The Feasibility of the Pressure pipe Method to Measure Vacuum Chamber Pressure

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Abstract. This paper aims to explore the feasibility of the Guiding tube method to measure vacuum chamber pressure. While the chamber was evacuated , using a gauge without Pressure pipe and another with Pressure pipe to measure the pressure of chamber wall at the same height. Comparing a pressure value drops one to another consumed time (response time) to determine the timeliness of the Pressure pipe, and changing the length of the Pressure pipe was to explore the influence to pressure measurement. Under the dynamic condition, using guide tube and the direct measurement same point pressure of chamber wall to study the accuracy of the Pressure pipe to measure the pressure. The results show that pressure is greater than 3 Pa in the chamber and the Pressure pipe method used to measure the vacuum internal pressure is feasible.

Keywords: Vacuum chamber, Pressure measure, Pressure pipe, Feasible.

1. Introduction

The uniformity of flow field of Integrated Circuit (IC) equipped vacuum chamber is a key factor that affect the quality of the coating [1]. Researching on the interior flow field of the vacuum chamber (mainly chamber interior pressure distribution) becomes a meaningful subject. To seek a method to measure the pressure at any point in the chamber, it is needed to consult the relevant literature on the vacuum chamber pressure measurement.

S.V. Prabhu [2] measured the pressure of different position by borehole, so as to study the jet throughout the semicircular concave pressure distribution. In order to study baffles have an impact on airflow in the chamber, S.S. Hong [3] Installed five sensors at different position to measure the pressure differences of different position. Heru Setyawan [4] used silicon particles as tracer particles to study the gas flow rate. WANG SL [5] studied pressure distribution by opening holes in NBI vacuum chamber. H. Al-Gahtani [6] used Pressure pipe to measure the partial pressure in pressure vessel. While measuring pressure in low pressure environment has not been reported.

In this experiment, using the Pressure pipe method that adopted a Pressure pipe to measure internal pressure in the chamber. Due to the tube flow resistance, the pressure difference existed in the ends of the Pressure pipe will cause measurement error. This experiment explored the measurement errors of the Pressure pipe, the influence of the Pressure pipe's length on the measurement and pressure measurement range, response time and accuracy of the Pressure pipe.

2. Experimental set-up

The experimental system mainly includes the gas intake system, pressure measurement system, extraction system. The height of the chamber is 320 mm while its inner diameter is 580 mm (capacity = 84.5 L) as shown in Fig.2a. And the vacuum chamber is made of 304 stainless steel. It is pumped by a high vacuum pumping system which is composed of a turbo molecular pump with pumping speed 300 L/s for N_2 backed by a 82 m^3/s roots pump. The gas of chamber is extracted through a flapper valve of diameter 100 mm. The main chamber is covered with a heating jacket used for backing (baking up to 100℃) so that after two hours baking, the chamber was extracted for about four hours achieving a base pressure was less than 2×10^{-4}Pa, the static pressure method to get boost the overall

leak rate for the chamber was 8.84×10^{-6}Pa.m^3/s. Choosing capacitance diaphragm gauges (CDGs, range for 1333 Pa and made of INFICON Instruments Inc, USA, and zeroed at pressure less than 4×10^{-4}Pa. Its accuracy is 0.2% of reading.) And Bayard-Alpert Pirani Combination Gauge (BPG400, range for 5×10^{-8}Pa to atmosphere) to measure the pressure of chamber wall.

3. Results and discussion

Controlling strictly the other experimental factors, such as, keeping the indoor temperature is 20 ± 0.5 degrees Celsius and the humidity respectively is 50 ± 2, ensured the experiments occur in the condition that in absence of noise and vibration. Design Pressure pipe experiments: analyze the influence of the Pressure pipe's length on the measurement, the response time of the Pressure pipe and the accuracy of the Pressure pipe.

3.1 Research the influence of the Pressure pipe's length

With high clean vacuum tube as the Pressure pipe, and its length can be changed. To connect the Pressure pipe with chamber by welding Fluid Feedthrough in the tube, and change the length of Pressure pipe through a joint as shown in Fig.1.

Fig.1 Variable lengths of pressure Pressure pipe

To explore the influence of tube's length on measurement, respectively captures two tubes (one's length is 100 mm, the other is 350 mm). Since the Fluid Feedthrough length is 150 mm, so one's tube length of this experiment is 250 mm and another is 500 mm. In order to reduce the experimental error, it is demanded to evacuate the chamber and bake the wall with heating jacket to desorb the gas molecules which was absorbed by the chamber wall material. Installing a high-precision vacuum gauge in the wall flange to measure the wall pressure, so as to measure the results as a standard of pressure measurement. While the chamber was evacuated , using a gauge without Pressure pipe and another with Pressure pipe to measure the pressure of chamber wall at the same height. Comparing a pressure value drops to another consumed time (response time) to determine the timeliness of the Pressure pipe, and changing the length of the Pressure pipe to explore the influence of length to pressure measurement.

This experiment used BPG400 to measure pressure. When the length of tube was changed in each experiment, valve openings remain the same size. Evacuating the chamber, and using LabVIEW to automatically collect data. The measured values were analyzed in three sessions as shown in Fig.2.3.4.

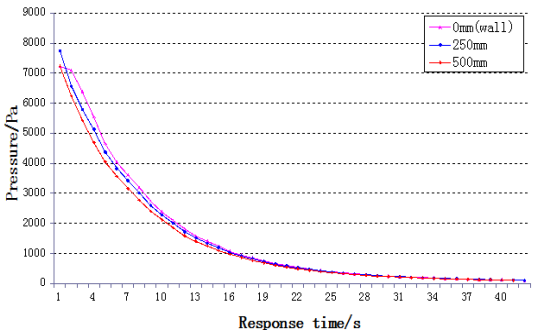

Fig.2. The pressure and response time curve from 8000Pa to 100Pa.

While vacuum pump starts evacuating, the chamber internal pressure decreases quickly. Analyzing the pressure value range from 8000 Pa to 100 Pa as shown in Fig.3, range from 100 Pa to 10 Pa as shown in Fig.4 and range from 100 Pa to 10 Pa as shown in Fig.5, the reduced rate of the three curves

and the response time of Pressure pipe are basically identical. So, when the length of Pressure pipe is less than 500 mm, the Pressure pipe method can be used to measure pressure value that between 3 Pa to 8000Pa.

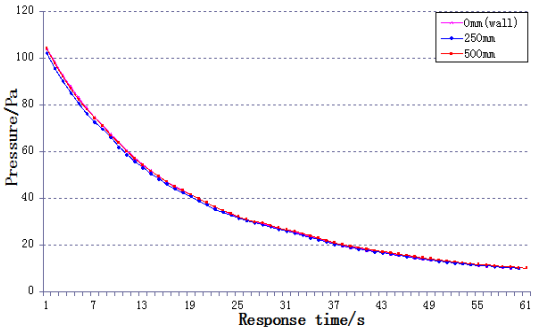

Fig.3. The pressure and response time curve from 100Pa to 10Pa.

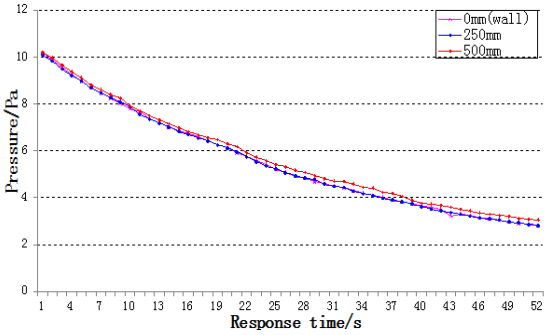

Fig.4. The pressure and response time curve from 10Pa to 3Pa.

3.2 Research the response time of the Pressure pipe

According to the IC process parameters and the simulation model, the key measurement range is 10 Pa to 100 Pa. This experiment used CDGs to measure pressure , when the length of tube was changed in each experiment, valve's openings remained the same size. Evacuating the chamber, and using LabVIEW to automatically collect data.

The experiment mainly study the response time of pressure value decreased from 100 Pa to 10 Pa in the case of different length and valve size. The response time indicates that a pressure value drops to another consumed time; The valve's size indicates the rotation angle of the outlet value. With t (s) as the response time,Δt (s) as the time difference for chamber wall. In certain cases pump speed, the measured data is treated in the following table 1.

Table.1 The response time of pressure in the range of 100Pa to 10Pa.

Length/mm	0 (wall)		300		500		400 (the degree of 90bend)	
Value/ degree	t	Δt	t	Δt	t	Δt	t	Δt
Rotating 270	87.6	0	88.6	1.0	90.6	2.0	94.9	6.3
Rotating 360	56.7	0	58.5	1.8	59.1	2.4	62.0	5.3
Rotating 720	26.0	0	27.3	1.3	28.1	2.1	28.9	2.9
Rotating 1440	16.2	0	17.4	1.2	18.2	2.0	18.0	1.8
Fully open	14.1	0	xx	xx	xx	xx	14.1	0

Note: The response time by averaging the testing values of repeated measurements

With the increase of valve's opening size, the response time becomes shorter and the response time difference between Pressure pipe and wall becomes smaller. It shows that the valve opening size has an effect on the timeliness of the Pressure pipe. With the increase of length, the response time becomes longer. It shows that the length of tube creates a delay on pressure measurement.

The experimental platform uses a degree of 90 bending Pressure pipe to measure the pressure at any point in the vacuum chamber. So, it is needed to verify the impact of bending tube to pressure measurement. The size of one side of the bending tube is 220 mm and the other one is 180 mm, the

fillet radius is 15 mm as shown in Fig.6. Studies have shown that the degree of 90 bending Pressure pipe created a delay on pressure measurement.

Fig.5 The diagram of the degree of 90 bending Pressure pipe

3.3 Research the accuracy of the Pressure pipe

Using MFC to precisely control the amount of N_2 (140 sccm, 230 sccm, 320 sccm) into the chamber, and adjusting export valve size to control CDG3's value (36 Pa, 45 Pa, 55 Pa) to establish the orthogonal experiment as shown in Table 1. CDG3 and CDG2 is measuring the pressure of the same point until the pressure is stabilized in the chamber. In the meantime, using LabVIEW to collect data automatically for a while, and the collected data will be processed to gain the average value for analysis.

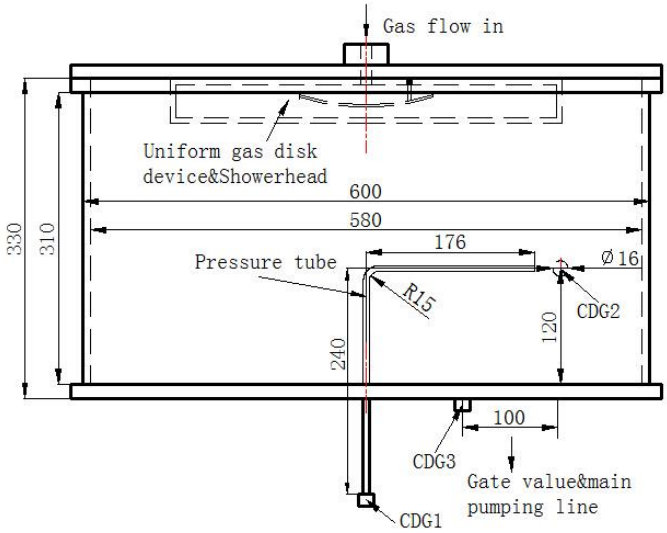

Fig.6 Chamber structure and CDGs location

Table 2. Inlet flow, outlet pressure, the average pressure and pressure differences

No.	Inlet flow /sccm	Outlet pressure /Pa	Average pressure of tube/Pa	Average pressure of chamber wall /Pa	Average pressure of outlet /Pa	Average pressure difference between chamber wall and tube/Pa	Relative deviations from the average of Pressure pipe/%
1	140	36	36.063	36.319	36.113	0.257	0.007
2	140	45	44.962	45.123	44.888	0.161	0.004
3	140	55	55.065	55.325	55.176	0.260	0.005
4	230	36	36.182	36.395	36.340	0.213	0.006
5	230	45	45.039	45.175	45.005	0.135	0.003
6	230	55	54.855	55.144	55.004	0.290	0.005
7	320	36	36.110	36.277	36.167	0.167	0.005
8	320	45	45.067	45.177	45.014	0.111	0.002
9	320	55	54.922	55.161	55.045	0.239	0.004

The relative deviations between the Pressure pipe's pressure and wall's average pressure is about 0.2~0.7%, also known as the accuracy of Pressure pipe's method to measure the chamber's pressure is 0.007; The pressure difference between the Pressure pipe and chamber wall is range of 0.1 Pa to 0.3 Pa in this experiment.

From the above three experiments, the Pressure pipe for measuring pressure existed error. In the same conditions, the longer the Pressure pipe, the greater the pressure loss in the tube, so that Pressure pipe method resulted in errors in the measurement pressure; Likewise the degree of 90 bending Pressure pipe will not only result in the loss of local resistance , but also result in the Pressure pipe measurement error.

4. Conclusions

Pressure pipe method have limitations for measuring pressure, such as, the value of outlet size, the amount of bend in tube and the demand of measurement accuracy. In order to use the Pressure pipe method to measure pressure accurately, measures should be taken to compensate the loss of pressure which caused by the length and the bend. While the gas is flowing in the Pressure pipe, adopting the pressure difference of two points in the tube can calculate the pressure value of the measure point. During this experiment platform, adopting this method to measure the chamber internal pressure provides data support to the software emulation of the project team, and the precision meets the requirements. Thus, the Pressure pipe method is feasible.

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