

DESCRIPTION

TITLE OF INVENTION: ACTUATOR AND VALVE DEVICE

TECHNICAL FIELD

[0001] The present invention relates to an actuator and a valve device.

BACKGROUND ART

[0002] JP2017-44290A discloses a valve device that opens a passage of a valve body by supplying air to two pressure chambers of an actuator.

SUMMARY OF INVENTION

[0003] However, in the valve device described in JP2017-44290A, because a length of one air passage through which the air is supplied from an air supply source to one pressure chamber and a length of the other air passage through which the air is supplied from the air supply source to the other pressure chamber are different, a time difference occurs for the air supply from the air supply source to the two pressure chambers, and responsiveness of the valve device is deteriorated when the passage of the valve body is opened/closed.

[0004] The present invention has been made in view of this problem, and an object thereof is to provide an actuator and a valve device capable of improving responsiveness.

[0005] According to an aspect of the present invention, there is provided an actuator used for a valve device, including: a cylinder; a first piston accommodated in the cylinder so as to be slidable with respect to an inner circumferential surface of the cylinder; a piston rod provided so as to project from the first piston to a first side; a second piston provided on a second side

of the first piston, the second piston being accommodated in the cylinder so as to be slidable with respect to the inner circumferential surface of the cylinder; a partition portion fixed in the cylinder so as to be positioned between the first piston and the second piston; a first pressure chamber formed by the first piston, the piston rod, a bottom wall of the cylinder, and a circumferential wall of the cylinder; a second pressure chamber formed by the second piston, the partition portion, and the circumferential wall of the cylinder; a first fluid passage configured to provide communication between the first pressure chamber and a fluid supply source; and a second fluid passage providing communication between the second pressure chamber and the fluid supply source, wherein a length from the fluid supply source to the second pressure chamber is same as a length of the first fluid passage from the fluid supply source to the first pressure chamber.

[0006] According to this aspect, it is possible to improve responsiveness of the valve device.

BRIEF DESCRIPTION OF DRAWINGS

[0007]

[FIG. 1] FIG. 1 is a sectional view showing a valve device according to this embodiment.

[FIG. 2A] FIG. 2A is a graph showing an example of a relationship between an operation time and an air pressure at valve opening for the valve device according to this embodiment and a valve device according to a conventional art.

[FIG. 2B] FIG. 2B is a graph showing an example of the relationship between an operation time and an air pressure at valve closing for the valve

device according to this embodiment and the valve device according to the conventional art.

[FIG. 3] FIG. 3 is an explanatory sectional view showing an operation of the valve device when air is supplied to a first pressure chamber and a second pressure chamber.

[FIG. 4] FIG. 4 is an explanatory sectional view showing an operation of the valve device when the air is discharged from the first pressure chamber and the second pressure chamber.

[FIG. 5] FIG. 5 is a sectional view showing an actuator according to a first modification.

[FIG. 6] FIG. 6 is a sectional view showing an actuator according to a second modification.

[FIG. 7] FIG. 7 is a sectional view showing an actuator according to a third modification.

DESCRIPTION OF EMBODIMENTS

[0008] Hereinafter, a form for carrying out the present invention (hereinafter, also referred to as this embodiment) will be described with reference to the attached drawings. Throughout this specification, the same reference signs are assigned to the same elements.

[0009] [Configuration of Valve Device]

First, a valve device 100 according to this embodiment will be described with reference to FIGs. 1 to 2B.

[0010] FIG. 1 is a sectional view showing the valve device 100 according to this embodiment. FIG. 2A is a graph showing an example of a relationship between an operation time and an air pressure at valve opening for the valve

device 100 according to this embodiment and a valve device according to a conventional art. FIG. 2B is a graph showing an example of the relationship between the operation time and the air pressure at valve closing for the valve device 100 according to this embodiment and the valve device according to the conventional art. Note that the valve device according to the conventional art is one described in JP2017-44290A. The operation time at valve opening is a time from receiving a command for valve opening until actually reaching an open state, and the operation time at valve closing is a time from receiving a command for valve closing until actually reaching a closed state.

[0011] As shown in FIG. 1, the valve device 100 according to this embodiment is provided in a fluid control device (not shown) that is used for manufacturing of a semiconductor. The fluid control device is used for supply means of a process gas or a purge gas in a semiconductor manufacturing apparatus (a CVD apparatus, a sputtering apparatus, an etching apparatus, or the like/not shown).

[0012] In addition, as shown in FIG. 1, the valve device 100 includes a valve body 1, a stem 2, a valve element 3, a support ring 4, a bellows 5, a bonnet 6, a coupling member 7, a first compression coil spring 8, an actuator 9, and a lock nut 10. In this embodiment, the valve device 100 is constituted by a normally closed (normal close) valve device.

[0013] The valve body 1 has: a valve-body main body 11; a fluid inflow passage 12 and a fluid outflow passage 13 that are formed in the valve-body main body 11; a valve chamber 14 that is formed in the valve-body main body 11 so as to provide communication between an upper end portion serving as one end portion of the fluid inflow passage 12 and an upper end portion serving as one end portion of the fluid outflow passage 13, the valve chamber 14 having

a step portion 14a; an annular (specifically, ring-shaped) valve seat 15 that is provided in the valve chamber 14 so as to be positioned at a peripheral edge of the upper end portion of the fluid inflow passage 12; a circumferential wall 16 that surrounds the valve chamber 14; and a first female thread 17 that is formed on an inner circumferential surface of an upper end portion of the circumferential wall 16 so as to be positioned above the valve chamber 14 and so as to be threaded with the bonnet 6.

[0014] The stem 2 is accommodated in the valve chamber 14. The stem 2 has: a column-shaped (specifically, circular column-shaped) stem body 21 that extends along the vertical direction; a first threaded rod 22 that projects from an upper end of the stem body 21 and that is coupled with the coupling member 7 by being threaded therewith; and an annular (specifically, ring-shaped) first flange 23 that is provided at a lower end portion serving as a tip end portion of the stem body 21.

[0015] The valve element 3 opens and closes the fluid inflow passage 12 serving as a passage by seating and unseating with respect to the valve seat 15. The valve element 3 is provided at a lower end portion serving as a tip end portion of the stem 2.

[0016] In this embodiment, the valve element is constituted by the valve element 3 that is fixed to the lower end portion of the stem 2, but the present invention is not limited to this configuration, and for example, the valve element may be constituted by a diaphragm positioned below the stem 2.

[0017] The support ring 4 is placed on the step portion 14a. The stem body 21 is inserted through the inner circumferential side of the support ring 4. A first O-ring O1 is provided between the support ring 4 and the circumferential wall 16.

[0018] The bellows 5 is provided between the support ring 4 and the first flange 23 such that an upper end portion and a lower end portion thereof are welded to the support ring 4 and the first flange 23, respectively, and such that the bellows 5 surrounds the stem body 21.

[0019] The bonnet 6 is a member for coupling the valve body 1 and the actuator 9. The bonnet 6 has: a substantially tube-shaped (specifically, cylindrical) bonnet body 61; a first male thread 62 that is formed on an outer circumferential surface of a lower end portion of the bonnet body 61 so as to be threaded with the first female thread 17; a ring portion 63 that is provided on the inner circumferential side of an upper end portion of the bonnet body 61; and a second female thread 64 that is formed on an inner circumferential surface of the ring portion 63 so as to be threaded with a second male thread 9114 of the actuator 9, which will be described later. Note that, in a state in which the first female thread 17 and the first male thread 62 are threadedly engaged, the support ring 4 is clamped between the step portion 14a and the bonnet body 61.

[0020] The coupling member 7 is a member for coupling the stem 2 and a piston rod 94 of the actuator 9, which will be described later. The coupling member 7 is accommodated inside the bonnet 6 (specifically, the bonnet body 61). In addition, the coupling member 7 has: a column-shaped (specifically, circular column-shaped) coupling member body 71; a first threaded hole 72 that is formed in an upper end portion of the coupling member body 71 and that is threaded with a second threaded rod 941, which will be described later; a second threaded hole 73 that is formed in a lower end portion of the coupling member body 71 and that is threaded with the first threaded rod 22; and a second flange 74 that is formed on an outer circumferential surface of the lower

end portion of the coupling member body 71.

[0021] The first compression coil spring 8 is held between the second flange 74 and the ring portion 63 so as to surround the coupling member body 71. With such a configuration, the first compression coil spring 8 biases the coupling member 7 downward.

[0022] The actuator 9 is a driving unit that performs seating and unseating of the valve element 3 with respect to the valve seat 15 by moving the stem 2 along the vertical direction (in other words, along the extending direction of the stem 2). Note that details of the actuator 9 will be described later.

[0023] The lock nut 10 is for locking the bonnet 6. A third female thread 101 that is threaded with the second male thread 9114 is formed on an inner circumferential surface of the lock nut 10.

[0024] [Configuration of Actuator]

Next, the actuator 9, which is a feature of this embodiment, will be described in detail with reference to FIG. 1.

[0025] As shown in FIG. 1, the actuator 9 is constituted by a multi-stage cylinder actuator. In addition, the actuator 9 has a cylinder 91, a partition plate 92 serving as a partition portion, a lower-stage piston 93 serving as a first piston, a piston rod 94, an upper-stage piston 95 serving as the second piston, a first pressure chamber 96, a second pressure chamber 97, a second compression coil spring 98 serving as a biasing portion, a first tube L1 constituting a first sub fluid passage, and a second tube L2 constituting a second sub fluid passage. Note that the lower-stage piston 93, the piston rod 94, and the upper-stage piston 95 constitute a piston portion.

[0026] In this embodiment, the cylinder 91 is formed to have a hexagonal outer circumference in a plan view, but the present invention is not limited to

this configuration, and the cylinder 91 may also be formed to have a quadrangular shape or an octagonal shape.

[0027] The cylinder 91 is constituted by only having a lower-stage cylinder 911 serving as a first-stage cylinder and an upper-stage cylinder 912 serving as a second-stage cylinder, but the present invention is not limited to this configuration, and the cylinder 91 may be constituted by, for example, having another-stage cylinder, in addition to the lower-stage cylinder 911 and the upper-stage cylinder 912. In this case, another piston is slidably accommodated in the another-stage cylinder.

[0028] The lower-stage cylinder 911 has: a tube-shaped lower-stage cylinder body 9111 that has an inner circumference and an outer circumference formed in a circular shape and a hexagonal shape, respectively; an annular (specifically, ring-shaped) bottom wall 9112 that is provided on the inner circumferential side of a lower end portion of the lower-stage cylinder body 9111; a tube-shaped (specifically, cylindrical) projecting portion 9113 that projects downward from an inner circumferential edge of the annular bottom wall 9112; the second male thread 9114 that is formed on an outer circumferential surface of the projecting portion 9113 so as to be threaded with both the second female thread 64 and the third female thread 101; a first communication hole 9115 that is formed in the lower-stage cylinder body 9111 near an upper end of the lower-stage cylinder body 9111; and a first supply and discharge port 9116 that is formed in the lower-stage cylinder body 9111 (i.e., in a circumferential wall of the lower-stage cylinder 911) near a lower end of the lower-stage cylinder body 9111.

[0029] The lower-stage piston 93 is accommodated inside the lower-stage cylinder body 9111 so as to be slidable with respect to the inner circumferential

surface of the lower-stage cylinder body 9111. A second O-ring O2 is provided between the lower-stage piston 93 and the lower-stage cylinder body 9111.

[0030] The piston rod 94 is inserted through the inner circumferential side of the annular bottom wall 9112. A third O-ring O3 is provided between the annular bottom wall 9112 and the piston rod 94.

[0031] The piston rod 94 is inserted through the inner circumferential side of the tube-shaped projecting portion 9113.

[0032] In a state in which the second male thread 9114 is threaded with the second female thread 64 and the third female thread 101, the actuator 9 is supported by the bonnet 6.

[0033] The first communication hole 9115 is a hole for providing communication between the outside and a space between the lower-stage piston 93 and the partition plate 92. With such a configuration, it is possible to discharge air in the space between the lower-stage piston 93 and the partition plate 92 to the outside.

[0034] The first supply and discharge port 9116 is a port that communicates with the first pressure chamber 96. One end of the first tube L1 is connected to the first supply and discharge port 9116 through a joint (specifically, a one-touch joint). With such a configuration, it is possible to perform supply and discharge of air to and from the first pressure chamber 96 through the first supply and discharge port 9116. Note that the first supply and discharge port 9116 has one end opening on a flat face (specifically, any one of six flat faces) of the outer circumference of the lower-stage cylinder body 9111. In this embodiment, the first supply and discharge port 9116 is constituted by a threaded hole that is threaded with the joint. Note that the one end of the first tube L1 is inserted into the joint.

[0035] In addition, in this embodiment, the first supply and discharge port is formed in the lower-stage cylinder body 9111 (in other words, in the circumferential wall of the cylinder 91), but the present invention is not limited to this configuration, and for example, the first supply and discharge port may be formed in the bottom wall 9112 of the lower-stage cylinder 911 (in other words, in the bottom wall of the cylinder 91).

[0036] The upper-stage cylinder 912 has: a tube-shaped upper-stage cylinder body 9121 that has an inner circumference and an outer circumference formed in a circular shape and a hexagonal shape, respectively; an annular (specifically, ring-shaped) top wall 9122 that is provided on the inner circumferential side of an upper end portion of the upper-stage cylinder body 9121; an annular (specifically, ring-shaped) first accommodating groove 9123 that is formed in a lower surface of the top wall 9122; a second communication hole 9124 that is formed in the upper-stage cylinder body 9121 near an upper end of the upper-stage cylinder body 9121; and a second supply and discharge port 9125 that is formed in the upper-stage cylinder body 9121 (specifically, in a circumferential wall of the upper-stage cylinder 912) near a lower end of the upper-stage cylinder body 9121.

[0037] The upper-stage piston 95 is accommodated inside the upper-stage cylinder body 9121 so as to be slidable with respect to the inner circumferential surface of the upper-stage cylinder body 9121. A fourth O-ring O4 is provided between the upper-stage piston 95 and the upper-stage cylinder body 9121.

[0038] A projecting column 953 of the upper-stage piston 95, which will be described later, is inserted into the inner circumferential side of the annular top wall 9122. A fifth O-ring O5 is provided between the top wall 9122 and the projecting column 953.

[0039] The second communication hole 9124 is a hole for providing communication between the outside and a space between the upper-stage piston 95 and the top wall 9122 (in other words, a space in which the second compression coil spring 98 is accommodated). With such a configuration, it is possible to discharge air in the space between the upper-stage piston 95 and the top wall 9122 to the outside.

[0040] The second supply and discharge port 9125 is a port that communicates with the second pressure chamber 97. One end of the second tube L2 is connected to the second supply and discharge port 9125 through a joint (specifically, a one-touch joint). With such a configuration, it is possible to perform supply and discharge of air to and from the second pressure chamber 97 through the second supply and discharge port 9125. Note that the second supply and discharge port 9125 has one end opening on a flat surface (specifically, any one of six flat surfaces) of the outer circumference of the upper-stage cylinder body 9121. In this embodiment, the second supply and discharge port 9125 is constituted by a threaded hole that is threaded with the joint. Note that one end of the second tube L2 is inserted into the joint.

[0041] One end of the first supply and discharge port 9116 and one end of the second supply and discharge port 9125 open flush on the same flat face. With such a configuration, it is possible to consolidate installation locations of the first tube L1 and the second tube L2 into a single location, and therefore it is possible to achieve space saving of the valve device 100. Note that one end of the first supply and discharge port 9116 and one end of the second supply and discharge port 9125 may respectively open on different flat surfaces.

[0042] The partition plate 92 is fixed in the cylinder 91 so as to be positioned between the lower-stage piston 93 and the upper-stage piston 95. Specifically, the partition plate 92 has: an annular (specifically, ring-shaped) thick plate 921; and a thin plate 922 serving as an annular outer edge provided on the outer circumferential side of the thick plate 921.

[0043] In a state in which the thin plate 922 of the partition plate 92 is clamped between the lower-stage cylinder 911 (specifically, an upper end of the lower-stage cylinder body 9111) and the upper-stage cylinder 912 (specifically, a lower end of the upper-stage cylinder body 9121), a sixth O-ring O6 is provided between the annular thick plate 921 and the upper-stage cylinder body 9121. In addition, in a state in which the thin plate 922 is clamped between the lower-stage cylinder body 9111 and the upper-stage cylinder body 9121, the lower-stage cylinder 911, the partition plate 92, and the upper-stage cylinder 912 are fixed by, for example, screw fastening.

[0044] The lower-stage piston 93 has: a substantially disk-shaped (specifically, substantially circular disk-shaped) lower-stage piston body 931 that is provided so as to be slidable with respect to the inner circumferential surface of the lower-stage cylinder body 9111; a restricting portion 932 that projects upward from the center of the lower-stage piston body 931; and a column-shaped (specifically, substantially circular column-shaped) insertion projection 933 that projects upward from the center of the restricting portion 932.

[0045] When the lower-stage piston 93 slides upward with respect to the lower-stage cylinder 911, the restricting portion 932 can restrict the upward sliding of the lower-stage piston 93 with respect to the lower-stage cylinder 911 by abutting against the thick plate 921 of the partition plate 92.

[0046] The insertion projection 933 is inserted through the partition plate 92 (specifically, the inner circumferential side of the annular thick plate 921), and a tip end thereof is inserted into an accommodating concave portion 955 of the upper-stage piston 95, which will be described later. With such a configuration, the lower-stage piston 93 and the upper-stage piston 95 can slide up and down integrally. Note that a seventh O-ring O7 is provided between the insertion projection 933 and the annular thick plate 921.

[0047] The piston rod 94 is provided so as to project to the lower side serving as the first side from the lower-stage piston 93 (specifically, from the lower-stage piston body 931). The piston rod 94 includes a second threaded rod 941 that is provided so as to project to the lower side from a lower end serving as a tip end thereof. Then, by threading the second threaded rod 941 and the first threaded hole 72, the coupling member 7 and the lower-stage piston 93 are coupled via the piston rod 94.

[0048] The upper-stage piston 95 has: a substantially disk-shaped (specifically, substantially circular disk-shaped) upper-stage piston body 951 that is provided so as to be slidable with respect to the inner circumferential surface of the upper-stage cylinder body 9121; a spring holding portion 952 that projects upward from the center of the upper-stage piston body 951; the projecting column 953 that projects upward from the center of the spring holding portion 952 so as to be inserted into the inner circumferential side of the annular top wall 9122; an annular (specifically, ring-shaped) second accommodating groove 954 that is formed in an upper surface of the upper-stage cylinder body 9121 so as to surround the spring holding portion 952; and the accommodating concave portion 955 that is formed at the center of a

lower surface of the upper-stage cylinder body 9121 such that the tip end of the insertion projection 933 is press-fitted.

[0049] The second compression coil spring 98 has, in a state in which it is held by the spring holding portion 952, an upper end portion and a lower end portion accommodated in the first accommodating groove 9123 and the second accommodating groove 954, respectively.

[0050] The first pressure chamber 96 is formed by the lower-stage piston 93, the piston rod 94, the bottom wall of the cylinder 91 (specifically, the bottom wall 9112 of the lower-stage cylinder 911), and the circumferential wall of the cylinder 91 (specifically, the lower-stage cylinder body 9111). Here, the first pressure chamber 96 is in communication with the first tube L1 through the first supply and discharge port 9116.

[0051] As the lower-stage piston 93 slides downward with respect to the lower-stage cylinder body 9111, the volume of the first pressure chamber 96 becomes minimum. Then, in this state, the sliding surface of the lower-stage piston body 931 and the second O-ring O2 are positioned above the first supply and discharge port 9116 (specifically, an opening of the first supply and discharge port 9116 positioned at an inner circumference of the lower-stage cylinder body 9111). With such a configuration, it is possible to avoid communication between the first pressure chamber 96 and the first supply and discharge port 9116 being blocked by the sliding surface of the lower-stage piston body 931 or the second O-ring O2.

[0052] The second pressure chamber 97 is formed by the upper-stage piston 95, the partition plate 92, and the circumferential wall of the cylinder 91 (specifically, the upper-stage cylinder body 9121). The second pressure chamber 97 is in communication with the second tube L2 through the second

supply and discharge port 9125.

[0053] As the upper-stage piston 95 slides downward with respect to the upper-stage cylinder body 9121, the volume of the second pressure chamber 97 becomes minimum. Then, in this state, the sliding surface of the upper-stage piston body 951 and the fourth O-ring O4 are positioned above the second supply and discharge port 9125 (specifically, an opening of the second supply and discharge port 9125 positioned at an inner circumference of the upper-stage cylinder body 9121). With such a configuration, it is possible to avoid communication between the second pressure chamber 97 and the second supply and discharge port 9125 being blocked by the sliding surface of the upper-stage piston body 951 or the fourth O-ring O4.

[0054] The second compression coil spring 98 biases the lower-stage piston 93 and the upper-stage piston 95 downward such that the volume of the first pressure chamber 96 and the volume of the second pressure chamber 97 become small.

[0055] In this embodiment, the actuator 9 is constituted by having the second compression coil spring 98, but the present invention is not limited to this configuration, and for example, the actuator 9 may be constituted without having the second compression coil spring 98. In such a case, the first compression coil spring 8 can bias the coupling member 7 and the piston portion (specifically, the lower-stage piston 93, the piston rod 94, and the upper-stage piston 95) coupled by the coupling member 7 downward.

[0056] The first tube L1 provides communication between the first pressure chamber 96 and a first solenoid valve B1 serving as a first valve. Specifically, the first tube L1 is provided such that one end and the other end are connected to the first supply and discharge port 9116 and the first solenoid valve B1,

respectively.

[0057] The second tube L2 provides communication between the second pressure chamber 97 and a second solenoid valve B2 serving as a second valve. Specifically, the second tube L2 is provided such that one end and the other end are connected to the second supply and discharge port 9125 and the second solenoid valve B2, respectively.

[0058] The first tube L1 and the second tube L2 are provided in parallel (in other words, separately). In addition, from a viewpoint of making the timing of supplying the air from the first solenoid valve B1 and the second solenoid valve B2 to the first pressure chamber 96 and the second pressure chamber 97, respectively, the same, it is preferable that a length of the first tube L1 and a length of the second tube L2 be the same. Note that inner diameters of the first tube L1 and the second tube L2 are the same. Therefore, the fluid volume from the first solenoid valve B1 to the first pressure chamber 96 and the passage volume from the second solenoid valve B2 to the second pressure chamber 97 are the same.

[0059] Both the first solenoid valve B1 and the second solenoid valve B2 are connected to an air compressor A serving as a fluid supply source through a branching tube C. The branching tube C is constituted by: a first branch passage C1 having one end connected to the first solenoid valve B1; a second branch passage C2 having one end connected to the second solenoid valve B2; and a common passage C3 having one end connected to both the other end of the first branch passage C1 and the other end of the second branch passage C2 and having the other end connected to the air compressor A.

[0060] In this embodiment, the first tube L1 (including the joint), the first solenoid valve B1, and the first branch passage C1 and the common passage

C3 of the branching tube C constitute a first fluid passage, and the second tube L2 (including the joint), the second solenoid valve B2, and the second branch passage C2 and the common passage C3 of the branching tube C constitute a second fluid passage.

[0061] The first solenoid valve B1 and the second solenoid valve B2 are configured to have the same specification (in other words, the same shape and the same dimensions). In addition, the first branch passage C1 and the second branch passage C2 are configured to have the same length and the same diameter. With such a configuration, the length of the first fluid passage from the air compressor A to the first pressure chamber 96 and the length of the second fluid passage from the air compressor A to the second pressure chamber 97 are the same. In addition, the volume of the first fluid passage from the air compressor A to the first pressure chamber 96 and the volume of the second fluid passage from the air compressor A to the second pressure chamber 97 are also the same.

[0062] In addition, in this embodiment, both the first solenoid valve B1 and the second solenoid valve B2 are connected to the air compressor A through the branching tube C, but the present invention is not limited to this configuration, and for example, the first solenoid valve B1 and the second solenoid valve B2 may be connected to the air compressor A through two tubes provided in parallel.

[0063] As described above, because the length of the first fluid passage constituted by the first tube L1 (including the joint), the first solenoid valve B1, and the first branch passage C1 and the common passage C3 of the branching tube C, and the length of the second fluid passage constituted by the second tube L2 (including the joint), the second solenoid valve B2, and the second

branch passage C2 and the common passage C3 of the branching tube C are the same, it is possible to suppress (eliminate) a time difference for the timing of air supply from the air compressor A to the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97). As a result, it is possible to improve responsiveness of the valve device 100 when opening the fluid inflow passage 12 of the valve body 1 (in other words, at valve opening of the valve device 100) or when closing the fluid inflow passage 12 (in other words, at valve closing of the valve device 100).

[0064] Specifically, as shown in FIG. 2A, in the valve device 100 according to this embodiment, the valve opening time (in other words, the response time) is significantly shortened at each operating air pressure compared to the valve device according to the conventional art. On the other hand, as shown in FIG. 2B, in the valve device 100 according to this embodiment, the valve closing time (in other words, the response time) is significantly shortened at each operating air pressure compared to the valve device according to the conventional art. Note that, at the time of full opening and the time of full closing of the valve device 100, the volume of the first pressure chamber 96 and the volume of the second pressure chamber 97 are the same.

[0065] Because the first sub fluid passage that provides the communication between the first pressure chamber 96 and the first solenoid valve B1 and the second sub fluid passage that provides the communication between the second pressure chamber 97 and the second solenoid valve B2 are constituted by the first tube L1 and the second tube L2 provided in parallel, respectively, compared to a case in which the air is supplied to the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97) through a single fluid passage, it is possible to improve the speed of the air

supply to each of the pressure chambers, and therefore, it is possible to improve the responsiveness of the valve device 100 when opening the fluid inflow passage 12 of the valve body 1 (in other words, at valve opening of the valve device 100).

[0066] On the other hand, compared to a case in which the air is discharged from the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97) through a single fluid passage, the flows of the air discharged from the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97) do not interfere with each other in the first tube L1 or the second tube L2, and it is also possible to improve responsiveness of the valve device 100 when closing the fluid inflow passage 12 of the valve body 1 (in other words, at valve closing of the valve device 100).

[0067] In addition, as described above, because one ends of the first tube L1 and the second tube L2 are connected to the first supply and discharge port 9116 formed in the lower-stage cylinder body 9111 (in other words, the circumferential wall of the cylinder 91) and the second supply and discharge port 9125 formed in the upper-stage cylinder body 9121 (in other words, the circumferential wall of the cylinder 91), respectively, through the joints, it is not necessary to separately form a fluid passage that communicates with the first pressure chamber 96 or the second pressure chamber 97 in the lower-stage piston 93 or in the upper-stage piston 95, and it is possible to achieve simplification of the structures of the lower-stage piston 93 and the upper-stage piston 95.

[0068] [Operation of Valve Device]

Next, an operation of the valve device 100 will be described with reference

to FIGs. 3 to 4.

[0069] FIG. 3 is an explanatory sectional view showing the operation of the valve device 100 when the air is supplied to the first pressure chamber 96 and the second pressure chamber 97. FIG. 4 is an explanatory sectional view showing the operation of the valve device 100 when the air is discharged from the first pressure chamber 96 and the second pressure chamber 97.

[0070] As indicated by arrows R1 in FIG. 3, when the air from the air compressor A is supplied to the first pressure chamber 96 through the first solenoid valve B1, the first tube L1, and the first supply and discharge port 9116 in a sequential manner, and the air from the air compressor A is supplied to the second pressure chamber 97 through the second solenoid valve B2, the second tube L2, and the second supply and discharge port 9125 in a sequential manner, the piston portion (specifically, the lower-stage piston 93, the piston rod 94, and the upper-stage piston 95) moves upward (in the direction indicated by an arrow R2 in FIG. 3) integrally with the coupling member 7, the stem 2, and the valve element 3 against the biasing forces of the first compression coil spring 8 and the second compression coil spring 98 such that the volume of the first pressure chamber 96 and the volume of the second pressure chamber 97 become large. Then, the valve element 3 is unseated from the valve seat 15 to open the fluid inflow passage 12 of the valve body 1. With such a configuration, the fluid such as a process gas from the fluid inflow passage 12 is supplied to the fluid outflow passage 13 through the valve chamber 14.

[0071] On the other hand, when the air from the air compressor A is not supplied to the first pressure chamber 96 and the second pressure chamber 97, the piston portion (specifically, the lower-stage piston 93, the piston rod

94, and the upper-stage piston 95) moves downward (in a direction indicated by an arrow R3 in FIG. 4) integrally with the coupling member 7, the stem 2, and the valve element 3 under the biasing forces imparted by the first compression coil spring 8 and the second compression coil spring 98 such that the volume of the first pressure chamber 96 and the volume of the second pressure chamber 97 become small. At this time, as indicated by arrows R4 in FIG. 4, the air in the first pressure chamber 96 and the air in the second pressure chamber 97 are discharged to the first solenoid valve B1 through the first supply and discharge port 9116 and the first tube L1, and discharged to the second solenoid valve B2 through the second supply and discharge port 9125 and the second tube L2, in a respective manner. Then, the valve element 3 is seated on the valve seat 15 to close the fluid inflow passage 12 of the valve body 1. With such a configuration, the fluid such as a process gas from the fluid inflow passage 12 is not supplied to the fluid outflow passage 13 through the valve chamber 14.

[0072] [Operational Advantages]

Next, operational advantages according to this embodiment will be described.

[0073] The actuator 9 according to this embodiment is the actuator 9 used for the valve device 100, and includes: the cylinder 91; the lower-stage piston 93 (the first piston) accommodated in the cylinder 91 so as to be slidable with respect to the inner circumferential surface of the cylinder 91; the piston rod 94 provided so as to project from the lower-stage piston 93 (the first piston) to the first side; the upper-stage piston 95 (the second piston) provided on the second side of the lower-stage piston 93 (the first piston), the upper-stage piston 95 (the second piston) being accommodated in the cylinder 91 so as to

be slidable with respect to the inner circumferential surface of the cylinder 91; the partition plate 92 (the partition portion) fixed in the cylinder 91 so as to be positioned between the lower-stage piston 93 (the first piston) and the upper-stage piston 95 (the second piston); the first pressure chamber 96 formed by the lower-stage piston 93 (the first piston), the piston rod 94, the bottom wall 9112 of the lower-stage cylinder 911 (the bottom wall of the cylinder 91), and the lower-stage cylinder body 9111 (the circumferential wall of the cylinder 91); the second pressure chamber 97 formed by the upper-stage piston 95 (the second piston), the partition plate 92 (the partition portion), and the upper-stage cylinder body 9121 (the circumferential wall of the cylinder 91); the first fluid passage configured to provide communication between the first pressure chamber 96 and the air compressor A (the fluid supply source); and the second fluid passage configured to provide communication between the second pressure chamber 97 and the air compressor A (the fluid supply source), wherein the length from the air compressor A (the fluid supply source) to the second pressure chamber 97 is the same as the length of the first fluid passage from the air compressor A (the fluid supply source) to the first pressure chamber 96.

[0074] The valve device 100 according to this embodiment includes: the valve body 1 in which the fluid inflow passage 12 (the passage) is formed and which has the valve seat 15; the valve element 3 that opens/closes the fluid inflow passage 12 (the passage) by seating and unseating with respect to the valve seat 15; the stem 2 having the valve element 3 provided at the tip end portion; and the actuator 9 described above that performs seating and unseating of the valve element 3 with respect to the valve seat 15 by moving the stem 2 along the extending direction of the stem 2.

[0075] According to these configurations, because it is possible to suppress (eliminate) the time difference for the timing of the air supply from the air compressor A to the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97), it is possible to improve the responsiveness of the valve device 100 when opening the fluid inflow passage 12 of the valve body 1 (in other words, at valve opening of the valve device 100) or when closing the fluid inflow passage 12 (in other words, at valve closing of the valve device 100).

[0076] In addition, in this embodiment, the first solenoid valve B1 (the first valve) is provided between the first pressure chamber 96 and the air compressor A (the fluid supply source), the first fluid passage has the first tube L1 (the first sub fluid passage) configured to provide communication between the first pressure chamber 96 and the first solenoid valve B1 (the first valve), the second solenoid valve B2 (the second valve) is provided between the second pressure chamber 97 and the air compressor A (the fluid supply source), and the second fluid passage has the second tube L2 (the second sub fluid passage) configured to provide communication between the second pressure chamber 97 and the second solenoid valve B2 (the second valve), the second fluid passage being provided separately from the first tube L1 (the first sub fluid passage).

[0077] According to this configuration, because, compared to a case in which the air is supplied to the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97) through a single fluid passage, it is possible to improve the speed of the air supply to each of the pressure chambers, it is possible to improve the responsiveness of the valve device 100 when opening the fluid inflow passage 12 of the valve body 1 (in

other words, at valve opening of the valve device 100).

[0078] On the other hand, compared to a case in which the air is discharged from the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97) through a single fluid passage, the flows of the air discharged from the two pressure chambers (specifically, the first pressure chamber 96 and the second pressure chamber 97) do not interfere with each other in the first tube L1 or the second tube L2, and it is also possible to improve the responsiveness of the valve device 100 when closing the fluid inflow passage 12 of the valve body 1 (in other words, at valve closing of the valve device 100).

[0079] In addition, in this embodiment, the lower-stage cylinder body 9111 (the circumferential wall of the cylinder 91) is formed with the first supply and discharge port 9116 in communication with the first pressure chamber 96, the upper-stage cylinder body 9121 (the circumferential wall of the cylinder 91) is formed with the second supply and discharge port 9125 in communication with the second pressure chamber 97, the first tube L1 (the first sub fluid passage) is connected to the first supply and discharge port 9116, and the second tube L2 (the second sub fluid passage) is connected to the second supply and discharge port 9125.

[0080] In addition, in this embodiment, the cylinder 91 has: the lower-stage cylinder 911 (the first-stage cylinder) in which the lower-stage piston 93 (the first piston) is accommodated; and the upper-stage cylinder 912 (the second-stage cylinder) in which the upper-stage piston 95 (the second piston) is accommodated, the upper-stage cylinder 912 (the second-stage cylinder) being provided separately from the lower-stage cylinder 911 (the first-stage cylinder), the partition plate 92 (the partition portion) has the thin plate 922 (the outer

edge) clamped between the lower-stage cylinder 911 (the first-stage cylinder) and the upper-stage cylinder 912 (the second-stage cylinder), the first supply and discharge port 9116 is formed in the lower-stage cylinder body 9111 (the circumferential wall of the lower-stage cylinder 911 (the first-stage cylinder)), and the second supply and discharge port 9125 is formed in the upper-stage cylinder body 9121 (the circumferential wall of the upper-stage cylinder 912 (the second-stage cylinder)).

[0081] According to these configurations, it is not necessary to separately form a fluid passage that communicates with the first pressure chamber 96 or the second pressure chamber 97 in the lower-stage piston 93 or the upper-stage piston 95, and it is possible to achieve simplification of the structures of the lower-stage piston 93 and the upper-stage piston 95.

[0082] [Modification]

Next, the actuator 9 according to each modification will be described with reference to FIGs. 5 to 7. Note that descriptions of points that are the same as those of the above-described embodiment are omitted, and mainly points that are different from those of the above-described embodiment will be described.

[0083] FIG. 5 is a sectional view showing the actuator 9 according to the first modification. FIG. 6 is a sectional view showing the actuator 9 according to the second modification. FIG. 7 is a sectional view showing the actuator 9 according to the third modification.

[0084] In the above-described embodiment, the first fluid passage and the second fluid passage are constituted by the first tube L1 that is connected to the first supply and discharge port 9116 and the second tube L2 that is connected to the second supply and discharge port 9125, respectively, but the

present invention is not limited to this configuration, and for example, as shown in FIG. 5, the first fluid passage may also be constituted by the first tube L1 that is connected to the first supply and discharge port 9116, and the second fluid passage may also be constituted by the second tube L2 that is connected to an inner circumferential edge of the annular top wall 9122 and an upper-stage piston passage 956 that is formed in the upper-stage piston 95.

[0085] In such a case, as shown in FIG. 5, the upper-stage piston passage 956 provides communication between the second tube L2 and the second pressure chamber 97. In addition, the second supply and discharge port is not formed in the upper-stage cylinder body 9121.

[0086] In addition, in the above-described embodiment, the first fluid passage and the second fluid passage are constituted by the first tube L1 that is connected to the first supply and discharge port 9116 and the second tube L2 that is connected to the second supply and discharge port 9125, respectively, but the present invention is not limited to this configuration, and for example, as shown in FIG. 6, the first fluid passage may also be constituted by the first tube L1 that is connected to an inner circumferential edge of the annular top wall 9122 and a piston passage L3 that is formed in both of the upper-stage piston 95 and the lower-stage piston 93, and the second fluid passage may also be constituted by the second tube L2 that is connected to the second supply and discharge port 9125.

[0087] In such a case, as shown in FIG. 6, the piston passage L3 provides communication between the first tube L1 and the first pressure chamber 96. In addition, the first supply and discharge port is not formed in the lower-stage cylinder body 9111.

[0088] In addition, in the above-described embodiment, the first fluid passage and the second fluid passage are constituted by the first tube L1 that is connected to the first supply and discharge port 9116 and the second tube L2 that is connected to the second supply and discharge port 9125, respectively, but the present invention is not limited to this configuration, and for example, as shown in FIG. 7, the first fluid passage may also be constituted by the first tube L1 that is connected to a first communication hole 9122a in the top wall 9122 and a first piston passage L4 that is formed in the upper-stage piston 95 and the lower-stage piston 93, and the second fluid passage may also be constituted by the second tube L2 that is connected to a second communication hole 9122b in the top wall 9122 and a second piston passage L5 that is formed in the upper-stage piston 95 and the lower-stage piston 93.

[0089] In such a case, as shown in FIG. 7, the first piston passage L4 provides communication between the first tube L1 and the first pressure chamber 96, and the second piston passage L5 provides communication between the second tube L2 and the second pressure chamber 97. The first piston passage L4 is longer than the second piston passage L5. It is preferable to make the length of the first tube L1 shorter than that of the second tube L2 by the difference in length between the first piston passage L4 and the second piston passage L5. In addition, the first supply and discharge port and the second supply and discharge port are not formed in the lower-stage cylinder body 9111 and the upper-stage cylinder body 9121.

[0090] According to the actuator 9 according to the third modification, because the first tube L1 and the second tube L2 are respectively connected to the first communication hole 9122a and the second communication hole 9122b that penetrate through the top wall 9122 of the cylinder 91, it is possible

to arrange the first tube L1 and the second tube L2 above the cylinder 91. As a result, compared to a structure in which the tubes are connected to the circumferential wall of the cylinder 91, it is possible to achieve size reduction in the radial direction of the actuator 9 (or the valve device 100).

[0091] As described above, the present embodiments have been described; however, the above-described embodiments merely show a part of application examples of the present invention, and the technical scope of the present invention is not intended to be limited to the specific configurations of the above-described embodiments.

[0092] This application claims priority based on Japanese Patent Application No. 2023-203068 filed before the Japan Patent Office on November 30, 2023, and the entire contents of this application are incorporated herein by reference.

SCOPE OF CLAIMS

Claim 1. An actuator used for a valve device, comprising:

a cylinder;

a first piston accommodated in the cylinder so as to be slidable with respect to an inner circumferential surface of the cylinder;

a piston rod provided so as to project from the first piston to a first side;

a second piston provided on a second side of the first piston, the second piston being accommodated in the cylinder so as to be slidable with respect to the inner circumferential surface of the cylinder;

a partition portion fixed in the cylinder so as to be positioned between the first piston and the second piston;

a first pressure chamber formed by the first piston, the piston rod, a bottom wall of the cylinder, and a circumferential wall of the cylinder;

a second pressure chamber formed by the second piston, the partition portion, and the circumferential wall of the cylinder;

a first fluid passage configured to provide communication between the first pressure chamber and a fluid supply source; and

a second fluid passage configured to provide communication between the second pressure chamber and the fluid supply source, wherein a length from the fluid supply source to the second pressure chamber is same as a length of the first fluid passage from the fluid supply source to the first pressure chamber.

Claim 2. The actuator according to claim 1, wherein

a first valve is provided between the first pressure chamber and the fluid

supply source,

the first fluid passage has a first sub fluid passage configured to provide communication between the first pressure chamber and the first valve,

a second valve is provided between the second pressure chamber and the fluid supply source, and

the second fluid passage has a second sub fluid passage configured to provide communication between the second pressure chamber and the second valve, the second sub fluid passage being provided separately from the first sub fluid passage.

Claim 3. The actuator according to claim 2, wherein

the circumferential wall of the cylinder is formed with a first supply and discharge port in communication with the first pressure chamber,

the circumferential wall of the cylinder is formed with a second supply and discharge port in communication with the second pressure chamber,

the first sub fluid passage is connected to the first supply and discharge port, and

the second sub fluid passage is connected to the second supply and discharge port.

Claim 4. The actuator according to claim 3, wherein

the cylinder has:

a first-stage cylinder in which the first piston is accommodated; and

a second-stage cylinder in which the second piston is accommodated, the second-stage cylinder being provided separately from the first-stage cylinder,

the partition portion has an outer edge clamped between the first-stage

cylinder and the second-stage cylinder,

the first supply and discharge port is formed in the circumferential wall of the first-stage cylinder, and

the second supply and discharge port is formed in a circumferential wall of the second-stage cylinder.

Claim 5. The actuator according to claim 2, wherein the circumferential wall of the cylinder is formed with: a first supply and discharge port in communication with the first pressure chamber, the first supply and discharge port being connected to the first sub fluid passage; or a second supply and discharge port in communication with the second pressure chamber, the second supply and discharge port being connected to the second sub fluid passage.

Claim 6. A valve device comprising:

a valve body in which a passage is formed, the valve body having a valve seat;

a valve element configured to open and close the passage by seating and unseating with respect to the valve seat;

a stem having the valve element at a tip end portion; and

the actuator according to any one of claims 1 to 5, the actuator being configured to perform seating and unseating of the valve element with respect to the valve seat by moving the stem along an extending direction of the stem.