mole fraction of DCS

$$y_{DCS} = \frac{Q_{DHS}}{Q_{NH3} + Q_{DCS}} = \frac{70\ sccm}{700\ sccm + 70\ sccm}$$

$$y_{DCS} = 0.0993$$

Concentration of DCS

$$750 \times 10^{-3}\ Torr \times \frac{133.322\ Pa}{1\ Torr} = 33.33\ Pa$$

$$\frac{n}{V} = \frac{P_g}{RT} = \frac{(0.0993)(33.33\ Pa)}{(8.314\ J/(K \cdot mol))(770+273)K}$$

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

Kinetic Eq'n

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

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

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

Deposition rate

Stoichiometric coefficient $SiCl_2H_2 : Si_3N_4 = 3 : 1$

approximate deposition rate $\approx \frac{1}{3}(9.44 \times 10^{-6}\ mol/(cm^2 \cdot s)) \approx 3.05 \times 10^{-6}\ mol/(cm^2 \cdot s)$ by neglecting surface kinetics.

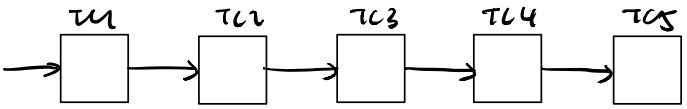
$MW_{Si_3N_4} = 140.28\ g/mol$

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

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

Deposition rate = 1.43 Å/s = 85.8 Å/min

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



40 wafers each.

Volume of Si_3N_4 = $(2)(200)(\pi)(0.15m)^2(1000\times10^{-10}m)$

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

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

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

0.0813 mol Si_3N_4 for 30 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 − $\left(\frac{0.183\ mol}{200}\right)(40) = 0$

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	+0.1464	0.1464

$y_{DCS,TC1} = \frac{0.2074}{0.2074 + 0.691 + 0.1464}$

$y_{DCS,TC1} = 0.1855$

Concentration of DCS exiting TC1 / entering TC2

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

Concentration of DCS

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

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

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}

$T_2 = 779°C$

At the end of TC2

	I	C	F
$SiCl_2H_2$	0.2074	−0.0366	0.1708
NH_3	0.691	−0.122	0.569
H_2	0.1496	+0.1496	0.4392

$$y_{DCS,TC1} = \frac{0.1708}{0.1708 + 0.569 + 0.4392}$$

$$y_{DCS,TC1} = 0.1449$$

Concentration of DCS

$$C_{DCS,TC2} = \frac{(0.1449)(33.33\ Pa)}{(8.314\ J/(K\cdot mol))(T_3)}$$

$$C_{DCS,TC2} = \frac{0.5809\ K}{T_3}$$

Trial and error

(°C)	$J\ [mol/(cm^3\cdot s)]$
787	9.32×10^{-6}
785	8.99×10^{-6}
790	9.83×10^{-6}

$T_3 = 786°C$

At the end of TC3

	I	C	F
$SiCl_2H_2$	0.1708	-0.0366	0.1342
NH_3	0.569	-0.122	0.447
H_2	0.4392	+0.1496	0.6588

$$y_{DCS,TC1} = \frac{0.1342}{0.1342 + 0.447 + 0.6588}$$

$$y_{DCS,TC1} = 0.1082$$

concentration of DCS

$$C_{DCS,TC2} = \frac{(0.1082)(33.33\ Pa)}{(8.314\ J/(K \cdot mol))(T_4)}$$

$$C_{DCS,TC2} = \frac{0.4338\ K}{T_4}$$

Trial and error

(°C)	J [mol / (m³·s)]
793	8.975×10^{-6}
795	9.294×10^{-6}
794	9.133×10^{-6}

$T_4 = 794\ °C$

At the end of TC4

	I	C	F
$SiCl_2H_2$	0.1342	-0.0366	0.0976
NH_3	0.447	-0.122	0.325
H_2	0.6588	+0.1496	0.8784

$$y_{DCS,TC1} = \frac{0.0976}{0.0976 + 0.325 + 0.8784}$$

$$y_{DCS,TC1} = 0.07502$$

concentration of DCS

$$C_{DCS,TC2} = \frac{(0.07502)(33.33\ Pa)}{(8.314\ J/(K \cdot mol))(T_5)}$$

$$C_{DCS,TC2} = \frac{0.3007\ K}{T_5}$$

Trial and error

T (°C)	J [mol / (m³·s)]
805	9.22×10^{-6}
804	9.07×10^{-6}
803	8.92×10^{-6}
801	8.62×10^{-6}

$T_5 = 805°C$

Final Temperature

Zone	Temperature (°C)
1	770
2	779
3	786
4	794
5	805

↓ +9°C
↓ +7°C
↓ +8°C
↓ +11°C