Product Introduction

MV-2000 Series
High Efficiency Mixed Injection

Ichiro NISHIKAWA

Recent semiconductor manufacturing processes are designed not only to miniaturize the device structure, but also to accommodate newly developed materials and to improve the productivity, with further consideration of increasing the wafer diameter to 450 mm. In conjunction with these trends, liquid materials used in semiconductor manufacturing are further diversified and processed in a larger flow volume. Market demand for vaporizers includes vaporization of a large flow volume, lower temperature vaporization, and reduction in the carrier gas flow used. This paper provides an introduction to a high efficiency mixed injection system, the MV-2000, with significantly improved vaporization performance compared to existing products to meet market needs.

Introduction

In recent years, liquid materials used in semiconductor manufacturing are further diversified and processed in a larger flow volume. The vaporization and supply method can be classified generally into three methods: direct vaporization method, bubbling method, and baking method. (Figure 1) The MV series corresponds to a direct vaporization method in which materials are delivered in a liquid state and directly vaporized near the point of use to control the flow rate. The advantage of the direct vaporization method is compact size compared to the bubbling method and baking method thereby enabling reduction of the installation area and cost. On the other hand, there are problems, such as production and clogging of reaction products from thermal decomposition of liquid materials, and difficulties in vaporizing a large flow volume due to compact size. Recent demands in the semiconductor market for vaporizers using the direct vaporization method can be summarized in the following four points:

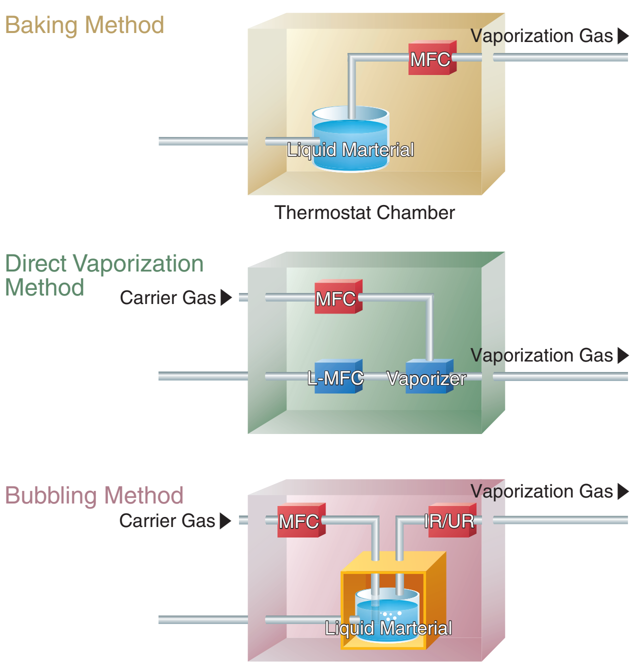

Figure 1 Three vaporization method

(1) Lower temperature vaporization to suppress thermal decomposition of liquid materials
(2) Vaporization of a large flow volume to accommodate 450 mm processes
(3) Reduction in carrier gas flow volume in the context of the He price increase
(4) Reduction in mist particles to accommodate miniaturization

We consider that solutions for all of the above demands can be provided by improving vaporization performance. This paper provides an introduction to a high efficiency mixed injection system, the MV-2000, (Figure 2) to meet these demands.

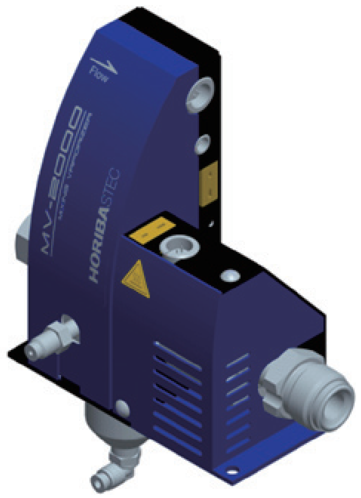

Figure 2 MV-2000

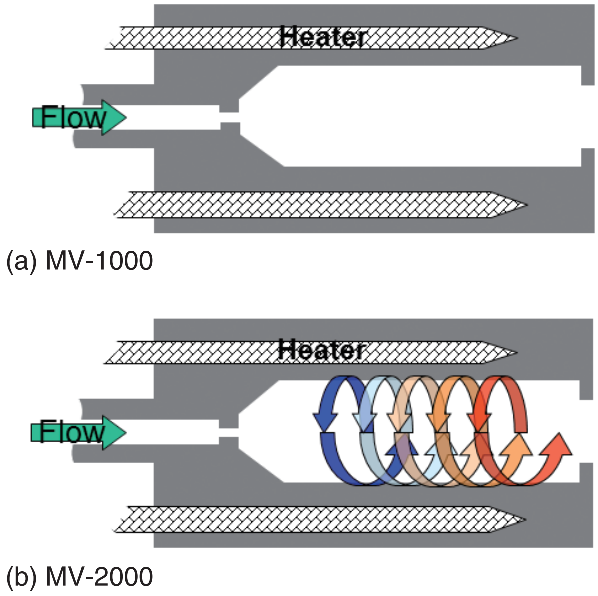

Figure 4 Structure of vaporizer

Structure of MV Series

TEMAZr (Tetrakis Ethyl Methyl Amino Zirconium), a typical high-k material, is used as an insulating film ($ZrO2$) with high dielectric constant of a capacitor, and the material has low vapor pressure, thus requiring a high temperature for vaporization. However, the material tends to be thermally decomposed at a high temperature for a long period of time, and is difficult to be used in vaporizers. In order to deal with such a material, the MV series has a structure divided into 2 parts. (Figure 3)

Part A shown in Figure 3 is a gas-liquid mixing valve (mixing valve), and Part B is a vaporizer (vaporizer). The advantage of this method is that each part can be thermally controlled independently of each other. The mixing valve part, which is a liquid retaining portion, can be set at a low temperature, thereby reducing the risk of thermal decomposition of the liquid material. (If the liquid material is thermally decomposed, decomposition products may cause clogging of the valve or nozzle part.) To the contrary, the vaporizer part can be set at a high temperature (max. 200°C) to deal with low vapor-pressure materials. As a vaporization flow, the liquid flow rate is sensed by the Liquid Flow Meter (LFM) and precisely controlled by the piezo actuator valve and feedback control. The liquid is mixed at the mixing valve part with the carrier gas at a flow rate controlled by the MFC and is miniaturized, heated, and vaporized by the spray nozzle of the vaporizer part to obtain stable vapor with high efficiency.

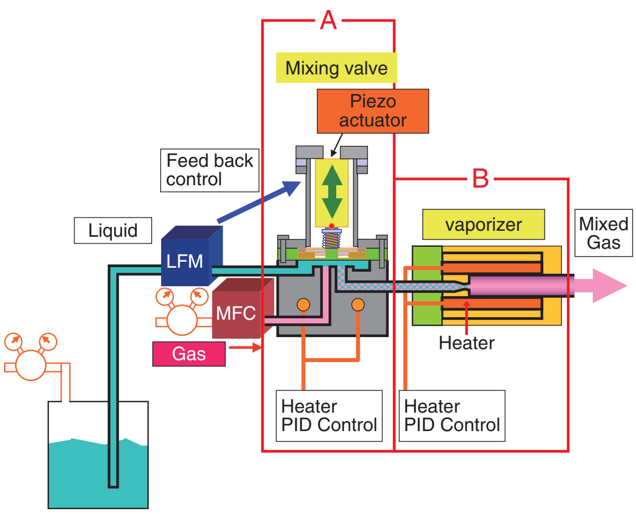

Figure 3 Structure of MV series

Improving Vaporization Performance

The existing product (MV-1000) has a hollow structure in the vaporizer part. Therefore, if the liquid flows in a large volume, perfect heat exchange cannot be obtained in the vaporizer part and mist will be scattered on the secondary side making it difficult to accommodate a large flow volume. (Figure 4a) The new product (MV-2000) is equipped with an internal heat exchange element having a structure capable of stirring fluid at a low pressure drop as a remedial measure to improve the heat exchange rate in the vaporizer part. (Figure 4b)

Figure 5 shows the result of CAE analysis on temperature distribution of the existing product and the new product under the same conditions. Red indicates an area of high temperature, and blue indicates an area of low temperature. The analysis of the existing product on the upper side shows that heat is not transmitted to the center of the product. (Figure 5a) To the contrary, in the case of the new product on the lower side, a swirling-like

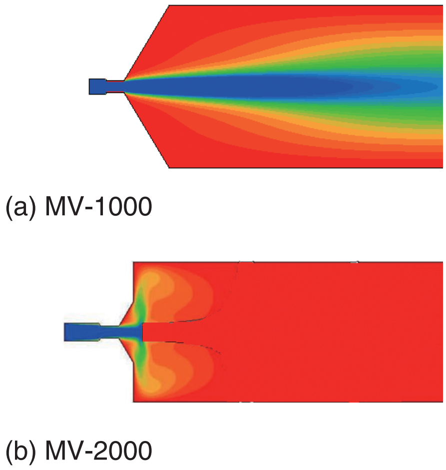

Figure 5 Temperature distribution in vaporizer

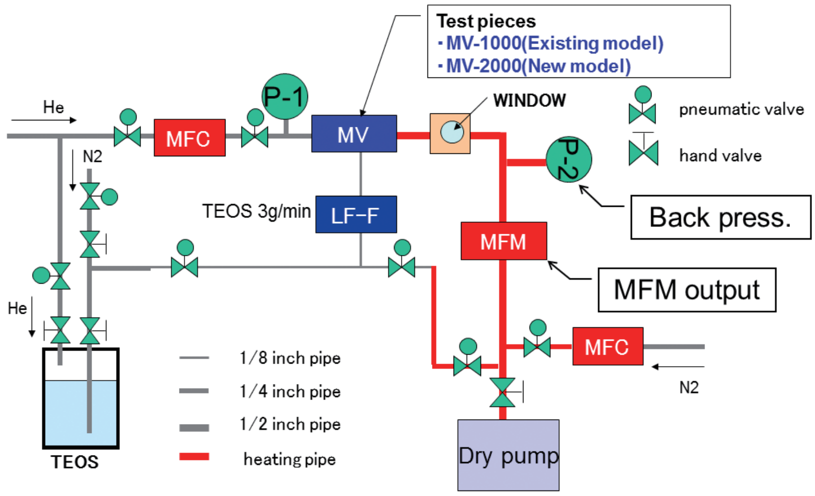

Figure 6 TEOS vaporization test flow

condition is observed immediately after introduction into the Vaporizer part and the temperature is uniform by promoting heat exchange. (Figure 5b) In the CAE analysis, improvement of heat exchange efficiency was confirmed.

Verification of Occurrence of Low Temperature Vaporization

A typical TEOS is used as a CVD (Chemical Vapor Deposition) material to verify that vaporization can occur at a lower temperature than the existing material. Whether or not vaporization can occur is determined by visual observation through the observation window and by the stability of the flow output of the MFM. (Figure 6) At 150°C, stable occurrence was possible in both the MV-1000 and MV-2000. (Figure 7a) At 120°C, there were significant fluctuations in the MFM output and pressure readings of the MV-1000. These were the effect of the mist generation due to poor vaporization. On the other hand, stable vaporization was possible at 120°C in the MV-2000. (Figure 7b) At a further lower temperature of 80°C, (Figure 7c) there were even greater fluctuations in the MV-1000 where a tailing phenomenon also occurred. This tailing indicates that the unvaporized TEOS remained inside at the end of the occurrence and was vaporized later. On the other hand, in the MV-2000, the result of the stability was obtained at 80°C, which means that it can accommodate to 80°C under the conditions that require 150°C in the existing product, achieving a reduction in the temperature of 70°C. This may significantly reduce the risk of thermal decomposition of liquid materials and improve the life against clogging. Also, in the case of occurrence at the same temperature, vaporization of a larger flow volume is possible than the existing products.

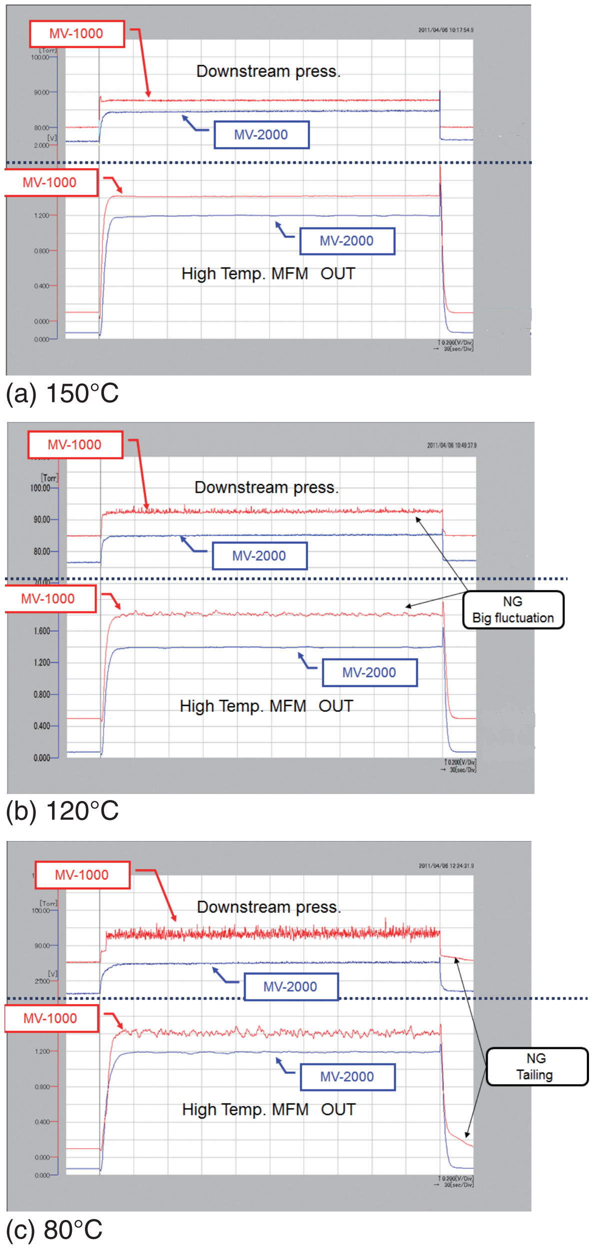

Figure 7 TEOS vaporization result

Table 1 Summary of TEOS vaporization

	Test condition					results		
	TEOS	Carrier He	Main temp.	Vaporizer temp.	Back pressure	DUT	MFM output fluctuation	Visual inspection of mist
01	3 g/min	1.5 SLM (He)	150°C	150°C	75torr	MV-1000	37 mV	○ : no mist
						MV-2000	8 mV	○ : no mist
02	3 g/min	1.5 SLM (He)	100°C	120°C	75torr	MV-1000	85 mV	× : mist
						MV-2000	11 mV	○ : no mist
03	3 g/min	1.5 SLM (He)	80°C	80°C	75torr	MV-1000	98 mV	× : mist
						MV-2000	16 mV	○ : no mist

MFM output fluctuation

Less than 20 mV	Full vaporization
20 mV-50 mV	Vaporization is possible
50 mV or more	Imperfect vaporization

Table 2 Conventional vaporizer

	Conventional	Carrier He	Judgement of vaporization				
			TEOS				
	temp.		1.4	2.8	4.2	5.6	7.0
	[°C]	[SCCM]	[g/min]				
01	180	1000	OK	NG	NG	NG	NG
02	180	500	OK	NG	NG	NG	NG
03	180	300	OK	NG	NG	NG	NG
04	180	100	OK	NG	NG	NG	NG
05	150	1000	OK	NG	NG	NG	NG
06	150	500	OK	NG	NG	NG	NG
07	150	300	OK	NG	NG	NG	NG
08	150	100	OK	NG	NG	NG	NG
09	150	5000	OK	OK	NG	NG	NG
10	180	5000	OK	OK	OK	NG	NG
11	200	5000	OK	OK	OK	NG	NG

Table 3 MV-2000

	MV-2000		Carrier He	Judgement of vaporization				
				TEOS				
	Valve	VAPO		1.4	2.8	4.2	5.6	7.0
	[°C]	[°C]	[SCCM]	[g/min]				
01	140	200	1000	OK	OK	OK	OK	OK
02	140	200	500	OK	OK	OK	OK	OK
03	140	200	300	OK	OK	OK	OK	OK
04	140	200	100	OK	OK	OK	OK	OK
05	140	180	100	OK	OK	OK	OK	OK
06	120	180	100	OK	OK	OK	OK	NG
07	110	170	100	OK	OK	NG	NG	NG

Reduction in Use of Carrier Gas

Table 1 shows the comparison result with our existing carrier gas-type vaporizers. The existing products do not achieve stable vaporization of TEOS at 7 g/min even with a carrier gas flow rate of 5 SLM. However, under the same temperature condition, the MV-2000 accommodates to a carrier gas flow rate of 100 SCCM, which is 1/50 of the above value, thereby enabling to significantly reduce the amount of use of carrier gas. (Table 2, 3)

Conclusion

The newly developed MV-2000 significantly improves vaporization performance compared to existing models. The improved vaporization performance can contribute to increasing the amount of vaporization, reducing the carrier gas flow rate, and suppressing thermal decomposition by lowering the vaporization temperature. Currently, there are demands for vaporization and supply of various liquids, and we believe that one of the solutions to them can be provided by this system.

Ichiro NISHIKAWA

Development Design Dept.2
Research & Development Division
HORIBA STEC, Co., Ltd.