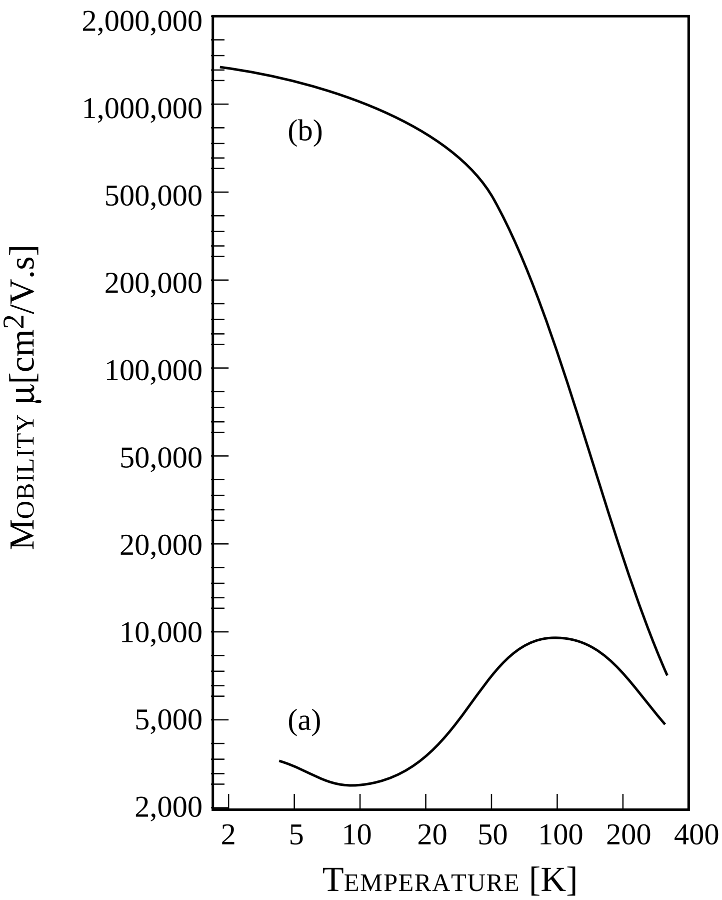
$$\lambda^2 = \frac{n_0 e^2}{\epsilon k_B T}$$

IONIZED IMPURITY LIMITED MOBILITY

$$\mu_i = \frac{e \langle\langle\tau\rangle\rangle}{m^*}$$

$$\frac{1}{\langle\langle\tau\rangle\rangle} = N_i \frac{1}{128\sqrt{2\pi}} \left(\frac{Ze^2}{\varepsilon}\right)^2 \frac{1}{m^{*1/2}(k_BT)^{3/2}}$$

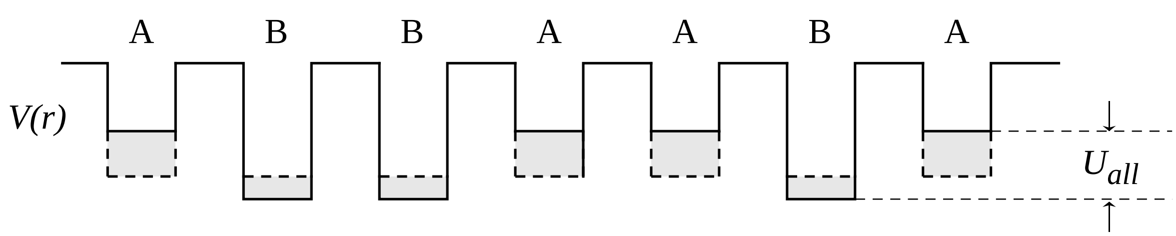
$$\times \left[ln\left(1 + \left(\frac{24m^*k_BT}{\hbar^2\lambda^2}\right)^2\right) - \frac{1}{1 + \left(\frac{\hbar^2\lambda^2}{24m^*k_BT}\right)}\right]$$



Typical measurements of electron mobility as a function of temperature in a uniformly doped GaAs with $N_D = 10^{17}$ cm^{-3}. The mobility drops at low temperature due to ionized impurity scattering becoming very strong. In contrast, the curve (b) shows the mobility in a modulation doped structure where ionized impurity is essentially eliminated.

ALLOY SCATTERING LIMITED MOBILITY

In a semiconductor alloy there are random potential fluctuations from which electrons scatter.



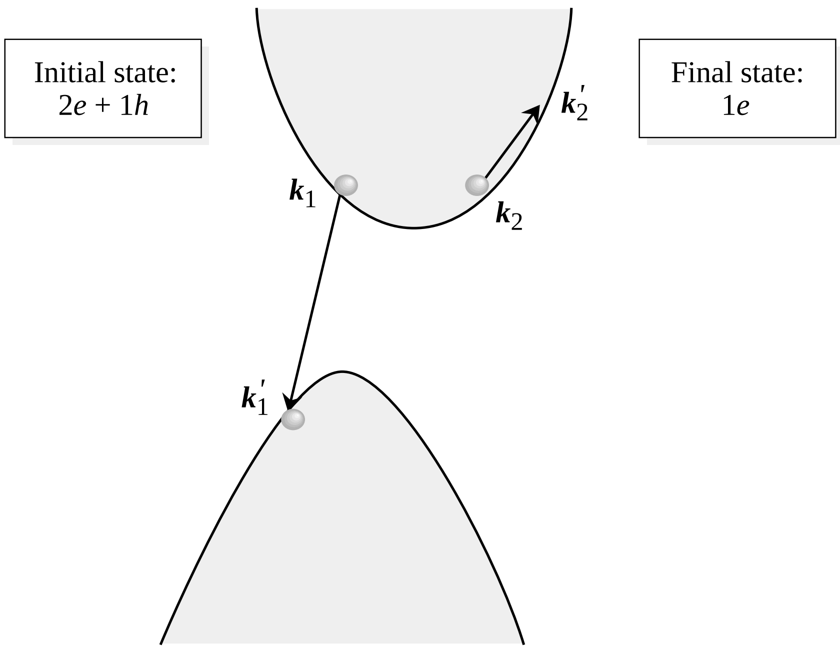
A schematic of the actual atomic potential (solid line) and the average virtual crystal potential (dashed line) of an A-B alloy. The shaded area shows the difference between the real potential and the virtual crystal approximation.

3D systems:

$$\frac{1}{\langle\langle\tau\rangle\rangle} = \frac{3\pi^3}{8\hbar} V_0 \, U_{all}^2 \, x(1-x) \, \frac{m^{*3/2}(k_B T)^{1/2}}{\sqrt{z}\,\pi^2\hbar^3} \, \frac{1}{0.75}$$

AUGER PROCESSES AND IMPACT IONIZATION

Auger process:
Electron-hole recombination → hot carrier



A schematic of the states of the electrons before and after an Auger scattering. The reverse of this process is the impact ionization process. This particular process is called CHCC (Conduction-heavy hole-conduction conduction).

Impact ionization:
Reverse of Auger recombination → hot carrier
→ e-h pair