Highly durable smart capacitance manometer with fault detection functions - Masaru Soeda

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Abstract

Sapphire-based capacitance manometer dedicated to advanced process like Atomic Layer Deposition (ALD) has been developed. Total amount of zero shifts is approximately 30 times smaller than that of existing products because its mechanical system of the manometer is really stable. Moreover, new algorithm of signal processing has been developed to reduce the downtime originate from vacuum pump failure etc. The developed manometer design and its performance are presented in this report.

Background

Recently, vacuum measurement asks for anti-corrosion and anti-deposition characteristics applicable to the process like ALD. Accurate measurements under harsh environment while heating the components of the manometer includes the vacuum chamber and the pipes to high temperature are also required. To meet these needs, we propose sophisticated design and the effective utilization of the internal capacitor for the manometer to realize fault detection and prediction.

Sensor design

A schematic overview of anti-deposition capacitance manometer is shown in Fig.1. Approximately 10x10 mm sensor chip is made of sapphire, thin and extremely flat diaphragm is fabricated accurately. Sensing and reference electrodes for detecting electrostatic capacities are placed with being protected by bulk material of sapphire. The sensor chip is mounted on sapphire disk and thin metal plate with sealing under high vacuum by unique low stressed bonding methods. A base chamber is maintained at high degree of vacuum for long period by non-evaporable getters. For eliminating effect of undesirable deposition, the structural parameters (ratios of a/b and d1/d2) are designed to cancel the signal shifts of the sensor output with controlling mechanical moment of the sensor components by their shallow circular concave at the diaphragm center as shown in Fig.2. In addition, the sensor components including baffle have been optimized with considering flow path of the gasses to sensor diaphragm to avoid active gas molecules reaching the surface of diaphragm.

In normal measurement, a differential value between the sensing capacitance (Cx) by sensing electrodes and the reference capacitance (Cr) by reference electrodes is mainly outputted. Since the sensor chip has thinner diaphragm and narrower gap between electrodes to get high sensitivity, the diaphragm is easy to contact to opposite surface inside the cavity and Cx becomes unstable. To recognize the pressure even in the over range of measurement, the available output signal of individual Cr has been designed to be outputted by the circuit of manometer as shown in Fig.3.

Result and discussion

The measurement results of sensor zero shifts in ALD process are shown in Fig.4. Total amount of zero shifts is less than half of metallic diaphragm manometer. Usually, conventional sensors show sudden rapid increase of zero point when subjected to excessive deposition. Our manometer doesn't show these increase and have 5 to 10 times longer lifetime. Consequently, frequencies of zero adjustment and replacement of sensor is reduced considerably because of its high durability against undesirable deposition in process.

The results from overpressure repetition tests are shown in Fig.5a, and outputs of Cx and Cr are shown in Fig.5b, respectively. The signal output of Cr is contentiously available as shown in the figure. High sensitivity measurements within the pressure range and monitoring overloads out of range have been realized by single sensor. This feature can be used to detect faults that show sudden pressure increase caused by malfunctions of vacuum pump or cut-off valve, for example.

A summary of comparison between conventional work and this work is shown in Table 1.

Conclusion

The capacitance manometer which has excellent stability in ALD process has been developed. Its performance of anti-deposition has been available to about 30 times better than that of existing products (more than twice that of metallic diaphragm). It is possible to diagnose function failures including that of manometer itself with utilizing internal data of the sensor.

Reference

M. Soeda, H Tochigi, M Sekine, T Ishihara, Proceedings of IVC-20 conference, Aug, 2016

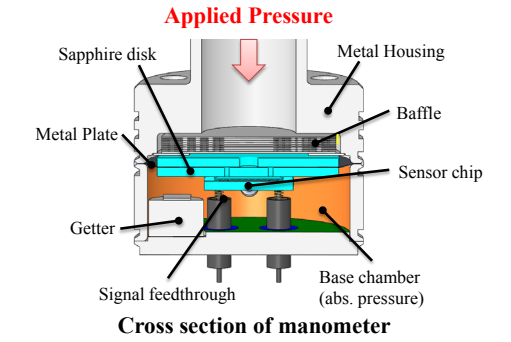
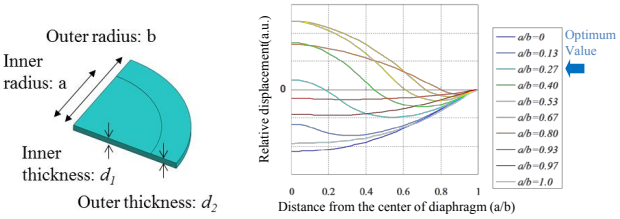
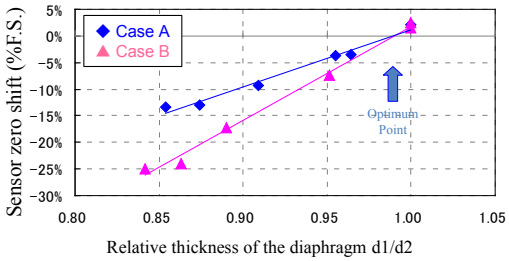


Fig.1 Overview of capacitance manometer



(1) Design of diaphragm structure



Sensor zero shift with varying inner and outer thickness

(2) Result of design verification

Fig.2 Design of anti-deposition model

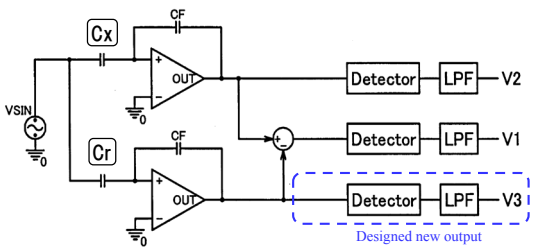


Fig.3 Signal output from the sensor

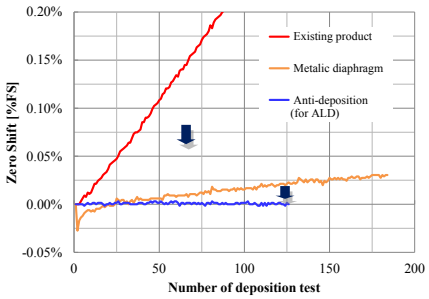
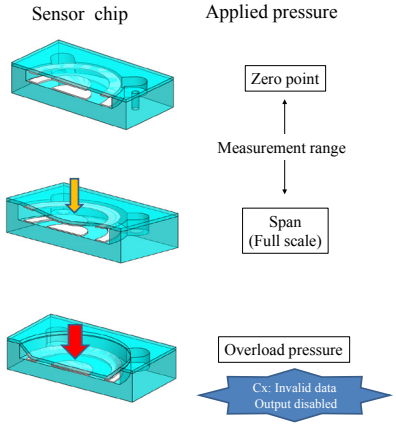
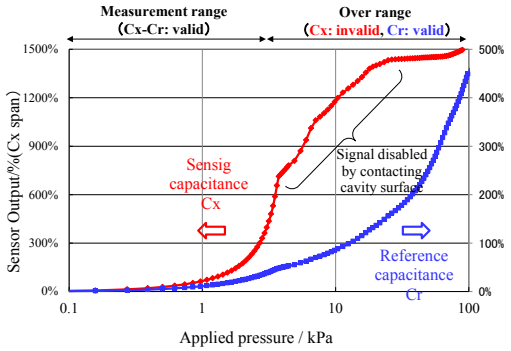


Fig.4 Zero shift of manometer in actual process



(a) Sensor behavior at overloaded pressure



(b) Example of sensor output Cx and Cr

Fig.5 Fault detection by utilizing Cr

Table.1 Comparison of models

	Conventional	This work
Sensor chip design	Normal	New (Moment control)
Package design	Normal	New (Baffle and flow path of gases)
Signal output	Cx and Cx-Cr	Cr alone possible
Durability to ALD process	Low	High
Fault detection	Impossible	Possible