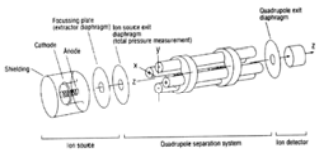
Design and Simulation of Mass Spectrometry System Monitor Programmable CVD Process

Yuhong Cai, Gary W. Rubloff, Raymond A. Adomaitis, Jae-Ouk Choo, Laurent Henn-Lecordier
Department of Materials Science and Engineering and Institute for System Research, University of Maryland, College Park

Introduction

- Mass spectrometer is an instrument which can measure the masses and relative concentrations of atoms and molecules.
- Mass Spectrometer comprises three physically important sub-systems: the ion source, separation system and ion trap. The ions must be able to travel along the path from the ion source and through the separation system to the ion trap, to the greatest possible extent without colliding with gas molecules.



- Inficon-Leybold quadrupole mass spectrometer (QMS) is used to provide real-time measurement of species concentration of gas phase above wafer surface and predict the thin film thickness deposited in programmable CVD process.

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System Response Time Simulation 1

In order to reach the real time *in-situ* process monitor, mass spectrometry response time should be as short as possible.

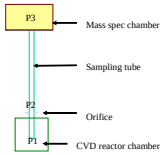
1: Install orifice at the bottom of sampling tube for chamber contamination monitor and fault detection.

$t_R = (V/Q)^* (P1+P2)/2$

Where:

t_R : response time V: sampling tube volume
Q: gas flow rate P1: CVD reactor pressire
P2: inside orifice pressure

Parameter	Value
Orifice hole diameter	35 um
L (sampling tube length)	40 inch
Sampling tube diameter	0.25 inch
Mass spec pumping speed	30L/sec
P1	0.5 torr
P3 (Mass spec chamber pressure)	10^{-6} torr
t_R	0.2 sec



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System Response Time Simulation 2

2: Apply capillary to control the gas flow into mass spec chamber.

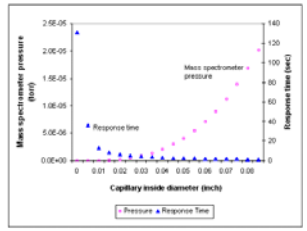
$$t_{response} = \frac{\pi(P_1 - P_2)d^2 L}{8 P_2 S}$$

$$P_1 = \frac{C}{C + S} P_i$$

$$C = 135 \frac{d^4}{L} \bar{P} + 12.1 \frac{d^3}{L} \frac{1 + 92 d \bar{P}}{1 + 237 d \bar{P}}$$

$$\bar{P} = \frac{P_1 + P_2}{2}$$

Where, $t_{response}$: response time
P_1 : pressure in CVD reactor chamber
P_2 : pressure in mass spectrometer
d: inside diameter of the capillary sampling tube
L: length of the capillary sampling tube
S: pumping speed of mass spectrometer
C: conductance of the capillary sampling tube



Results: Based on the simulation results, capillary inside diameter is 0.04inch, capillary length is 40 inch and the response time will be around 3 sec.

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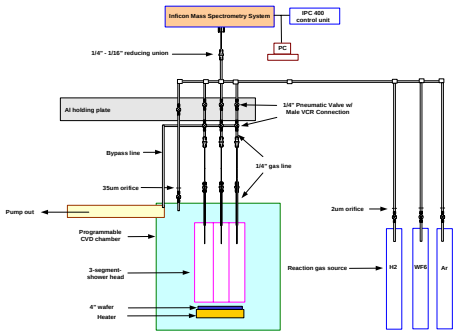
Mass Spectrometry Multi-sampling System Design



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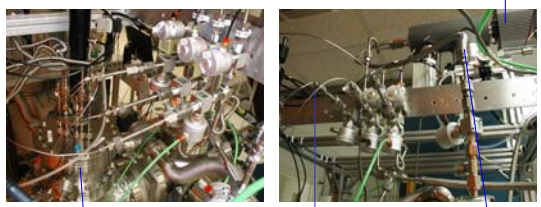
Mass Spectrometry Sampling System



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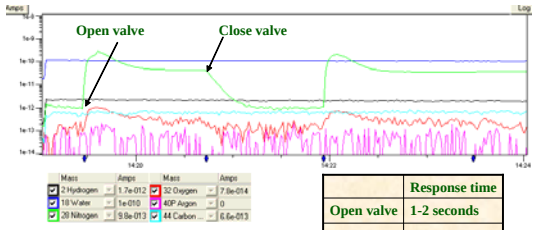
Initial Experiment Result with Capillary Sampling



	Response time
Open valve	1-2 seconds
Close valve	30 seconds

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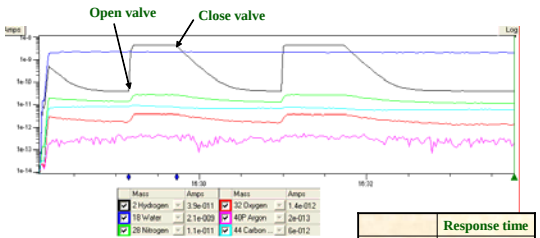
Initial Experiment Result with Orifice Sampling



	Response time
Open valve	0.2 seconds
Close valve	100 seconds

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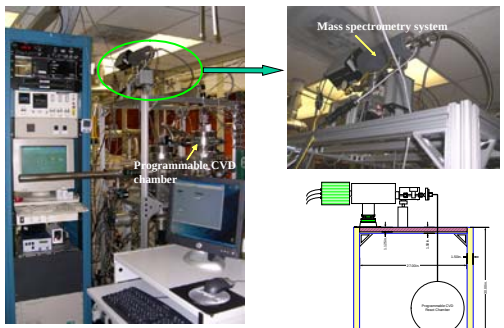
Mass Spectrometry System and Programmable CVD system



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Conclusion and Future Work

1. Mass spectrometer multi-sampling system has been designed and developed to measure the species concentration of gas phase above wafer surface in programmable CVD process.
2. Simulation results evaluate time sharing of mass spectrometer monitoring.
3. In addition to monitor the gas concentration from the different segment, mass spectrometer sample system is also designed for the fault detection and monitoring chamber contamination.
4. Initial mass spectrometer monitor experiments have been performed and further system optimization is being conducted to achieve shorter response time.

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