MOCVD – SiH_4 double dilution

In our Aixtron 200/4 RF-S metal-organic vapor-phase epitaxy (MOVPE) system, SiH_4 is used as the precursor for Si doping atoms. As is shown in Fig. 1, the SiH_4 gas is diluted twice before entering the reactor chamber. The first dilution stage includes the SiH_4 source MFC (Mass Flow Controller) and SiH_4 dilute MFC. The second dilution stage include the SiH_4 inject MFC. This double dilution stage enables us to control the SiH_4 molar flow rate in a larger range than single dilution stage.

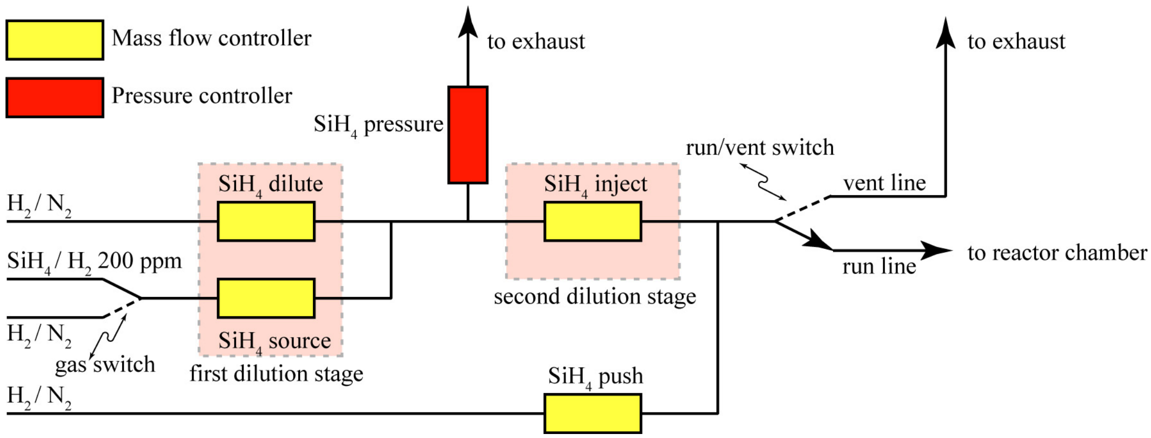

Figure 1: Schematic diagram of SiH_4 double dilution stage

All the MFCs have a maximum operating range. For example, the operating range is 0 ~ 50 sccm (standard cubic centimeter per minute) for the SiH_4 source MFC, 0 ~ 1000 sccm for the SiH_4 dilute MFC, and 0 ~ 100 sccm for the SiH_4 inject MFC. However, it is recommended not to operate the MFCs close to their limits because the accuracy of the MFCs may decrease under the extreme operating conditions. Therefore, we usually operate the MFCs in the range between 10% and 90% of their limits. Under this condition, the SiH_4 source MFC is operated in the range of 5 ~ 45 sccm, while the SiH_4 dilute MFC and SiH_4 inject MFC are operated in the range of 100 ~ 900 sccm and 10 ~ 90 sccm, respectively.

The effective SiH_4 volume flow rate VF can be calculated by using the equation:

$$VF = \frac{VF_{\text{source}}}{VF_{\text{source}} + VF_{\text{dilute}}} \times VF_{\text{inject}} \times 200 \times 10^{-6}, \qquad (1)$$

where the factor 200×10^{-6} is due to the fact that SiH_4 is already diluted to 200 ppm (parts per million) inside the gas cylinder before entering the SiH_4 source MFC. The relation between the molar flow rate, MF, and the volume flow rate, VF, of SiH_4 is:

$$MF = 0.0446 \text{ mmol/cm}^3 \times VF. \qquad (2)$$

Therefore, the effective molar flow rate of SiH_4 can be expressed as:

$$MF = 0.0446 \text{ mmol/cm}^3 \times 200 \times 10^{-6} \times \frac{VF_{\text{source}}}{VF_{\text{source}} + VF_{\text{dilute}}} \times VF_{\text{inject}}. \qquad (3)$$

Table 1 shows the typical values we use for SiH_4 source, dilute, and inject flows and the corresponding effective SiH_4 volume flow rate and SiH_4 molar flow rate. From this table it is clear that the SiH_4 molar flow rate can be changed by more than three orders of magnitude. That is very important for precisely controlling the Si doping concentration in the semiconductors.

Table 1: Typical values for SiH_4 source, dilute and inject MFCs

SiH_4 source (sccm)	SiH_4 dilute (sccm)	SiH_4 inject (sccm)	Effective volume flow rate (10^{-6} sccm)	Effective molar flow rate (nmol/min)	Carrier concentration in GaN
Below are very low doping levels that we try to avoid					
2	896	5	2.23	0.10	
3	890	5	3.36	0.15	
2	896	10	4.45	0.20	
3	890	10	6.72	0.30	
5	900	10	11	0.50	
7	890	10	15.6	0.70	
Below are medium doping levels that we use					
10	880	10	22.5	1.0	Mid 10^{17} cm^{-3}
15	880	10	33.5	1.5	
20	870	10	44.9	2.0	
24	830	12	67.4	3.0	
30	612	12	112	5.0	
30	585	16	156	7.0	
30	450	18	225	10	
30	450	27	338	15	
30	450	36	450	20	
32	445	50	671	30	
35	300	53	1110	50	
38	298	69	1560	70	High 10^{18} cm^{-3}
Below are very high doping levels that we try to avoid					
40	220	75	2310	100	
40	150	80	3370	150	
40	112	85	4470	200	
45	100	90	5590	249	