EE 87024 - Wide Bandgap Device Physics

Debdeep Jena (djena@nd.edu)
Department of Electrical Engineering
University of Notre Dame

Midterm Exam

1 Wide Bandgap Semiconductors

a) Drawing from results of $\mathbf{k} \cdot \mathbf{p}$ theory, explain the relationship between energy bandgap and effective masses of electrons.

b) Drawing upon results of $\mathbf{k} \cdot \mathbf{p}$ theory again, explain why wide bandgap semiconductors have smaller conduction band non-parabolicity than narrow bandgap semiconductors.

2 Perturbation Theory

a) Consider a free electron of mass m_0 constrained to move in 1 dimension. Assuming periodic boundary conditions of a large length L such that the electron can move between $-L/2 \leq x \leq +L/2$, write down the energy eigenvalues and normalized wavefunctions for the electron as a function of its wavevector k.

b) Now assume a small constant perturbation V_0 appears between $-d/2 \leq x \leq +d/2$, i.e., the perturbation potential is $W(x) = V_0\theta(d/2 - |x|)$, where $d << L$. Sketch the perturbation potential.

c) Assume that an electron moving in the state $|k\rangle$ is scattered into the state $|k + q\rangle$ by the perturbation potential. Find the scattering matrix element, and an expression for the scattering rate $1/\tau(q)$ where $\hbar q$ is the change in momentum due to scattering.

d) Using Fermi's golden rule and energy conservation, show that the only scattering allowed for state $|k\rangle$ is into the state $|-k\rangle$, i.e., $q = -2k$. This is characteristic of 1D transport - and is called backscattering for obvious reasons.

e) Use Fermi's golden rule to show that the *total* scattering rate for an electron starting from state $|k\rangle$ integrated over all final states (shown in part d to be just one!) has the dependence $1/\tau(k) \propto m_0 V_0^2 \sin^2(kd)/(\hbar k)^3$, that is, the scattering rate reduces as the third power of the electron momentum. Try to explain this from a classical viewpoint.