The test is take home. If you have any questions, please post them on GoPost. I will post any comments/corrections/hints there. Show all work. Be sure to state all assumptions made and check them when possible. The tests are due at my office (slide under door if I am not in) or via email on Monday, December 13 at 10am. Please limit your active working time to 9 h.

1. Consider a coherent imaging system with \( \lambda = 0.193\mu m \) and \( NA = 1.5 = 2.0 \sin \theta \). A mask with an isolated slit of width 35 nm is used to expose photoresist with thickness 50 nm. The absorption depth of the UV is also 50 nm (ignore bleaching and reflection from substrate).

   (a) What is the absorbed light intensity as function of distance from the center of the exposed region and depth into the photoresist?

   (b) If the rate of resist removal in developer solution is proportional to the cube of the absorbed light intensity and the development time is 10% more than that required to fully remove the resist at the center of the exposed region, what is the width of total removal of photoresist? How wide is the transition region to the point where at least 50% of the photoresist remains?

2. LPCVD is used to deposit a film within a very deep trench of width \( a \). If the incident flux from the gas phase is isotropic (\( \cos \theta \)), and the sticking coefficient is \( S_C \), calculate the thickness deposited on the sidewalls of the trench as function of depth. Normalize as proportion of deposition on the horizontal surface. Assume that re-emission is isotropic. Note that you need to account self-consistently for re-emission.

3. Silicon is etched in an Ar/CF4 plasma at room temperature. A simplified model of the plasma reactions includes the following reactions:

   \[
   \begin{align*}
   CF_4 + e^- & \rightarrow CF_3 + F + e^- \\
   CF_3 + F & \rightarrow CF_4 \\
   Ar + e^- & \rightarrow Ar^+ + 2e^- 
   \end{align*}
   \]

   At the silicon surface, the CF3 passivates the surface in a reversible process and prevents etching, while the atomic F etches the Si via an irreversible linear reaction at any unpassivated sites. The incident ions remove the passivating CF3 with probability \( \alpha \) if they hit a passivated site.

   (a) Determine expressions for the steady-state molecular concentrations in the plasma chamber in terms of the CF4 and Ar input flow rates, the pump rate, the reactor volume, the electron concentration and the reaction rates. Neglect loading.

   (b) Determine an expression for the steady-state etch rates on horizontal and vertical surfaces.

   (c) Determine an expression for the amount of additional lateral etching (beyond the steady-state value) that occurs on bottom sidewalls as bare Si is newly exposed due to etching of adjacent horizontal surfaces. Sketch the resulting shape of etched trench. Assume that CF3 forms only a single monolayer.