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SCHOOL OF PHYSICS AND ASTRONOMY

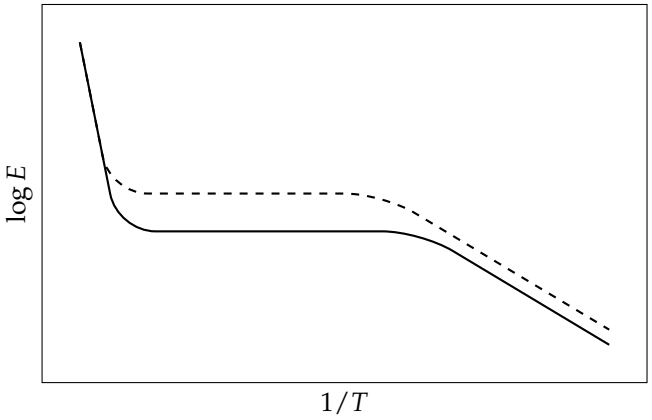
Structure and Properties of Functional Materials

Exercise Set 8

Friday, 15 March, 2013

1. *For discussion*

   Consider the following sketch of the electron concentration in the conduction band of two n-type semiconductors (solid and dashed lines). Why do the curves have the shape they do? What is happening in each of the three identifiable temperature regions? What is the difference between the materials that gave the solid and dashed lines?



2. Consider a sample of gallium arsenide doped with Se on the As sites to a concentration of $10^{16}\,\mathrm{cm}^{-3}$.
   (a) Is this an n- or a p-type semiconductor?
   (b) Estimate the ionisation energy of a Se atom in this system: that is, the distance $E_C - E_D$ between the Se ground state and the conduction band. The dielectric constant of GaAs is $\epsilon = 12.9$; take the effective mass of an electron to be $m_c^* = 0.85m$ (this is actually an average over different directions).
   (c) At $T = 300\,\mathrm{K}$, what are the concentrations of electrons n and holes p in the sample? The band gap of GaAs is $E_g = 1.424\,\mathrm{eV}$; the effective heavy hole mass is $m_{hh}^* = 0.51m$, and the effective electron mass is given above.
   (d) Estimate the temperature above which this sample would exhibit intrinsic conductivity.

3. *Challenge*

   Why does the chemical potential μ of metals tend to decrease with temperature while the chemical potential of semiconductors tends to increase with temperature?