Product Introduction

XF-100 series
Pressure Base Liquid Digital Mass Flow Meter

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In order to accommodate higher performance of semiconductor devices, higher efficiency process, and improvement of the productivity, we developed the XF series, a pressure type mass flow meter with a measurement method fully renewed for the first time in a quarter century. The XF series is equipped with oil-free safe pressure sensors of the electrostatic capacitance type, thereby enabling a single path structure even in a flow range of 5 g/min or more. This may also reduce flow errors due to residence of bubbles. The XF series also achieves an improved sensor linearity and an accuracy of ±0.8% F.S. by using physical property values of materials in the flow conversion formula, which corresponds to an improvement of 20% compared to existing meters. A faster response within 0.8 sec is also achieved, enabling a reduction in time for the flow rate to be stable by speeding up the time, which contributes to a reduction in the amount of use of expensive high-technology materials.

Introduction

Flow measurement equipment is used to control the flow of high-technology liquid materials used in high-performance semiconductor devices. Higher performance semiconductor devices are produced using ultra-miniaturization technology and three-dimensional technology so that multiple thin films having individual functions, including an insulating film, are formed on a silicon wafer. Because expensive high-technology liquid materials are used, there is a demand for precise measurement of the flow rate to a chamber for forming thin films and fast response. The XF-100 series is developed to meet such a demand.

XF-100 Series

Structure

Figure 1 shows the exterior appearance of the XF-100 series. There are two existing VCR type fittings connected in 1/4 inch and 1/8 inch sizes. Three types of communication, i.e., DeviceNet™ communication, digital communication, and analogue communication, are available. Figure 2 schematically shows the internal structure of the XF-100. It comprises, from the inlet side, a filter for protection from external particles, two absolute pressure sensors, and a flow resistive element (hereafter, "Restrictor") in between, and an electric circuit. The flow sensing is performed using a method of measuring the differential pressure between the pressure sensors placed before and after the Restrictor and converting it into flow rate.

Figure 1 XF-100 series exterior

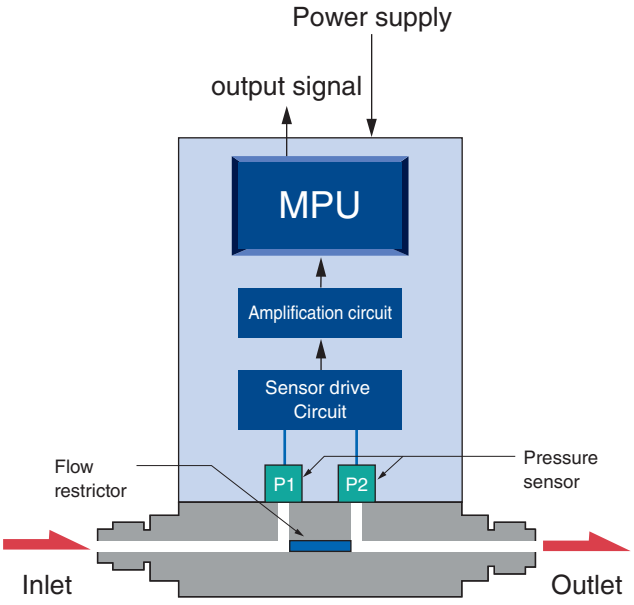

Figure 2 Structural view

In recent years, there are larger wafers and higher flow rates of flow meters for use. In a large flow range, there is a demand for single path structures to reduce flow errors due to entrainment of bubbles and to improve signal fluctuations. In a thermal type mass flow meter, the flow allowed in each pipe is limited for sensitivity reasons; our existing models need a bypass for the flow specifications of 5 g/min or more. However, the XF is a pressure type mass flow meter, the Restrictor of which can be designed based on the liquid flow requirement, thereby permitting the use of a single path structure for all specifications. The specifications state that all wetted parts are made of metal so that internal reactions can be prevented, even with highly reactive high-technology liquid materials used in high-performance semiconductor devices.

Interface

The existing models are different from our gas mass flow controllers with the pin assignment for the power cable and LAN cable for communication with a PC. This is because there are power supply lines and signal lines used only by the existing models and preventive measures, such as reversing the male and female connectors, are taken to prevent erroneous connection to a gas mass flow controller. Therefore, customers who use both gas and liquid mass flow controllers need to provide for two types of cables. In this newly developed model, both cables used for the power supply and signal lines are unified in accordance with a gas mass flow controller.

Major Specifications

Flow accuracy : ±0.8% F.S. (F.S.: Full scale)
Response speed: (Meter) Within 100 msec
(Controller) Within 0.8 sec
(in combination with a piezo valve)
Flow range : 0.2 to 30 g/min (IPA conversion)
Applicable liquid types
: Any liquid other than acid, base, and those that may corrode SUS
External dimensions
: 94 (W) × 36 (D) × 125 (H) mm

Features of XF-100 Series

Flow measurement equipment generally employs a thermal type using a thermal sensor. HORIBA STEC is the only one in the world that adopts a cooling system using a Peltier element in a liquid mass flow meter to measure a flow rate without increasing the temperature of the liquid material. Accordingly, the release of dissolved gas can be reduced and even heat-sensitive liquid materials can be measured. However, the following considerations should be made:

(1) The response speed may be about 5 seconds depending on the conditions
(2) A bypass is necessary for large flow specifications

These problems have been addressed by optimizing the PID control and temperature setting on the cooling unit for improvement, but not yet solved. Therefore, the problems need to be solved by changing the measurement principle.

Adoption of a Pressure Type Model

In order to solve these problems, the measurement principle needs to be drastically changed. The measurement principle keeps the previous advantage of not heating material and adopts a pressure type measurement for which fast-response pressure sensors are equipped to achieve fast response, and a single path structure is designed to accommodate to a large flow range. A pressure type model can control the pressure drop by changing the size of the Restrictor between the pressure sensors, and thus no bypass is necessary. While an existing model, which uses various types of sensors and has so many parts, takes a long time for assembly and adjustment, a pressure type model requires only a few types of Restrictors and the parts can be designed as common parts, thereby reducing the assembly and adjustment time and enabling a shorter delivery time.

Flow Conversion Formula

$$Q = \frac{\pi \Delta P D^4}{128 L \eta}$$

Q: Flow rate, ΔP: Differential pressure,
D: Diameter of the cylinder
L: Length of the cylinder, η: Viscosity

The Hagen-Poiseuille equation is used as a theoretical equation to convert a pressure difference between the downstream and upstream sides into a flow rate. This equation is independent from density and can be used in a laminar flow range. A flow conversion can be done by entering viscosity data.

Response Speed Improvement/ Accuracy Improvement

As this model measures the pressure and converts it into a flow rate, the response speed is fast, in principle. Furthermore, even more stable and faster response speed is achieved by the conventional PID control technology. Compared with the existing model, an approximately 4 times improved speed is obtained. (Figure 3) The response speed improvement results in the reduction of materials discarded while waiting for stabilization of expensive high-technology materials and thereby contributes to a cost reduction in the materials.

Accuracy is also improved by 20% compared to existing models. This is caused by the improved linearity of the sensor output, which results in removal of excessive compensation and a higher resistance to the effect of external disturbances. With regard to temperature effects, by assigning the temperature property data to the XF theoretical equation, temperature effects on the real liquid are reduced, thereby contributing to the accuracy improvement.

Electrostatic Capacitance Type Pressure Sensor Equipped

HORIBA STEC's electrostatic capacitance type pressure sensors are installed in the XF-100 series. In general, a compact sensor is a distortion type using oil in the medium that transmits the force. On the other hand, the electrostatic capacitance-type pressure sensor equipped in the XF-100 series uses no oil, and therefore in case of breakage, high safety is ensured without concerns about oil leakage to the line and chamber. The diaphragm material used in this pressure sensor adopts very high-strength special high-performance alloy, thereby achieving high compressive strength and high stability, even as a small and high-sensitive sensor.

Use with a Vaporizer

The XF can be used as a simple meter, but when manufacturing semiconductor devices, it is normally used with a vaporizer. The XF can be connected to a vaporizer that directly vaporizes liquid in the vaporizer, including our injection system, the MV-2000. The connection can be established only by inserting the cable attached to the vaporizer into the XF connector, and then the XF measures a flow rate and the valve integrated in the vaporizer performs a feedback control to control the amount of vaporization. The use of this combination can achieve vaporization of the liquid material just before the chamber, thereby contributing to space saving. In the case of the XF and MV-2000 combination, (Figure 4) an improvement of response speed and vaporization performance is obtained compared to the existing system; there may be a proposal for a new vaporization system.

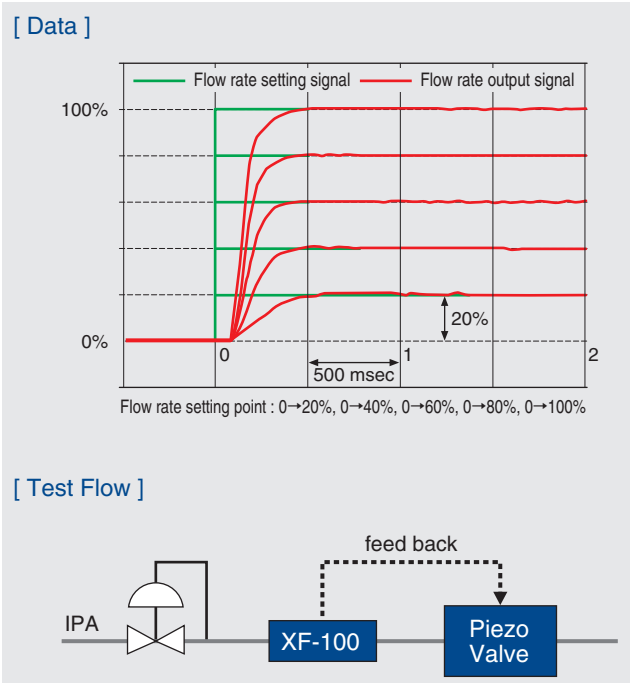

Figure 3 Response time

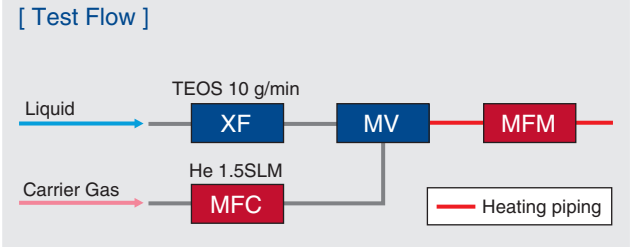

Figure 4 XF and MV-2000 combination example

Conclusion

As the higher integration of semiconductor chips has advanced, there have been new problems, such as the occurrence of leak current, and to solve such problems, an insulating film is formed using a high-technology material. As well as the insulation film, a thin film having a condenser function also uses a high-technology material, and there is increasing demand for a liquid mass flow meter that can be used for high-accuracy and high-speed measurement.

In order to overcome the problems of the existing liquid mass flow meter, there has been demand for faster responses in liquid flow measurement, improved throughput, and reduction in materials used for stability time (reduction in drain time for expensive high-technology materials) for over ten years. In this new XF series, we worked to drastically solve these problems by fully renewing the measurement method for the first time in a quarter century. The XF series adopts a pressure type model, thereby improving the sensor linearity and improving the accuracy by 20% by using physical property values of materials, and achieving the response speed of 0.8 s or less (in combination with a piezo valve). In the case of the combination use of the XF and MV-2000, which is our latest model of an injection system released around the same time, high-speed measurement of flow rate and low-temperature vaporization can be achieved, thereby reducing the semiconductor process time compared to the existing systems and, we believe, contributing to improvement of the productivity.

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