Pressure-Based Mass Flow Control Module CRITERION D507 Series

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Recently, with the increase of IoT applications for semiconductor devices, it is important to minimize process system downtime at front-edge device factories. Therefore parameters are increasing and criteria are tightening in their process line control, to detect system or component failures before their process execution. In order to satisfy these criteria, not only higher process gas flow control accuracy, minimal instrumental error, and pressure resistant flow control, but also high speed control communication and early anomaly detection are required for recent mass flow control modules. D507 series is newly lined up on D500 series to meet these strict specifications at recent semiconductor factories.

Introduction

With an increase in the applications of semiconductor device, minimizing the down-time of semiconductor manufacturing equipment is an important issue at stateof-the-art semiconductor plants. Therefore, in order to detect failures of manufacturing equipment and its com-ponent units in advance, semiconductor process control parameters are increasing and its specification is getting tighter in the sites of semiconductor plants. In such a situation, mass flow controllers and mass flow control modules[*1] (hereinafter referred to as "MFC") are required to have the ability of high speed communication and the function to detect its failure before occurrence recently as well as flow rate accuracy and small individual differences for process the gas, better pressure insensitive performance, to satisfy required specification. In such a situation, mass flow controllers and mass flow control modules[*1] (hereinafter referred to as "MFC") are required to have the ability of high speed communication and the function to detect its failure before occurrence recently as well as flow rate accuracy and small individual differences for process the gas, better pressure insensitive performance, to satisfy required specification.

These performances and functions can also meet to severe semiconductor process control specification with the vertical structuration of memory devices. This article introduces mass flow control module of CRITERION D500-series accepted at state-of-the-art semiconductor plants, the trend of of component devices control of manufacturing equipments in semiconductor plants, and EtherCAT communication model of D507-series which was developed to meet these trends.

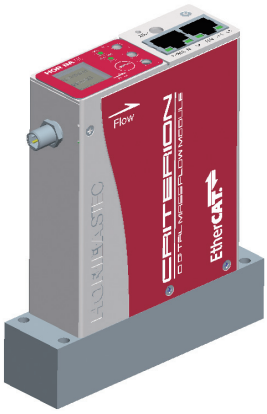

Figure 1 D507 Appearance

*1: Mass flow control module consists of mass flow controllers with other necessary functions beyond flow rate control.

Pressure-control MFCs realized faster response and better accuracy than conventional thermal-control MFCs by high-speed response and better stability of pressure sensor. The D500, which are HORIBA STEC's second-generation Pressure-based MFCs following D200-series, have been used mainly in etching process equipment.

Figure 1 shows the external appearance of a D500-series. The external dimensions of D500 MFCs are compliant with the SEMI F82 international standard on semiconductor manufacturing equipment, as is the case with our conventional MFCs.

Figure 2 shows the structure of a D500. It consists of a pressure sensor for monitoring the gas line supply pressure, a gas filter for protecting the main body gas line from foreign materials, a control valve, two pressure

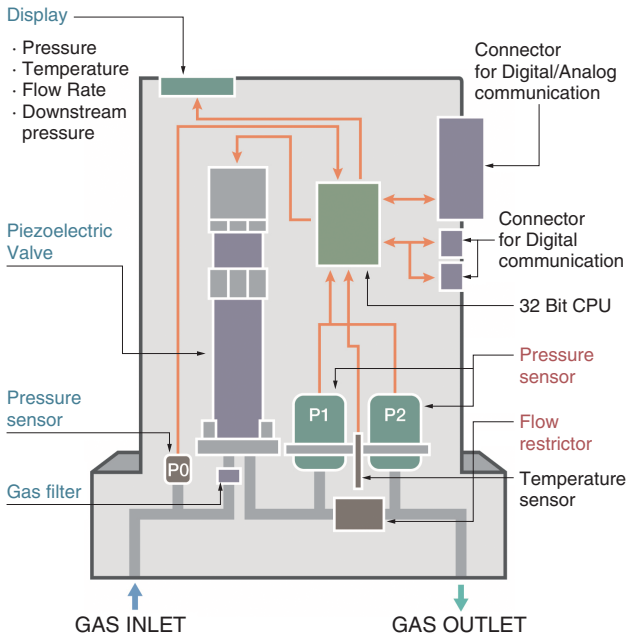

Figure 2 D500 Internal structure

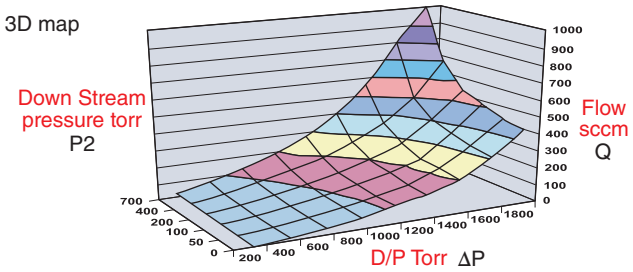

Figure 3 Flow rate and pressure property of restrictor

sensors and laminar flow element restrictors (hereinafter referred to as "flow restrictor"), and a temperature sensor.

The control valve is driven by a piezo-actuator with superior high-speed drive and low-power consumption properties. Flow rate mesurement is executed by the calculation from the pressures at both upstream and downstream sides of the restrictor, and the gas temperature. And the flow rate is controlled with the control valve driven by calculation feedback from the comparison of arbitrarily set flow rate and the measured flow rate output described above.

Figure 3 shows the flow rate properties of the flow restrictor, where the flow rate properties of process gas is three dimensionally mapped based on pressure and flow rate. D500-series MFCs is installed with the flow restrictor gas data gathered on actual process gases, and so these installed flow rate properties enable highly precise flow rate measurement and guaranty of +/- 1% accuracy vs set-point for real process gases.

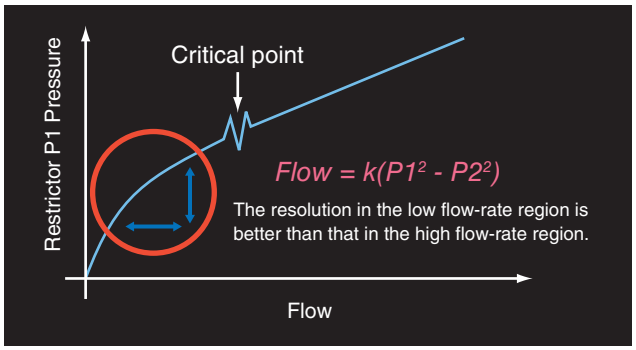

Figure 4 Non-Linearity property of restrictor

Wide range controllability

Figure 4 shows the relationship between the upstream pressure of the flow restrictor and the flow rate where the downstream pressure is reduced. The differential pressure shows non-linear property and the gradient increase toward the lower flow rate region. This enables to detect the flow rate variation in low flow rate region as a large differential pressure output.
This properties that even the lower flow rate can be measured with higher resolution is suitable for low flow rate setting, and is the greatest feature of the D500 series MFCs.

This series enable to control from 100% to as low as 0.2% of the full scale. Since a single unit of D500 MFC can cover the flow range covered by multiple MFCs conventionally, the necessary units of MFCs or corresponding parts can be reduced.

Improved corrosion resistance

Although the D500-series MFCs had been adopted mostly in etching process equipment, they are increasingly used in various applications recently, and especially in a harsher environment. In particular, in the cleaning process of diffusion process equipment, highly corrosive gases such as HF and F2 are used. In the case of the D507 MFC, nickel alloy and cobalt-nickel alloy with superior corrosion resistance were adopted for critical parts such as the pressure sensor and control valve. This enhances the durability of the product against corrosive gases, contributing to the reduction in the downtime of manufacturing systems.

Trend of the control of semiconductor processes and EtherCAT

The specifications of the control for semiconductor manufacturing equipment and their component devices are getting stricter. The number of components under such control is increasing. And for conventional devices under

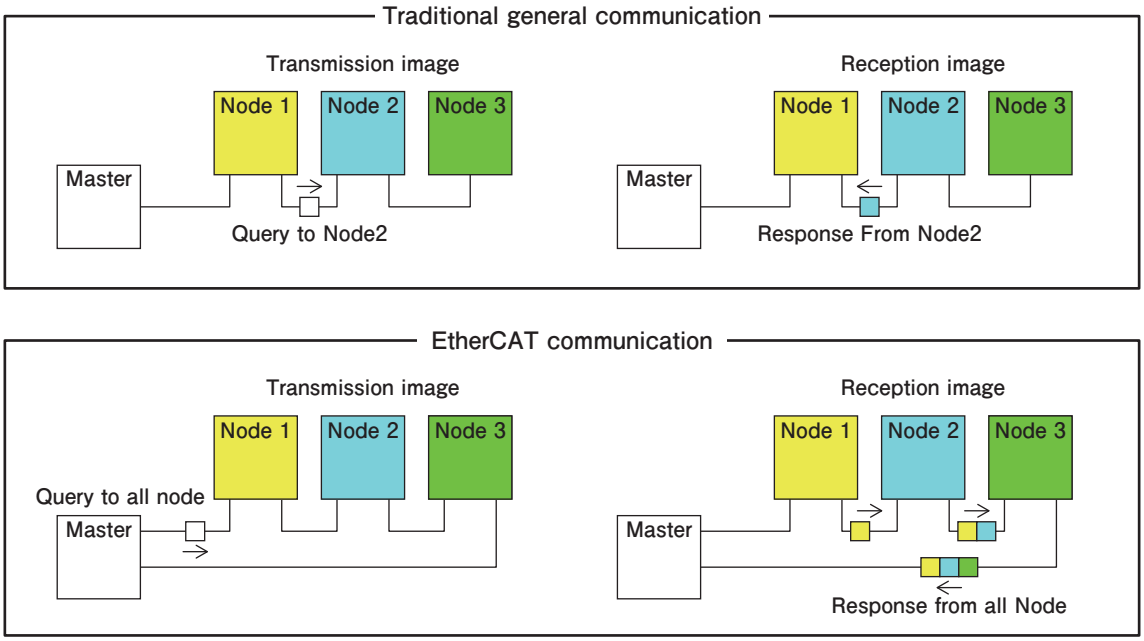

Figure 5 Transmission and reception of traditional communication and EtherCAT communication

the control, the number of control parameters is increasing, and also their specifications are getting stricter.

Since MFCs are important control devices that may affect the quality of product semiconductor devices, the specifications of the control are especially strict. Although only the flow output and supply pressure had been under such control in the past, not only the sensor output, which is the source of flow output, but also all kinds of signals related to the functions of MFC are now required to be under such control. These signals are monitored in chronological order and used for the purpose of detecting a failure and an abnormality in the equipment.

There is a concern that the communication sampling rate might decrease due to increase of component devices under such control which increase connected devices and information volume between manufacturing equipment and component devices. Therefore, EtherCAT communication was introduced to eliminate such concerns.

EtherCAT, developed by Beckhoff Automation in Germany, is an open field network compatible with Ethernet. For the purpose of maintaining mutual compatibility, the functional requirements and certification procedures for EtherCAT are stipulated and managed by the EtherCAT Technology Group (abbreviated as "ETG") established in 2003. In addition, they are also making efforts to stipulate common power supplies and communication specification items as one of SEMI working groups in order to specify the profiles of EtherCAT for semiconductor.[1]

The most distinctive feature of EtherCAT is that it realizes real-time communication in a way different from conventional methods such as polling, time division, and broadcasting. The EtherCAT packets are designed to depart from the master, to pass through all slaves in order, to turn back, and then to return to the master again.

Conclusion

Our D500-series MFCs has continually complied with strict performance requirements and management specifications in state-ofthe-art semiconductor process fields. Now with the launch of the D507 MFC compatible with EtherCAT communication, this series can continually comply with the performance requirements and specifications of the control increasingly getting stricter. Through D507 MFCs, we will continually support future state-of-the-art semiconductor processes, and will contribute to the development of semiconductor technologies.

References

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