

FLOW RATE MEASUREMENT DEVICE AND FLOW RATE MEASUREMENT METHOD FOR FLOW RATE CONTROLLER FOR GAS SUPPLY DEVICE

Technical Field

[0001] The present invention relates to an improvement in a flow rate measurement device and a flow rate measurement method for a flow rate controller of a gas supply device to be used in a semiconductor manufacturing apparatus and a drug production apparatus, etc., and, to a flow rate measurement device and to a flow rate measurement method for a flow rate controller for a gas supply device, which enables downsizing, structural simplification, higher measurement accuracy, and quicker flow rate measurement of the gas supply device.

Background Art

[0002] A gas supply device of a semiconductor manufacturing apparatus, etc., is generally configured to switch and supply a large variety of gases to an object to use the gas, such as a process chamber, so that a necessary process gas, whose flow rate is controlled by a flow rate controller provided for each kind of supply gas, is supplied to the object to use the gas. The flow rate measurement of each flow rate controller described above is performed at appropriate time intervals generally by a build-up method (or rate of pressure rise (ROR) method), and flow rate measurement is performed by comparing a set flow rate of the flow rate controller with an actual control flow rate measured by the build-up method, etc.

[0003] Fig. 5 and Fig. 6 show examples of conventional flow rate measurement methods of a flow rate controller for a gas supply device. Specifically, in the measurement method shown in Fig. 5, first, a flow rate measurement unit U_0

including a build-up tank BT with a known inner volume, an inlet on-off valve V_1 , an outlet on-off valve V_2 , a pressure detector P_d , and a gas temperature detector T_d , is joined to a gas supply line L in a branched form. Next, for example, to measure a flow rate controller MFC_1 of a gas supply device GF, first, on-off valves V_{02} , V_{0n} , and V_0 are closed and on-off valves V_{01} , V_1 , and V_2 are opened, so as to flow the gas into the tank BT, and a pressure detected value P_1 and a temperature detected value T_1 at a time t_1 , in a state where the on-off valves V_1 and V_2 are opened, or at a time t_1 in a state where the on-off valve V_2 is closed after the on-off valves V_1 and V_2 are opened, are measured. Next, a pressure detected value P_2 and a temperature detected value T_2 are measured Δt seconds after the on-off valve V_1 is closed from the opened state of the on-off valves V_1 and V_2 or Δt seconds after the time t_1 in a state where the on-off valve V_2 is closed after the on-off valves V_1 and V_2 are opened.

[0004] Then, from the respective measured values described above, a rate of pressure rise $\Delta P/\Delta t$ is obtained, a flow rate Q is calculated based on $Q = (\Delta P/\Delta t) \times (V/RT)$, and a flow control value of the flow rate controller MFC_1 is confirmed. The flow rate calculation formula is for arithmetically operating a build-up flow rate into the tank BT on the assumption that the gas is an ideal gas, and V is a total inner volume of the build-up tank VT and the pipe passage on the upstream side, R is a gas constant, and T is a gas temperature inside the tank BT.

[0005] On the other hand, in the measurement method shown in Fig. 6, a flow rate measurement unit U_1 without the build-up tank is joined to a gas supply line L in a branched form. Then, for example, to measure the flow rate controller MFC_1 of the gas supply device GF, first, on-off valves V_0 , V_{00} , V_{02} , and V_{0n} are closed and on-off valves V_{01} , V_1 , and V_2 are opened to supply the gas at a set flow rate from the flow rate controller MFC_1 to the flow rate measurement unit

U_1 , and then, the on-off valve V_2 is closed. After the on-off valve V_2 is closed, when the pressure detected value of the pressure detector P_d reaches P_1 , a first measurement is performed to measure the pressure P_1 and the temperature T_1 . Thereafter, when the pressure detected value of the pressure detector P reaches P_2 (or when a set time of t seconds elapses), a second measurement is performed to measure the pressure P_2 and the temperature T_2 . [0006] In addition, by arithmetically calculating a sum V of a pipe passage inner volume V_e of the portion of the gas supply lines L and L_s from the on-off valve V_{00} , the on-off valve V_{01} , the on-off valve V_{02} , and the on-off valve V_{0n} on the upstream side of the flow rate measurement unit U_1 to the on-off valve V_1 and an inner volume V_t of the flow passage between the on-off valve V_1 and the on-off valve V_2 of the flow rate measurement unit U_1 based on the flow rate formula $Q = (\Delta P / \Delta t) \times (V / RT)$ by using a rate of pressure rise $\Delta P / \Delta t$ obtained by the same measurement method as in the case of Fig. 5, and the flow rate value Q of the flow rate controller MFC_1 at that time, the total inner volume V is obtained in advance.

[0007] Then, from the respective measured values described above, a gas absolute flow rate Q_0 at a temperature of 0°C at 1 atm from the flow rate controller MFC_1 is obtained based on the relationship between the inflow mass dG and an elapsed (inflow) time dt of the gas. That is, the inflow mass dG can be expressed by $dG = \rho_0 \cdot Q_0 \cdot dt$ (provided that dt is an elapsed (inflow) time and ρ_0 is a specific weight). Based on the pressures P and temperatures T measured by the first measurement and the second measurement described above, an ideal gas has a relationship of $PV = nRT$, and by substituting the mass G for the mole number n , the relationship of $PV = GRT$ is established.

[0008] Therefore, on the assumption that the gas pressure P_1 , gas temperature T_1 , gas mass G_1 are measured by the first measurement, and the gas pressure

P_2 , gas temperature T_2 , and gas mass G_2 are measured by the second measurement, the difference in mass G (inflow mass dG) is expressed by $dG = G_2 - G_1 = P_1/T_1 \cdot V/R - P_2/T_2 \cdot V/R = (P_1/T_1 - P_2/T_2) \cdot V/R$... Formula (1), and from the above-described formula $dG = r_o \cdot Q_o \cdot dt$, the absolute flow rate Q_o of the gas can be calculated by $Q_o = (P_1/T_1 - P_2/T_2) \cdot V/R \cdot 1/(r_o \cdot t)$. Based on the calculated value Q_o , it is determined whether the flow rate control performance of the flow rate controller MFC_1 is proper.

[0009] In the method shown in Fig. 6, the objects of the invention are (1) to reduce errors of the calculated reference flow rate by using a coefficient that is a compression factor in Formula (1) described above since application of the ideal gas equation becomes difficult depending on the kind of gas, and (2) to determine the timing to start the second measurement after the first measurement based on a pressure rise value when the control flow rate is in the range of 1000 to 2000 SCCM or based on an elapsed time when the control flow rate is in the range of 2 to 1000 SCCM.

[0010] In the method shown in Fig. 6, it is also a matter of course that a rate of pressure rise $\Delta P/\Delta t$ is obtained from the respective measured values described above, a flow rate Q is calculated based on $Q = (\Delta P/\Delta t) \times (V/RT)$, and it can be determined whether the flow rate control value of the flow rate controller MFC_1 is proper based on the calculated value.

[0011] The method using the build-up tank BT shown in Fig. 5 has problems including that (1) the flow rate measurement device increases in size due to the use of the build-up tank BT and it is not possible to downsize the dimensions of the gas supply device, (2) the measured value of the gas temperature inside the tank BT significantly fluctuates according to the position of attachment of the temperature detector T_d , (3) the gas temperature T during rise of the gas pressure inside the tank significantly fluctuates and does not become a constant

temperature T , and (4) when a temperature change of the outside air is large, the gas temperature during pressure detection changes and fluctuation of the temperature detected value T increases, etc., so that even if the gas is close to an ideal gas, high flow rate measurement accuracy cannot be obtained.

[0012] On the other hand, in the method shown in Fig. 6, the valve V_1 is provided on the flow-in side of the flow rate measurement unit U_1 , and via this valve, the unit U_1 is joined to the end portion of the branched connection pipe passage L_s . However, this valve V_1 is not used for flow rate measurement at all, rather, the presence of this valve V_1 poses various problems, namely, that fluid resistance increases, a drive mechanism of the valve V_1 , for example, an electromagnetic valve and drive fluid piping, etc., become necessary, the component cost and assembly cost increase, an operation delay is caused by the driving performance of the valve V_1 , and timing adjustment becomes necessary, etc.

[0013] In the method shown in Fig. 6, in order to measure a sum volume V of the flow passage inner volume V_e of the fluid supply line L and the branched connection pipe passage L_s and the flow passage inner volume V_t of the flow rate measurement unit U_1 , the valve V_1 is opened and closed twice, and during this time, the inside of the flow rate measurement unit U_1 is vacuumed. Thus it takes too many procedures to perform flow rate measurement.

Prior Art Documents (Patent Documents)

[0014] Patent Document 1: Japanese Published Unexamined Patent Application No. 2006-337346; and

Patent Document 2: International Publication No. WO 2007/102319.

Summary

Problems to be Solved

[0015] Example embodiments of the present application seek to provide a flow rate measurement device for a flow rate controller for a gas supply device that is small in size, can be easily attached to the gas supply device, and realizes highly accurate flow rate measurement by easy operation. This also includes providing a flow rate measurement method using the flow rate measurement device by solving the above-described problems in flow rate measurement of a flow rate controller using a conventional flow rate measurement unit U_1 , that is, the valves V_1 and V_2 are provided on each of the fluid inlet side and the fluid outlet side of the flow rate measurement unit U_1 . Due to provision of the inlet side valve V_1 , the fluid resistance increases, the inlet side valve V_1 requires a drive mechanism including an electromagnetic valve and drive fluid piping, etc., so the assembly cost for this increases, and the drive mechanism causes operation delay due to its driving performance and requires timing adjustment, etc. Thus, the example embodiments of the present application can solve the problem that calculation of a total inner volume V of the fluid supply line L and the branched connection pipe passage L_s and an inner volume V_t of the flow rate measurement unit U_1 , takes too many operations.

[0015a] In accordance with a first aspect of the present application, there is provided a flow rate measurement device for a flow rate controller for a gas supply device, comprising: a branched pipe passage L_b having an inlet side end portion detachably joined in a branched form to an upstream portion of an on-off valve V_0 provided on an outlet end portion of a gas supply line L , and an outlet side end portion of the branched pipe passage L_b is detachably joined to a gas flow-out side pipe passage that communicates with a vacuum pump VP ;

an on-off valve V provided on an outlet side of the branched pipe passage Lb;
a pressure detector Pd and a temperature detector Td disposed to detect a gas pressure and a gas temperature of a gas flowing in the branched pipe passage Lb; an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input, and the arithmetic operation control device arithmetically calculates a flow rate of the gas flowing in the branched pipe passage Lb; an electromagnetic valve EV that supplies a drive fluid to the on-off valve V; a drive fluid source DGS that supplies a drive fluid to the electromagnetic valve EV; an I/O board IO for the arithmetic operation control device CP; and a power source device ES.

[0015b] In accordance with a second aspect of the present application, there is provided a flow rate measurement method for a flow rate controller for a gas supply device wherein, in the gas supply device that supplies a plurality of kinds of gases to a gas use portion in a switchable manner through each of the flow rate controllers, respectively, an inlet side end portion of a branched pipe passage Lb of a flow rate measurement device U is detachably joined in a branched form to an upstream portion of an on-off valve V₀ provided on an outlet end portion of a gas supply line L, wherein the flow rate measurement device U includes the branched pipe passage Lb, an on-off valve V provided on an outlet side of the branched pipe passage Lb, a gas pressure detector Pd and a gas temperature detector Td disposed to detect a gas pressure and a gas temperature of a gas flowing in the branched pipe passage Lb, and an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input, and the arithmetic operation control device arithmetically calculates a flow rate of the gas flowing in the branched pipe passage Lb, an electromagnetic valve EV that supplies a drive fluid to the on-off valve V, a drive fluid source DGS that supplies a drive

fluid to the electromagnetic valve EV, an I/O board IO for the arithmetic operation control device CP, and a power source device ES, and wherein an outlet side end portion of the branched pipe passage Lb is connected to a gas flow-out side, and first, outlet side on-off valves V_{01} to V_{0n} of each flow rate controller of the flow rate control device and the on-off valve V_0 on the outlet end portion of the gas supply line L are closed and the on-off valve V provided on the outlet side of the branched pipe passage Lb of the flow rate measurement device U is opened, and then, only one of the outlet side on-off valves V_{01} to V_{0n} of a flow rate controller to be measured is opened to flow the gas into the branched pipe passage Lb of the flow rate measurement device U at a set flow rate, and the on-off valve V on the outlet side of the branched pipe passage Lb is closed after the gas pressure and the gas temperature in the branched pipe passage Lb become stable, a first measurement of a gas temperature T_1 and a gas pressure P_1 is performed at a time t_1 at which the gas pressure reaches a set pressure P_1 , second measurement of a gas temperature T_2 and a gas pressure P_2 is then performed at a time t_2 at which the gas pressure reaches a set pressure P_2 , and from the respective measured values described above, a gas flow rate Q is arithmetically calculated based on $Q = (22.4V/R \cdot \Delta t) \times (P_2/T_2 - P_1/T_1)$ (provided that V is the total inner volume of the branched pipe passage Lb and the gas supply line L, R is a gas constant, and Δt is $t_2 - t_1$).

[0015c] In accordance with a third aspect of the present application, there is provided a flow rate measurement method for a flow rate controller for a gas supply device wherein, in the gas supply device that supplies a plurality of kinds of gases to a gas use portion in a switchable manner through each of the flow rate controllers, respectively, an inlet side end portion of a branched pipe passage Lb of a flow rate measurement device U including the branched pipe passage Lb, an on-off valve V provided on the outlet side of the branched pipe

passage Lb, a gas pressure detector Pd and a gas temperature detector Td disposed to detect a gas pressure and a gas temperature of a gas flowing in the branched pipe passage Lb, and an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input, and the arithmetic operation control device arithmetically calculates a flow rate of the gas flowing in the branched pipe passage Lb, an electromagnetic valve EV that supplies a drive fluid to the on-off valve V, a drive fluid source DGS that supplies a drive fluid to the electromagnetic valve EV, an I/O board IO for the arithmetic operation control device CP, and a power source device ES is detachably joined in a branched form to an upstream portion of an on-off valve V₀ provided on an outlet end portion of a gas supply line L of the gas supply device, and an outlet side end portion of the branched pipe passage Lb is connected to a gas flow-out side, and first, outlet side on-off valves V₀₁ to V_{0n} of each flow rate controller of the flow rate control device and the on-off valve V₀ on the outlet end portion of the gas supply line L are closed and the on-off valve V provided on the outlet side of the branched pipe passage Lb of the flow rate measurement device U is opened, and then, only one of the outlet side on-off valves V₀₁ to V_{0n} of a flow rate controller to be measured is opened to flow the gas into the branched pipe passage Lb of the flow rate measurement device U at a set flow rate, the on-off valve V on the outlet side of the branched pipe passage Lb is closed after the gas pressure and the gas temperature in the branched pipe passage Lb become stable, a rate of gas pressure rise $\Delta P/\Delta t$ is measured, and a flow rate Q is arithmetically calculated based on $Q = \Delta P/\Delta t \times V/R \cdot T$ (provided that V is the total inner volume of the branched pipe passage Lb and the gas supply line L, R is a gas constant, Δt is a measurement time, and T is a gas temperature).

[0016] An example embodiment of the present application is basically constituted so that a flow rate measurement device includes a branched pipe passage Lb having an inlet side end portion that is detachably joined in a branched form to an upstream portion of an on-off valve V_0 provided on an outlet end portion of a gas supply line L, and an outlet side end portion of the branched pipe passage Lb is joined to a gas flow-out side. The flow rate measurement device further includes an on-off valve V provided on the outlet

side of the branched pipe passage Lb, a pressure detector Pd and a temperature detector Td, which detects a gas pressure and a gas temperature of a gas flowing in the on-off valve V, and an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input, and which arithmetically calculates a flow rate of a gas flowing in the branched pipe passage Lb, and the flow rate measurement device is detachably joined in a branched arrangement to an upstream portion of the on-off valve V₀ provided on the outlet end portion of the gas supply line L of the gas supply device GF.

[0017] Another example embodiment of the present application is basically constituted so that, in a gas supply device that supplies a plurality of kinds of gases to a gas use portion in a switchable manner through each of the flow rate controllers, respectively, a flow rate measurement device U including a branched pipe passage Lb, an on-off valve V provided on the outlet side of the branched pipe passage Lb, a gas pressure detector Pd and a gas temperature detector Td in the branched pipe passage Lb, and an arithmetic operation control device CP that is joined in a branched arrangement to a gas supply line L of the gas supply device, wherein the on-off valve V of the flow rate measurement device U is connected to a gas flow-out side, and first, the outlet side on-off valves V₀₁ to V_{0n} of each flow rate controller of the flow rate control device, and an on-off valve V₀ on the outlet end portion of the gas supply line L, are closed and the on-off valve V of the flow rate measurement device U is opened, and then, only the outlet side on-off valve of a flow rate controller to be measured is opened to flow the gas into the flow rate measurement device U at a set flow rate, and the on-off valve V is closed after the gas pressure and the gas temperature become stable. A first measurement of a gas temperature T₁ and a gas pressure P₁ is performed at a time t₁ at which the gas pressure reaches a set pressure P₁, a second

measurement of a gas temperature T_2 and a gas pressure P_2 is performed at a time t_2 at which the gas pressure reaches a set pressure P_2 , and from the respective measured values described above, a gas flow rate Q is arithmetically calculated based on $Q = (22.4V/R \cdot \Delta t) \times (P_2/T_2 - P_1/T_1)$, (provided that V is the total inner volume of the branched pipe passage L_b and the gas supply line L , R is a gas constant, Δt is $t_2 - t_1$).

[0018] Another example embodiment of the present application is basically constituted so that, in a gas supply device that supplies a plurality of kinds of gases to a gas use portion in a switchable manner through each of the flow rate controllers, respectively, a flow rate measurement device U including a branched pipe passage L_b , an on-off valve V provided on the outlet side of the branched pipe passage L_b , a gas pressure detector P_d and a gas temperature detector T_d in the branched pipe passage L_b , and an arithmetic operation control device CP , is joined in a branched structure to a gas supply line L of the gas supply device, and the on-off valve V of the flow rate measurement device U is connected to a gas flow-out side, and first, outlet side on-off valves V_{01} to V_{0n} of each flow rate controller of the flow rate control device and an on-off valve V_0 on the outlet end portion of the gas supply line L are closed and the on-off valve V of the flow rate measurement device U is opened, and then, only the outlet side on-off valve of a flow rate controller to be measured is opened to flow the gas into the flow rate measurement device U at a set flow rate, and the on-off valve V is closed after the gas pressure and the gas temperature become stable, a rate of gas pressure rise $\Delta P/\Delta t$ is measured, and a flow rate Q is arithmetically calculated based on $Q = \Delta P/\Delta t \times V/R \cdot T$ (provided that V is the total inner volume of the branched pipe passage L_b and the gas supply line L , R is a gas constant, Δt is a measurement time, and T is a gas temperature).

[0019] Another example embodiment is constituted so that, the flow rate measurement device U includes a branched pipe passage Lb having an inlet side end portion to be joined to a gas supply line L and an outlet side end portion to be joined to a gas flow-out side, respectively, the on-off valve V provided on the outlet side of the branched pipe passage Lb, the pressure detector Pd and the temperature detector Td, which detects a gas pressure and a gas temperature of a gas flowing in the on-off valve V, an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input and which arithmetically calculates a gas flow rate of the gas flowing in the branched pipe passage Lb, an electromagnetic valve EV that supplies a drive fluid to the on-off valve V, a drive fluid source DGS that supplies a drive fluid to the electromagnetic valve EV, an I/O board IO for the arithmetic operation control device CP, and a power source device ES.

Effects of the Example embodiments

[0020] In the present application, the above described volume V can be easily obtained based on $V = \Delta t \times Q \times R \times T / \Delta P$ (provided that Q is a flow rate, P is a fluid pressure, T is a temperature, R is a gas constant, $\Delta P / \Delta t$ is a rate of pressure rise) by measuring a rate of pressure rise at the gas flow rate Q by using a nitrogen gas, etc. That is, even if the on-off valve V₁ is not provided, the total inner volume V of the branched pipe passage Lb and the gas supply line L necessary for flow rate measurement can be easily calculated, so that the flow rate measurement operation of the flow rate controller becomes easier.

[0021] In the present application, the on-off valve V that is provided in the branched pipe passage Lb of the flow rate measurement device U is provided only on the outlet side end of the branched pipe passage Lb, so that not only can the flow rate measurement device U be downsized and structurally simplified, but also the gas flow passage resistance can be reduced. During

operation of the gas supply device GF, the gas pressure in the gas supply line L on the secondary side can always be monitored by the pressure detector Pd, and it can be immediately confirmed in advance whether the pressure state allows flow rate measurement.

[0022] At the time of the flow rate measurement operation, not only can an alarm be immediately issued in response to a measurement start signal when the pressure state is abnormal, but also the pressure state in the gas supply line L on the secondary side can always be monitored, so that the pressure detector Pd can be utilized as a gas pressure monitor of the gas supply line L. Furthermore, when the flow rate controller is a pressure type flow rate control device, a detection signal of the pressure detector Pd can also be utilized as an alarm showing a lower limit value of the flow rate control range of the flow rate controller.

Brief Description of the Drawings

[0023] Fig. 1 is a schematic configuration diagram of a flow rate measurement device of a flow rate controller for a gas supply device according to the present invention.

Fig. 2 illustrated a schematic view of a gas supply device including a flow rate measurement device.

Fig. 3 illustrates a schematic view of a method for measuring a pipe passage inner volume.

Fig. 4 is a graphic diagram showing change situations of a gas pressure and a gas temperature in the measurement method shown in Fig. 3.

Fig. 5 illustrates a schematic view of a flow rate measurement method based on a conventional build-up method.

Fig. 6 illustrates a schematic view of a flow rate measurement method

based on another conventional build-up method.

Best Mode for Carrying Out the Invention

[0024] Fig. 1 is an illustrated schematic view showing a configuration of a flow rate measurement device of a flow rate controller for a gas supply device according to the present invention, and Fig. 2 is an illustrated schematic view showing an embodiment of a measurement method for a flow rate controller in the case where flow rate measurement of a pressure type flow rate controller FCS provided in the gas supply device GF is performed.

[0025] In Fig. 1 and Fig. 2, GF denotes a gas supply device, FCS_1 to FCS_n denote flow rate controllers, G_0 to G_n denote kinds of supply gases, L_1 to L_n and L denote gas supply lines, L_s denotes a branched connection pipe passage, L_b denotes a diverging pipe passage, V_{00} to V_{0n} denote on-off valves, V_0 denotes an on-off valve, V denotes an on-off valve, CH denotes a process chamber, VP denotes a vacuum pump, Td denotes a temperature detector, Pd denotes a pressure detector, B denotes a branch point, F denotes a connecting flange, EV denotes an electromagnetic valve, DGS denotes a drive fluid source, Tu denotes a drive fluid supply pipe, IO denotes an I/O board, ES denotes a DC power source, 1 denotes a pressure regulator, 2 denotes a pressure gauge, 3 and 4 denote on-off valves, U denotes a flow rate measurement device, and CP denotes an arithmetic operation control device. A predetermined kind of gas is switched and supplied from the gas supply device GF to the process chamber CH through the gas supply line L and the on-off valve V_0 .

[0026] The flow rate measurement device U is detachably joined in a branched structure to an upstream portion of the on-off valve V_0 provided on the outlet end portion of the gas supply line L. The flow rate measurement device U includes a straight branched pipe passage L_b with an appropriate inner

diameter having an inlet side end portion to be joined to the gas supply line L and an outlet side end portion to be joined to the gas flow-out side, a fluid pressure-driven metal diaphragm type on-off valve V provided on the outlet side of the branched pipe passage Lb, a pressure detector Pd and a temperature detector Td that detect a gas pressure and a gas temperature on the upstream side of the on-off valve V, an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input and which arithmetically operates to calculate a gas flow rate of a gas flowing in the branched pipe passage Lb, an electromagnetic valve EV that supplies a drive fluid to the on-off valve V, a drive fluid source DGS that supplies a drive fluid to the electromagnetic valve EV, an I/O board IO for the arithmetic operation control device CP, and a power source device ES.

[0027] Respective detected outputs of the pressure detector Pd and the temperature detector Td of the flow rate measurement device U, and a control signal of the on-off valve V, etc., are output and input into the arithmetic operation control device CP, and as described later, display and arithmetic calculation, etc., of a gas flow rate value are performed.

[0028] First, the inventor of the present invention made the flow rate measurement unit U' shown in Fig. 3, and by using this device, raised the gas pressure by means of a build-up method, and investigated changes in gas temperature and gas pressure inside the unit U' (inner volume: 1.0996 liters). That is, in the embodiment shown in Fig. 1, a reference flow rate regulator was attached instead of the flow rate controller FCS, and the flow rate measurement unit U' shown in Fig. 3 was connected instead of the flow rate measurement device U, and then, the on-off valves V_{02} , V_{0n} , and V_0 , were closed and the on-off valve V is opened to flow an N_2 gas at a flow rate of 500 SCCM for a predetermined time. After it was confirmed that the flow rate, pressure, and

temperature of the N_2 gas became stable, the on-off valve V was closed and build-up was performed for 10 seconds, and during this time, changes in gas temperature and pressure, etc., inside the unit U' were observed. As the reference flow rate regulator, the pressure type flow rate controller with a flow rate range of 1 SLM manufactured by Fujikin Incorporated was used, and the inner volume V of the unit U' was set to 1.0996 liters (known). The gas flow rate (N_2) was set to 500 SCCM, and the build-up time was set to 10 seconds. Furthermore, the outside air temperature (indoor temperature) was 21.7°C.

[0029] Fig. 4 shows changes in gas temperature and gas pressure, etc., inside the flow rate measurement unit U' in the build-up method described above. In Fig. 4, the curve A₁ indicates the flow rate output of the flow rate controller, the curve A₂ indicates the gas pressure detected value, the curve A₃ indicates the gas temperature detected value, the curve A₄ indicates the outside air temperature (indoor temperature), and the curve A₅ indicates the control signal for the output side on-off valve V. As the pressure detector Pd, a (Baratron) capacitance manometer TYPE 627D (1000 Torr F.S.) made by MKS Instruments was used. As the temperature detector Td, a thermocouple (wire type) with a diameter of 2.5 mm was used, and as a measuring instrument, a data logger NR-500 made by KEYENCE CORPORATION was used.

[0030] Specifically, as evident in Fig. 4, when the outlet side on-off valve V is closed and build-up is started at the point t₁, the gas pressure inside the tank increases from 30.6 Torr to 94.1 Torr at the point t₂. The gas temperature inside the tank rises gradually. By arithmetically calculating a gas inflow mass by performing measurement when the outlet side on-off valve V of the flow rate measurement unit U' is closed (when starting build-up) (the time t₁, first measurement) and the second measurement at the time t₂ after completion of the build-up, when the mole number of the gas that flowed in during build-up is

determined by Numerical formula 1 below:

[0031] [Numerical formula 1]

$$\Delta n = \frac{V}{R} \left(\frac{P_2}{T_2} - \frac{P_1}{T_1} \right)$$

is converted into a gas volume V_G in a standard state (0°C, 1 atm), the following result:

[0032] [Numerical formula 2]

$$V_G = \frac{22.4V}{R} \left(\frac{P_2}{T_2} - \frac{P_1}{T_1} \right)$$

is obtained, and the gas flow rate Q into the flow rate measurement unit U' can be calculated as:

[0033] [Numerical formula 3]

$$Q = \frac{\Delta V_G}{\Delta t} = \frac{22.4V}{R\Delta t} \left(\frac{P_2}{T_2} - \frac{P_1}{T_1} \right).$$

Here, Δt is the build-up time, and $\Delta t = t_2 - t_1$.

[0034] As described later, a rate of pressure rise $\Delta P/\Delta t$ is obtained from the respective measured values described above. By using this rate of pressure rise, the total inner volume V is arithmetically calculated based on $V = \Delta t \times Q \times R \times T / \Delta P$ (provided that Q is a flow rate, T is a temperature, R is a gas constant, and $\Delta P/\Delta t$ is a rate of pressure rise).

[First Embodiment]

[0035] Referring to Fig. 1 and Fig. 2, in order to perform flow rate measurement of the flow rate controllers FCS of the gas supply device GF, first, the flow rate controller measurement device U is connected to the gas supply line L in a branched manner. Next, in order to measure the flow rate controller FCS_1 , the on-off valves V_{00} , V_{02} , V_{0n} , and V_0 are closed and the on-off valves V_{01} and V are opened to supply a gas flow at a set flow rate Q_s from the flow rate

controller FCS_1 to the flow rate measurement device U, and the gas is exhausted by the vacuum pump VP.

[0036] Next, when the gas temperature T_o and the gas pressure P_o inside the branched pipe passage Lb of the flow rate measurement device U become stable, at the time t_1 , gas build-up is started by closing the outlet side on-off valve V and the gas temperature T_1 and the gas pressure P_1 inside the branched pipe passage Lb are detected and input into the arithmetic operation control device CP. When build-up of the gas into the branched pipe passage Lb proceeds and the gas pressure reaches the set value P_2 (or the set time t_2 is reached), the pressure P_2 and the temperature T_2 inside the branched pipe passage Lb are detected and the detected values are input into the arithmetic operation control device CP. After the second detection of the pressure and the temperature at the time t_2 is finished, the outlet side on-off valve V is opened to exhaust the gas inside the branched pipe passage Lb.

[0037] On the other hand, in the arithmetic operation control device CP, the flow rate Q is arithmetically calculated by using the above-described detected values P_1 , T_1 , P_2 , and T_2 based on the Numerical formula 3 described above, and the set flow rate Q_s of the flow rate regulator FCS_1 and the calculated flow rate Q are compared, and based on predetermined standards, the judgment of flow rate control performance of the flow rate regulator FCS_1 and measurement are performed.

[0038] By performing the above-described measurement operation for each of the flow rate regulators FCS_1 to FCS_n , the flow rate controllers of the gas supply device GF are measured.

[0039] In the present embodiment, the flow rate Q is arithmetically calculated by using the Numerical formula 3, and it is a matter of course that the rate of pressure rise is calculated from the measured values measured by the first

measurement and the second measurement described above, the flow rate Q is calculated based on $Q = (\Delta P/\Delta t) \times (V/RT)$. Based on the calculated value, it is judged whether the flow rate control value of the flow rate controller FCS is appropriate based on the calculated value.

[0040] In the present invention, it is assumed that the inner volume V in the arithmetic expression of the flow rate Q , that is, the sum of the inner volume of the gas supply line L on the upstream side of the gas supply on-off valve V_0 for the process chamber CH and the inner volume of the branched connection pipe L_s and the branched pipe passage L_b is known. However, when the inner volume is changed by alteration, etc., of the gas supply device GF , the changed inner volume is required to be measured. In this case, for example, a gas close to an ideal gas, such as a nitrogen gas, is used as the gas G_0 in Fig. 2, and first, the on-off valves V_{01} to V_{0n} and V_0 are closed and the on-off valves V_{00} and V are opened to flow the gas into the branched pipe passage L_b . When the pressure and temperature of the gas reach set values and become stable, the on-off valve V is closed and the pressure detected value P_1 and the temperature detected value T_1 at the time t_1 are measured. Next, at the time t_2 after an appropriate time elapses, the pressure detected value P_2 and the temperature detected value T_2 are measured.

[0041] Then, from the respective measured values described above, a rate of pressure rise $\Delta P/\Delta t$ is obtained, and by using this rate of pressure rise, the total inner volume V is arithmetically calculated based on $V = \Delta t \times Q \times R \times T / \Delta P$ (provided that Q is a flow rate, P is a fluid pressure, T is a temperature, R is a gas constant, and $\Delta P/\Delta t$ is a rate of pressure rise).

[0042] In the above-described embodiment, a pressure type flow rate control device is used as the flow rate controller, however, the flow rate controller may be a thermal type flow rate controller. Also, the connecting flange may be

connected by using a pipe joint, etc., or by using a block-shaped joint member, etc. As the on-off valve V, etc., AOVs (air operated valves) are used, however, when electromagnetic valves are used, it is also possible to omit the drive fluid source DGS, the drive fluid supply pipe Tu, and the electromagnetic valve EV that controls the drive fluid.

Industrial Applicability

[0043] The present invention is applicable to measurement tests not only of a gas supply device (gas box) for a semiconductor manufacturing apparatus but also of various flow rate controllers for gas supply devices, and flow rate controllers for gas supply systems, to be used for various purposes.

Description of Reference Symbols

[0044] GF: Gas supply device

FCS₁ to FCS_n: Flow rate controller

G_o to G_n: Supply gas kind

L, L₁ to L_n: Gas supply line

Ls: Branched connection pipe

Lb: Diverging pipe passage

F: Connecting flange

B: Branch point

V₀₀ to V_{0n}: On-off valve

V₀: On-off valve

U: Flow rate measurement device

V: On-off valve

CH: Process chamber

VP: Vacuum device (vacuum pump)

Td: Temperature detector

Pd: Pressure detector

1: Pressure regulator

2: Pressure gauge

3, 4: On-off valve

CP: Arithmetic operation control device

EV: Electromagnetic valve

DGS: Drive fluid source

Tu: Drive fluid supply pipe

IO: I/O port

ES: DC power source

CLAIMS

1. A flow rate measurement device for a flow rate controller for a gas supply device, comprising:

a branched pipe passage Lb having

an inlet side end portion detachably joined in a branched form to an upstream portion of an on-off valve V_0 provided on an outlet end portion of a gas supply line L and

an outlet side end portion of the branched pipe passage Lb is detachably joined to a gas flow-out side pipe passage that communicates with a vacuum pump VP;

an on-off valve V provided on an outlet side of the branched pipe passage Lb;

a pressure detector Pd and a temperature detector Td disposed to detect a gas pressure and a gas temperature of a gas flowing in the branched pipe passage Lb;

an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input, and the arithmetic operation control device arithmetically calculates a flow rate of the gas flowing in the branched pipe passage Lb;

an electromagnetic valve EV that supplies a drive fluid to the on-off valve V;

a drive fluid source DGS that supplies a drive fluid to the electromagnetic valve EV; an I/O board IO for the arithmetic operation control device CP; and a power source device ES.

2. A flow rate measurement method for a flow rate controller for a gas supply device wherein, in the gas supply device that supplies a plurality of kinds

of gases to a gas use portion in a switchable manner through each of the flow rate controllers, respectively, an inlet side end portion of a branched pipe passage Lb of a flow rate measurement device U is detachably joined in a branched form to an upstream portion of an on-off valve V_0 provided on an outlet end portion of a gas supply line L, wherein the flow rate measurement device U includes the branched pipe passage Lb, an on-off valve V provided on an outlet side of the branched pipe passage Lb, a gas pressure detector Pd and a gas temperature detector Td disposed to detect a gas pressure and a gas temperature of a gas flowing in the branched pipe passage Lb, and an arithmetic operation control device CP into which detection signals from the pressure detector Pd and the temperature detector Td are input, and the arithmetic operation control device arithmetically calculates a flow rate of the gas flowing in the branched pipe passage Lb, an electromagnetic valve EV that supplies a drive fluid to the on-off valve V, a drive fluid source DGS that supplies a drive fluid to the electromagnetic valve EV, an I/O board IO for the arithmetic operation control device CP, and a power source device ES, and wherein an outlet side end portion of the branched pipe passage Lb is connected to a gas flow-out side, and first, outlet side on-off valves V_{01} to V_{0n} of each flow rate controller of the flow rate control device and the on-off valve V_0 on the outlet end portion of the gas supply line L are closed and the on-off valve V provided on the outlet side of the branched pipe passage Lb of the flow rate measurement device U is opened, and then, only one of the outlet side on-off valves V_{01} to V_{0n} of a flow rate controller to be measured is opened to flow the gas into the branched pipe passage Lb of the flow rate measurement device U at a set flow rate, and the on-off valve V on the outlet side of the branched pipe passage Lb is closed after the gas pressure and the gas temperature in the branched pipe passage Lb become stable, a first measurement of a gas temperature T_1 and a gas pressure P_1 is performed at a time t_1 at which the gas pressure reaches a

set pressure P_1 , second measurement of a gas temperature T_2 and a gas pressure P_2 is then performed at a time t_2 at which the gas pressure reaches a set pressure P_2 , and from the respective measured values described above, a gas flow rate Q is arithmetically calculated based on $Q = (22.4V/R \cdot \Delta t) \times (P_2/T_2 - P_1/T_1)$ (provided that V is the total inner volume of the branched pipe passage L_b and the gas supply line L , R is a gas constant, and Δt is $t_2 - t_1$).

3. A flow rate measurement method for a flow rate controller for a gas supply device wherein, in the gas supply device that supplies a plurality of kinds of gases to a gas use portion in a switchable manner through each of the flow rate controllers, respectively, an inlet side end portion of a branched pipe passage L_b of a flow rate measurement device U including the branched pipe passage L_b , an on-off valve V provided on the outlet side of the branched pipe passage L_b , a gas pressure detector P_d and a gas temperature detector T_d disposed to detect a gas pressure and a gas temperature of a gas flowing in the branched pipe passage L_b , and an arithmetic operation control device CP into which detection signals from the pressure detector P_d and the temperature detector T_d are input, and the arithmetic operation control device arithmetically calculates a flow rate of the gas flowing in the branched pipe passage L_b , an electromagnetic valve EV that supplies a drive fluid to the on-off valve V , a drive fluid source DGS that supplies a drive fluid to the electromagnetic valve EV , an I/O board IO for the arithmetic operation control device CP , and a power source device ES is detachably joined in a branched form to an upstream portion of an on-off valve V_0 provided on an outlet end portion of a gas supply line L of the gas supply device, and an outlet side end portion of the branched pipe passage L_b is connected to a gas flow-out side, and first, outlet side on-off valves V_{01} to V_{0n} of each flow rate controller of the flow rate control device and the on-off valve V_0 on the outlet end portion of the gas supply line L are closed and the on-off valve V

provided on the outlet side of the branched pipe passage Lb of the flow rate measurement device U is opened, and then, only one of the outlet side on-off valves V_{01} to V_{0n} of a flow rate controller to be measured is opened to flow the gas into the branched pipe passage Lb of the flow rate measurement device U at a set flow rate, the on-off valve V on the outlet side of the branched pipe passage Lb is closed after the gas pressure and the gas temperature in the branched pipe passage Lb become stable, a rate of gas pressure rise $\Delta P/\Delta t$ is measured, and a flow rate Q is arithmetically calculated based on $Q = \Delta P/\Delta t \times V/R \cdot T$ (provided that V is the total inner volume of the branched pipe passage Lb and the gas supply line L, R is a gas constant, Δt is a measurement time, and T is a gas temperature).