Homework #6 - due Thursday, 3 November 2005, in class

1. **Molecular Beam Epitaxy:** The evaporation of a material from a Knudsen cell is given by the Langmuir equation on p. 206 of the text (Waser). Assuming that the evaporated atoms travel ballistic trajectories, following a cosine distribution versus angle as shown in Figure 13, calculate the flux of atoms striking a unit area of substrate per second at a distance \( L \) from the source. Using this equation, calculate the arrival rate of gallium (as in the growth of GaAs). For Ga, use the atomic mass of 70; length \( L = 15 \text{ cm} \); the area of the Knudsen orifice of 5 cm\(^2\); and the equilibrium vapor pressure of Ga = \( 4 \times 10^{-3} \text{ Torr} \) at \( T = 1000^\circ \text{C} \). Estimate the corresponding growth rate in \( \mu \text{m per hour} \).

2. **Chemical Vapor Deposition:** Analyze the two fundamental types of limitations to chemical deposition, using the nomenclature of the text (Waser). The rate \( j_k \) due to chemical reaction kinetics follows a thermal activation energy \( E_{\text{act}} \) such as:

\[
j_k \sim \exp\left[- \frac{E_{\text{act}}}{k_B T}\right]
\]

where \( k_B \) is Boltzmann’s constant and \( T \) is the absolute temperature.

The growth rate limitation due to the mass transport of chemicals to the growing film follows a diffusion equation such as:

\[
j_t \sim \sqrt{\frac{D}{T}}
\]

where \( D \) is a diffusivity.

Using these equations, analyze the data of Figure 37 on page 214, for the growth of polysilicon. Estimate the activation energy \( E_{\text{act}} \), and the effective diffusivity \( D \). Discuss in your own words the sensitivity of the growth rate to temperature in the two regimes of: (a) reaction kinetics -limited growth, and (b) mass transport -limited growth. Give the temperature ranges for the two growth rate limitations.

Homework assignments will appear on the web at:
http://www.ece.udel.edu/~kolodzey/courses/eleg667_016f05.html

Note: On each homework and report submission, you must please give your name, the due date, assignment number and the course number.