Feature Article

Application

Development to Ultra Thin MFC

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I introduce the efforts of miniaturization of the Mass Flow Controller (see Figure 1). It also leads to cost reduction solution and energy saving solutions, and high performance by reducing the unnecessary part. It is thought to be useful for new needs in the semiconductor process gas control. I introduce development of thinner mass flow controller which is main product of HORIBA STEC.

Introduction

Many MFCs are used in gas control in semiconductor manufacturing equipment processes, and today's major products are based on a basic design from 10 years ago. In Figure 2, MFCs have been getting slimmer, from a width of 1.5 inches (3.81 cm) to a width of 1.125 inches (2.857 cm), but there hasn't been any significant slimming beyond 1.125 inches. As semiconductor structures have become more integrated, the types of gases used in semiconductor processes have been increasing every year. More precise gas control is now required, which means that the manufacturing processes must be refined to a very detailed level. Specifically, the number of MFCs required for one process chamber has increased, and the new processes require better high-speed control and a lower cost than conventional processes. Also, currently, the gas boxes where MFCs are stored are very large, and the installation location inside the semiconductor manufacturing equipment has moved from the side to the top of the device or the area under the floor, and sufficient installation space can no longer be ensured. Therefore, we set the target size to a width of 10 mm, which is approximately 1/3 of the conventional product, and decided to develop an MFC that is thin and will allow us to propose total

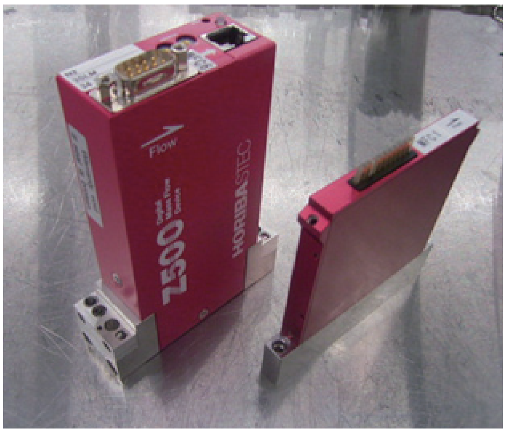

Figure 1 (Left) 1.125 inch MFC (Right) Ultra thin MFC

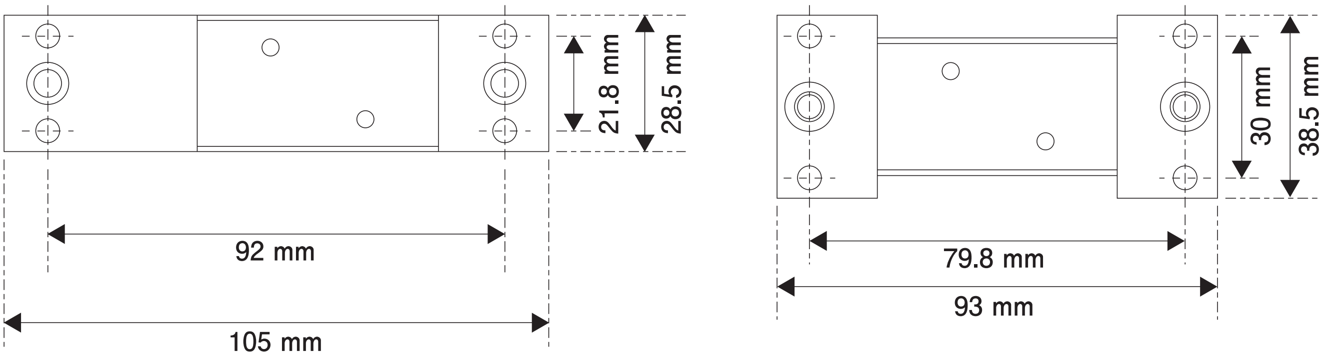

Figure 2 (Left) 1.125 inch MFC (Right)1.5 inch MFC

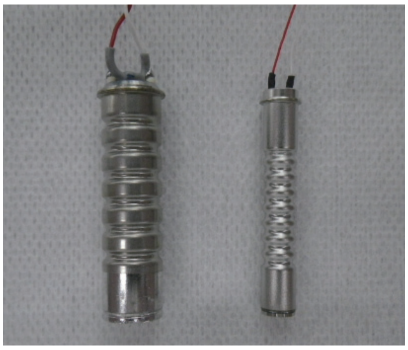

Figure 3 (Left) Standard bellows (Right) Small bellows

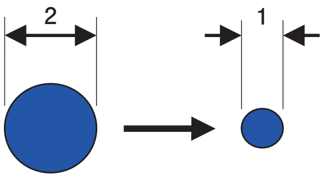

Figure 4 Comparison of cross-sectional area of bellows

Figure 5 (Left) Standard Diaphragm (Right) Small Diaphragm

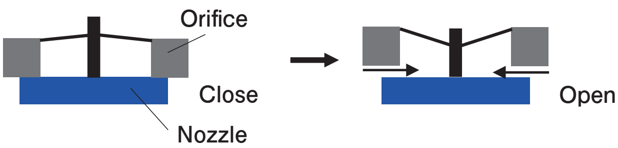

Figure 6 Normally Close valve operating principle

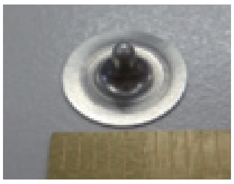

Figure 7 Pressed diaphragm

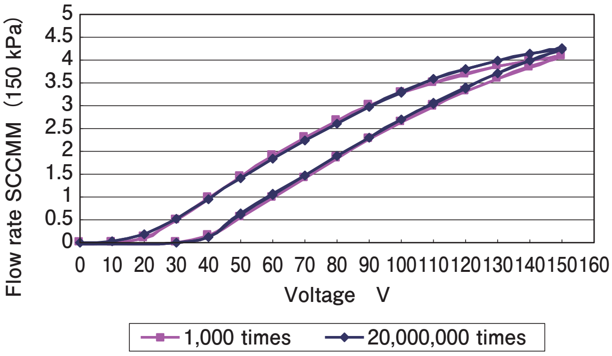

Figure 8 Valve characteristics

Investigating making each Part more Compact/Thinner

Compact valve diaphragm

To make a thinner MFC, the diameter of the round diaphragm used in the valve needs to be decreased. The shape is round, so the width of the MFC is a constraint. The actuator also uses piezoelectric elements, and we needed to make it compact while still using the conventional bellows structure (see Figure 3) in order to ensure reliability, so we investigated making the piezoelectric elements compact. However, the cross-section area decreases proportionally to the square of the diameter, so the force generated by the piezoelectric elements would also significantly decrease (see Figure 4). To make up for the decreased generated force, we needed to process the diaphragm so that it has even thinner walls than the current, and there was a limit to what could be achieved with machining (see Figure 5). Also, The conventional NC valve (closed when no electricity is supplied) structure that we have been using is a structure (see Figure 6) in which a nozzle on the lower part of the orifice is pressed, and we needed to put a pin on the diaphragm. Putting this pin area on another structure or making it into a welding structure causes problems with the product, so with the conventional technology, shaving was used to process the pin into the diaphragm as an integrated piece. This time, we tried using press working as a manufacturing method for processing the diaphragm pin area, to solve issues with the conventional design, including the machining limits. It was manufactured using rolled material with approximately 1/2 the thickness of the conventional diaphragm. Figure 7, 8 shows in there were no locations where stress was focused on the actuator drive, and we completed a diaphragm with low repulsive force, high displacement, and excellent high-durability characteristics.

Thinner case

The case needs to be made thinner to ensure that there will be enough space inside to install the parts. We judged that it would be difficult to make the entire unit thinner because the strength would decrease. We investigated metal injection, which can change the thickness in certain areas, but metal injection could not achieve the target thickness of 0.3 mm. Also, shaving would be required in areas that require processing accuracy. This time, we investigated a manufacturing method involving making the case out of bulk aluminum material and shaving it (see Figure 9). The part is relatively thin at 10 mm, so we can shorten the processing time, which would make it possible to use shaving in mass-production. This method would also have an increased degree of freedom in design, compared to working sheet metal. Also, we used a low-hardness aluminum, which would allow us to achieve a case that is lightweight and has a very hard film, if we combined that with Almite treatment or ceramic coating. There would be no concerns about scratching or discoloration, as there are with conventional painted surfaces, and this type would be easy to handle on production lines.

Compact laminar flow resistor (restrictor)

The conventional restrictor has radial flow paths configured on a disk (see Figure 10). Using an O-ring would be an efficient configuration, but would also generate wasted space on the outer circumference. We changed from a radial configuration to a parallel configuration, and used a structure that increases efficiency (see Figure 11). Also, to go along with these changes, we developed an elliptical-shaped metal gas socket (see Figure 12).

Changing the valve case processing method

In Figure 13, a valve case is required to anchor the piezoelectric stack. To maximize the stack size, we need a thinner valve case. We used material with a low coefficient of thermal expansion, but the conventional manufacturing method used shaving. Also, it is difficult to use shaving to manufacture a cylindrical case with a diameter of 10 mm or less. So we investigated a method in which material is cut into a pipe shape (see Figure 14). A thin-walled pipe with walls that are 0.3 mm thick can be manufactured, and parts can also be cut to the necessary lengths. Compared to shaving, significantly less material is used, which makes things easier in terms of procurement. Figure 15 shows for pipes are seamless and compare favorably with shaved parts in terms of performance, and making their walls thinner also doesn't result in a cost increase.

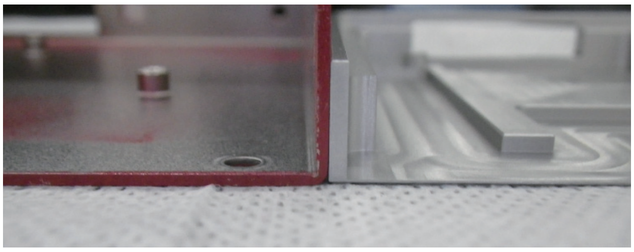

Figure 9 (Left) Metal sheet case (Right) Aluminum case

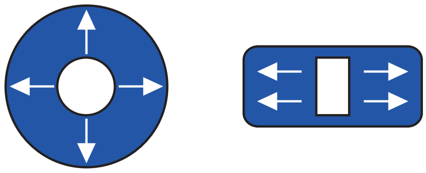

Figure 10 (Left) Radial layouts (Right) Parallel arrangement

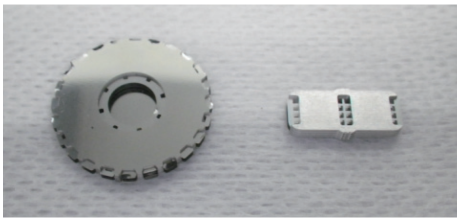

Figure 11 (Left) Radial layout product (Right) Parallel layout product

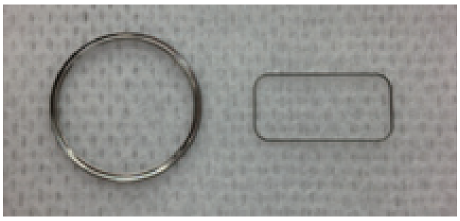

Figure 12 (Left) Circular shape gasket (Right) Rectangle shape gasket

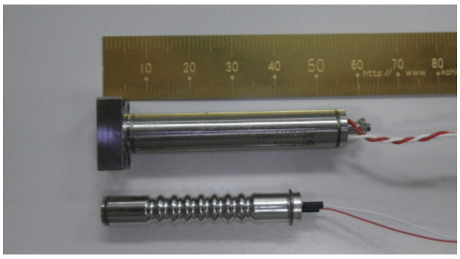

Figure 13 (Up) Piezo valve case (Down) Piezo stack

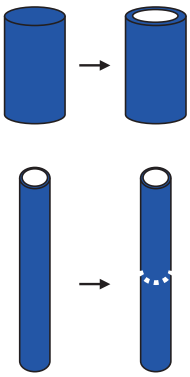

Figure 14 (Up) Previous machined case (Down) small pipe case

Figure 15 (Left) Previous machined case (Right) New small case

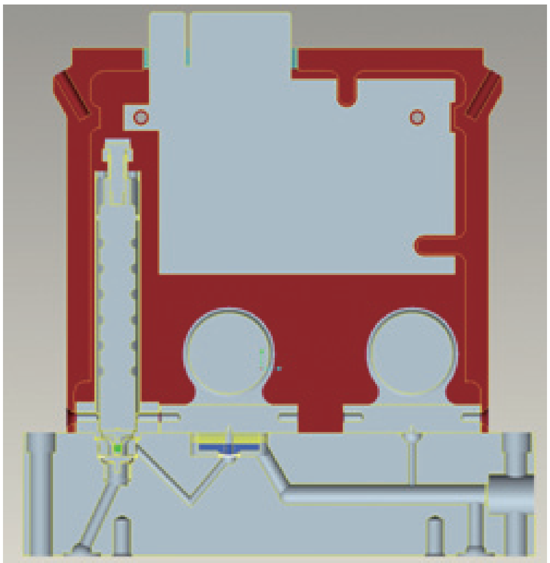

Figure 16 MFC cross-sectional view

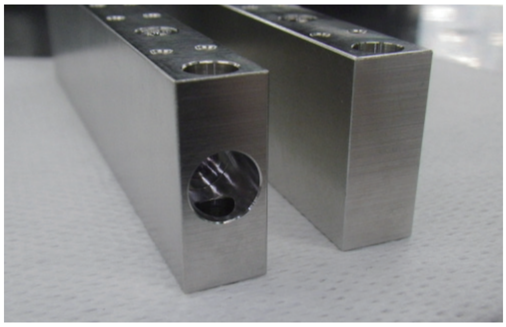

Figure 17 (Left) High flow block (Right) Standard block

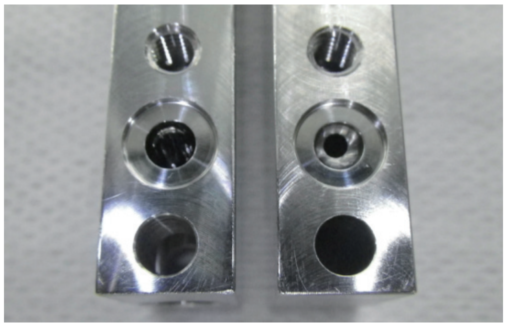

Figure 18 (Left) High flow block (Right) Standard block

Block that can handle a large flow rate

The conventional design had 4 bolts attached to two joint seal areas at the gas inlet/outlet. This time, to make the product more compact, we used a structure in which 2 bolts are attached to the respective seal areas from the outside (see Figure 16). Also, when we used a method in which the internal flow path was processed by drilling diagonal holes from the joint area, there was a limit to the flow path diameter. Then we used laser welding to weld on the bottom of the spot face holes (Figure 17). This made it possible to ensure the same flow path diameter as conventional parts, while making the part more compact (Figure 18). The area behind the restrictor is in a vacuum state, and has a major effect on enlarging the flow path diameter.

Required Product Performance

Flow rate accuracy

The restrictor and pressure sensor are related in terms of the accuracy of measuring the flow rate. Using a resistor with the same shape of flow path as the conventional parts and using the same model of pressure sensor as the conventional parts makes it possible to maintain the same flow rate measurement accuracy that we have had until now. In particular, using a common design for the restrictor enables us to use various gas flow rate data that we have accumulated over time.

Effect of pressure fluctuations on performance

We use a pressure differential system for measuring flow rates, which means that the MFC can operate as a Pressure-Insensitive MFC (PIMFC) (Figure 19). Also, making the piezoelectric stack more compact allows us to shorten the valve response time. We can probably achieve a higher operation speed than the conventional parts.

Weight reduction

The MFC unit also eliminates wasted areas and can lead to a reduction in the number of parts. Less material is used, which leads to shorter processing time and total cost solutions. There are significant benefits to making the unit

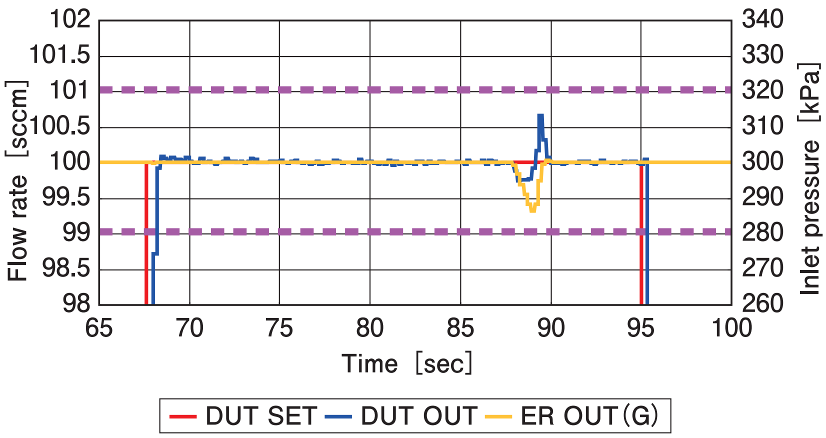

Figure 19 Inlet pressure in-sensitive test results

more compact, such as shorter processing time reducing the number of man-hours, and the degree of parallelism and flatness leading to better MFC valve part performance. The weight is approximately 1/3 of the conventional parts, which significantly reduces the space required to store inventory. If the gas box can be made small enough to fit in the hand, this will lead to reduced transportation costs and reduced work time.

Compact control board

If multiple MFCs can be controlled with one CPU, the space will be more compact, and this will also result in decreased energy consumption. This time, we succeeded in using one CPU to control 4 MFCs (Figure 20). Only 1/4 of the conventional number of cables were used, and this is a major benefit in terms of equipment.

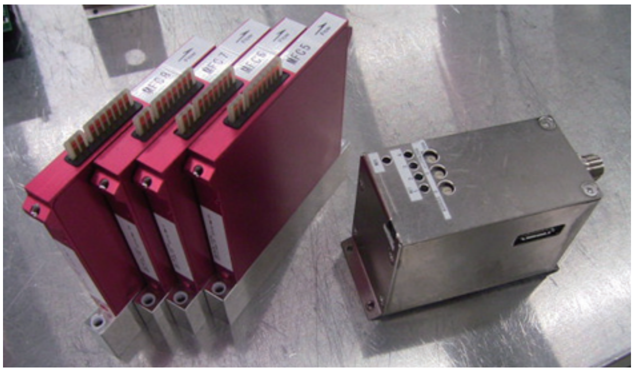

Figure 20 (Left) MFC body (Right) Control unit

Conclusion

We were concerned that making the part itself thinner would cause the cost of the individual sub-parts to increase, but in actuality, there was no cost increase. This is probably because the streamlined design that we used to reduce processing time and effectively use space eliminated those concerns. Also, considering the points that we improved from the conventional parts, we can say that we have achieved a part that is compact and has the same or better level of performance as the conventional part. We would like to take this technology for making parts compact that we developed this time and apply it to other products in the future.

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