N.CHEUNG **EE143, Fall 2010**

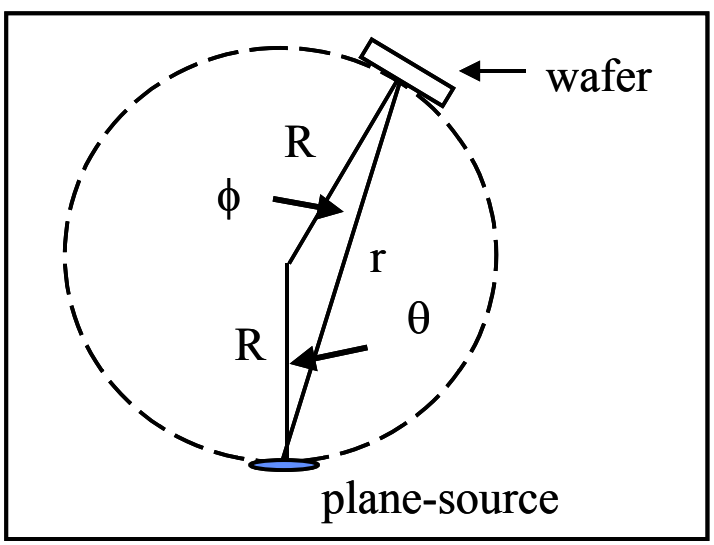
Homework Assignment # 6 (Due October 15, Fri 9am)

Reading Assignment
Chapter 6 of Jaeger (Sections 6.4.2 and 6.4.3 are not required)
EE143 website Handouts Directory - EE143 Notes on CVD Kinetic
BSpace- Qualitative reading only-Chapter 13 of Campbell on CVD.You can skip Section 13.2

Optional for those who want to explore further
BSpace- "A Short course on Vacuum Pump Technology"

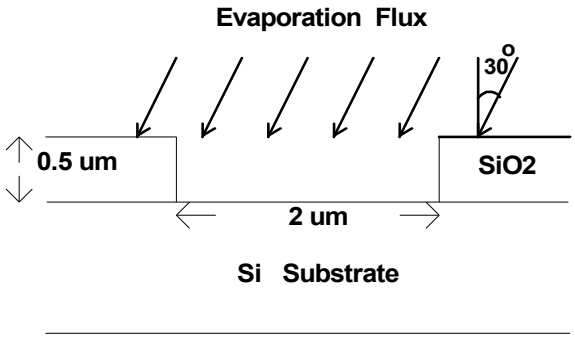
Problem 1 Thickness Uniformity and Step Coverage

From most textbooks, one can derive that a small-area cos θ emission cource and a spherical receiving surface (see figure below), will give a constant deposited thickness for all values of **r** from the emission source.



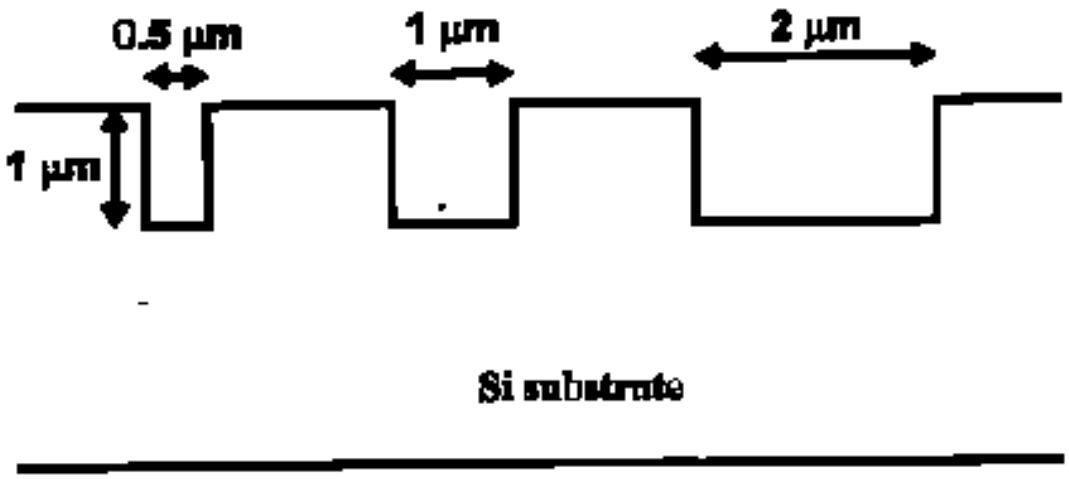
(i) Suppose the small-area source actually have a $(\cos\theta)^2$ flux emission dependence instead of cos θ. How will the thickness deposited depend on **r** ? Show your derivation.
(ii) Using the above geometry to deposit thin films over contact holes or across steps on the wafers, do you still expect to see step coverage problems . Explain.

Problem 2 Evaporation Shadowing
If the evaporation source is very far from the wafer, we can treat the evaporation fluxes to be uniform and parallel. The following contact opening has vertical SiO_2 sidewalls and the evaporating flux is making an angle 30° with respect to the normal of the wafer's surface. If the film deposition rate is 1000Å/min, sketch the cross-sectional profile of the film over the SiO_2 and Si after (a) 1 min, and (b) 2 min. The SiO_2 step height is 5000Å and the contact opening is 2 μm. Dimensions of your sketches have to be proportional.



Probelm 3 Conformal Deposition

(a) Complete conformal coverage will have identical deposition rates **normal** to the suface for all surface topography. With a deposition rate of 0.1 micron/min on planar surfaces, sketch the cross-sections of the deposited film for a completely conformal deposition (e.g. CVD) at time = 1 min, 2 min, 3 min, and 4min.



(b) Briefly comment on the deposited thickness required to obtain a planarized surface for substrate with various trench aspect ratios (i.e., height/width ratio).

Problem 5 CVD temp dependence

A CVD process deposition rate is known to be surface-reaction limited at 700 °C with an activation energy of 2 eV. The measured deposition rate at 700 °C was found to be 1000 Å /min

(i) Calculate the deposition rate at 800 °C by assuming the deposition rate is still surface-reaction limited. [Hint: kT at T=300K is 0.026eV]

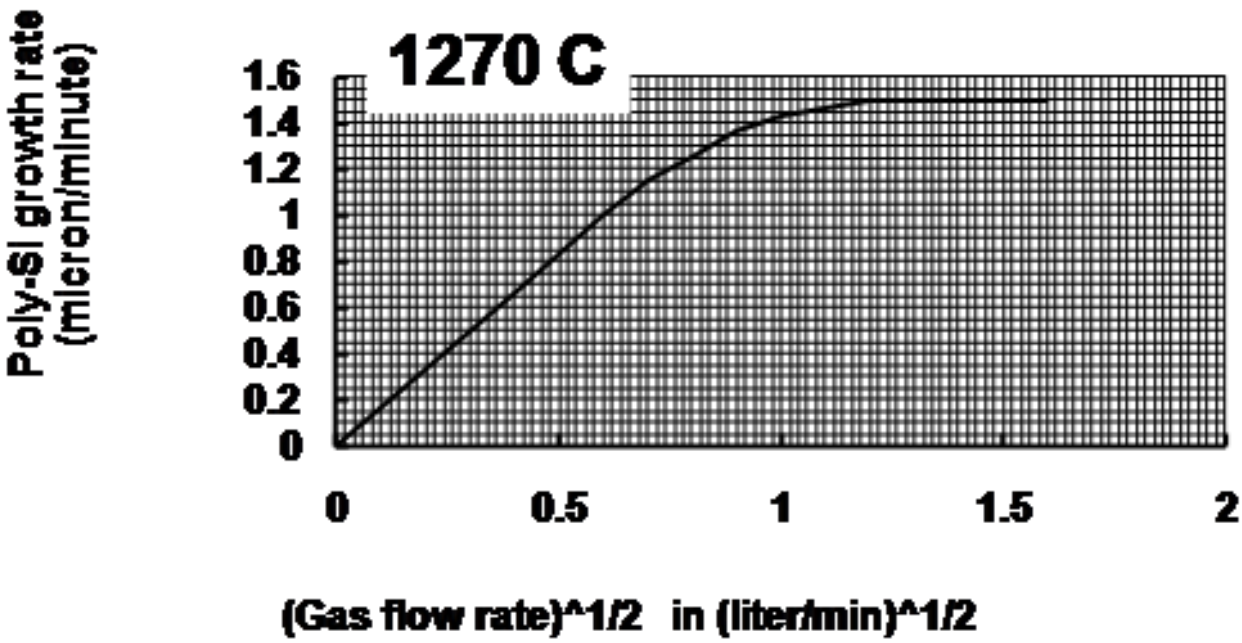
(ii) If the measured deposition rat at 800 °C is **less than** the predicted value of part (i), explain the cause of the deviation in terms of the Grove Model.

(iii) Propose an experiment to verify your explanation which you give in part (ii).

Problem 5 CVD: Mass Transport Limited versus Surface Reaction Limited

Poly-Si is deposited by CVD at 1270°C. The concentration of Si atoms in the gas stream is 4×10^{16} /cm^3.

The growth rate versus (gas flow-rate)$^{1/2}$ curve is shown below:



a) If the surface reaction rate coefficient k_s is given by :$k_s = 10^7 \exp(-\Delta E/kT)$ cm/sec. Find the value of ΔE from data shown in curve.
b) Calculate the mass-transfer coefficient h_G when the growth rate is 1.4 μm/min? (Use the Grove Model for this calculation). Use k_s value derived in part(a).
c) h_G can also be determined from data in the low flow rate region. Find the h_G value by this method. You will find the h_G values in parts c) and b) are not consistent. This is probably due to other experimental complications which were not described by the Grove Model.
d) Assuming the Grove model is correct, use results from part(b) to calculate the percentage change in growth rate if the given deposition temperature changes by 1%.

Problem 6 Qualitative questions on thin film deposition

1) Why we prefer sputtering deposition instead of evaporation if we want to deposit a compound film?
2) Epitaxial growth of a lightly doped Si layer over a heavily doped Si substrate is common in IC technology. Can such doping profile be created by dopant diffusion ?
3) How do we control deposited thickness with atomic layer deposition (ALD) ?
4) CVD is usually not used for the Liftoff Process. Why?