Green Engineering – Electronic Materials Processing

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Green Engineering Design - Maximizing feed gas utilization using OSU's Virtual CVD Reactor

Student Problem Statement

Related Green Engineering principles:

- Minimize depletion of natural resources.
- Strive to prevent waste.
- Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.

Student Problem Statement

Your task is to develop a "recipe" (i.e. choice of process parameters) for high volume manufacturing of a thin film of silicon nitride (Si_3N_4) using low pressure chemical vapor deposition (LPCVD) within manufacturing and cost constraints. You will optimize this process based on green engineering principles by maximizing the utilization of dichlorosilane while meeting uniformity specifications. The growth and measurements will be made via computer simulation in OSU's VirtualCVD reactor available via: http://che.oregonstate.edu/research/VirtualCVD.

You will need a student account Username and Password from your instructor. You can then download the 3D client software to run the Virtual CVD application. It is available at: http://che.oregonstate.edu/research/VirtualCVD/jump_in_to_virtual_fab.html

The silicon nitride films will be used as insulating material in one of the layers in a stacked oxide-nitride-oxide dynamic random access memory (DRAM) chip. The solid film is grown from a gas feed of dichlorosilane (SiH_2Cl_2) and ammonia (NH_3) according to the following stoichiometry:

$$10NH_3(gas) + 3SiH_2Cl_2(gas) \rightarrow Si_3N_4(solid) + 6NH_4Cl(gas) + 6H_2(gas)$$

According to the MSDS, dichlorosilane gas is extremely flammable, toxic by inhalation and corrosive to eyes, respiratory systems and skin. Therefore, minimizing its use protects human health; while maximizing the utilization will decrease the amount of waste released to the natural ecosystem.

You should develop a recipe that grows Si_3N_4 to a target thickness of 1500 Å with 99% uniformity within the wafer, and from wafer to wafer. Uniformity, U, can be estimated based on target thickness, t, and the standard error, s, as follows:

$$U = \left(1 - \frac{s}{t}\right) * 100\%$$

where s can be obtained from your measured thicknesses, x_i:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - t)^2}{n - 1}}$$

The furnace has a capacity for batches of up to two hundred 300 mm wafers. The wafer spacing is 6.35 mm. It has 5 temperature zones that can be set individually. In addition, you can set the flow rates of ammonia and dichlorosilane feed gases, the reactor pressure and the time. You will also have access to a (Virtual) ellipsometer, with which you can measure the film thicknesses at the points on any wafer that you select. You will be charged $5,000 for each run and $75 for each measurement (in Virtual$, of course).

Additional information on the engineering science and operation of low-pressure CVD reactors for Si_3N_4 films is available in the following references.

1. Wolf, Stanley and Richard N. Tauber, *Silicon Processing for the VLSI Era*, Lattice Press, Sunset Beach, CA, (2000). pages 202-206.
2. May, Gary S. and Simon M. Sze, *Fundamentals of Semiconductor Fabrication*, John Wiley and Sons Inc, Hoboken, NJ (2004). pages 160-162.
3. Xiao, Hong, *Introduction to Semiconductor Manufacturing*, Prentice Hall, Columbus, OH (2001). pages 166-169.

These references also have information about CVD, in general, and electronic materials processing as well.