mole fraction of DCS

$$y_{DCS} = \frac{Q_{DCS}}{Q_{NH_3} + Q_{DCS}} = \frac{70 \text{ sccm}}{200 \text{ sccm} + 70 \text{ sccm}}$$

$$y_{DCS} = 0.2593$$

concentration of DCS

$$250 \times 10^{-3} \text{ Torr} \times \frac{133.322 \text{ Pa}}{1 \text{ Torr}} = 33.33 \text{ Pa}$$

$$\frac{n}{V} = \frac{Pa}{RT} = \frac{(0.2593)(33.33 \text{ Pa})}{(8.314 \text{ J}/(\text{K}\cdot\text{mol}))(770+273)\text{ K}}$$

$$C_{DCS} = 9.97 \times 10^{-4} \text{ mol/m}^3$$

kinetic Eq'n

$$J = k_0 \exp\left[\frac{-E_a}{RT}\right] C_{DCS}^{0.49}$$

$$= 82300 \text{ s}^{-1} \exp\left[\frac{-(169.4 \times 10^3 \text{ J/mol})}{(8.314 \text{ J}/(\text{K}\cdot\text{mol}))(770+273)\text{ K}}\right] (9.97 \times 10^{-4} \text{ mol/m}^3)^{0.49}$$

$$= 9.14 \times 10^{-6} \text{ mol}/(\text{cm}^2\cdot\text{s})$$ rate of change of C_{DCS}

Deposition rate

Stoichiometric coefficient $SiCl_2H_2 : Si_3N_4 = 3:1$

approximate deposition rate $\approx \frac{1}{3}(9.14 \times 10^{-6} \text{ mol}/(\text{cm}^2\cdot\text{s})) \approx 3.05 \times 10^{-6} \text{ mol}/(\text{cm}^2\cdot\text{s})$

by neglecting surface kinetics.

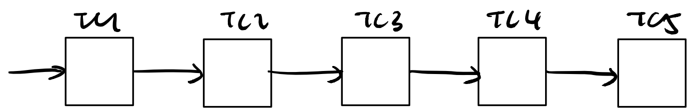
$$MW_{Si_3N_4} = 140.28 \text{ g/mol}$$

$$\rho_{Si_3N_4} = 3000 \text{ kg/m}^3$$

$$\frac{3.05 \times 10^{-6} \text{ mol}}{\text{m}^2\cdot\text{s}} \times \frac{140.28 \text{ g}}{\text{mol}} \times \frac{\text{m}^3}{3000 \times 10^3 \text{ g}} = 1.43 \times 10^{-10} \text{ m/s}$$

$$\boxed{\text{Deposition rate} = 1.43 \text{ Å/s} = 85.8 \text{ Å/min}}$$

$$\frac{2000 \text{ Å}}{85.8 \text{ Å/min}} = 23.31 \text{ mins} \approx 25 \text{ mins}.$$



40 wafers each.

Volume of Si_3N_4 = $(2)(200)(\pi)(0.15m)^2(2000\times10^{-10}m)$

$= 2.83\times10^{-6}\ m^3$

$n_{Si_3N_4} = (2.83\times10^{-6}\ m^3)\left(\frac{3000\ kg}{m^3}\right)\left(\frac{1\ mol}{0.14\ kg}\right)$

$n_{Si_3N_4} = 0.061$ mol which is $n_{DCS} = 0.183$ mol

0.0813 mol Si_3N_4 for 20 sccm DCS flow
200 sccm NH_3 flow

which is 0.244 mol of DCS

	n (mol)
Si_3N_4	0.0813
$SiCl_2H_2$	0.2439
NH_3	0.813

Material Balance on DCS

In − Out + ~~Gen~~ − Cons = ~~Acc~~

In − Out − Cons = 0

$0.244\ mol - Out - \left(\frac{0.183\ mol}{200}\right)(40) = 0$

$\boxed{Out = 0.2074\ mol}$ TC1

Overall chem eq'n

$3SiCl_2H_2 + 10NH_3 \rightarrow Si_3N_4 + 6NH_4Cl + 6H_2$

At the end of TC1

	I	C	F
$SiCl_2H_2$	0.244	−0.0366	0.2074
NH_3	0.813	−0.122	0.691
H_2	0	+0.2296	0.2296

$y_{DCS,TC1} = \frac{0.2074}{0.2074 + 0.691 + 0.2296}$

$y_{DCS,TC1} = 0.1855$

Concentration of DCS exiting TC1 / entering TC2

$\frac{n}{V} = \frac{P_A}{RT}$

Concentration of DCS

$C_{DCS,TC2} = \frac{(0.1855)(33.33\ Pa)}{(8.314 J/(K\cdot mol))(T_2)}$

$C_{DCS,TC2} = \frac{0.7437\ K}{T_2}$

Kinetic Eq'n ⇒ we want the same deposition rate for each temp. zone.

$$J = k_0 \exp\left[\frac{-E_A}{RT}\right] C_{DCS}^{0.49}$$

$$= 82300\ s^{-1} \exp\left[\frac{-(169.4\times10^3\ J/mol)}{(8.314\ J/(K\cdot mol))(770+273)K}\right](9.97\times10^{-4}\ mol/m^3)^{0.49}$$

$$= 9.14\times10^{-6}\ mol/(cm^3\cdot s)$$ rate of change of C_{DCS}

$$9.14\times10^{-6}\ mol/(cm^3\cdot s) = 82300\ s^{-1} \exp\left[\frac{-(169.4\times10^3\ J/mol)}{(8.314\ J/(K\cdot mol))(T_2)}\right]\left(\frac{0.7437\ K}{T_2}\right)^{0.49}$$

Trial and error

T_2	$J\ [mol/(cm^3\cdot s)]$
775°C = 1048K	8.49×10^{-6}
780°C = 1053K	9.29×10^{-6}
779°C = 1052K	9.12×10^{-6}