CLEANING APPARATUS AND GAS NOZZLE DEVICE, GAS PATH DEVICE, CONTROL METHOD, INTERFACE CIRCUIT AND CONTROL SYSTEM THEREOF

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to the technical field of semiconductor manufacturing equipment, and in particular, to a cleaning apparatus for cleaning a wafer, and a gas nozzle device, a gas path device, a control method, an interface circuit and a control system thereof.

BACKGROUND

[0002] A load port (LP) is an interface device disposed at a front end of wafer processing equipment and provided with a load plate. In a wafer transfer process, a front open unified pod (FOUP) is placed on the load plate of the LP. After a pod door is opened, a wafer may be loaded from the FOUP into the wafer processing equipment, or the wafer may be placed back into the FOUP after being processed in the wafer processing equipment. Therefore, a cleaning apparatus configured on the LP is required to maintain a clean environment inside the FOUP during the pod door opening stage.

[0003] In a cleaning apparatus configured in an existing machine, a gas nozzle docked with a FOUP uses a rigid component as a gas inlet/outlet of the gas nozzle, and an elastic damping structure and a sealing connection structure are provided for the gas inlet/outlet of the rigid component. Although the elastic damping structure can reduce a collision force when the FOUP contacts the gas nozzle to some extent, and the sealing connection structure can ensure a sealed connection between a gas path and the gas nozzle, a sealed connection between the gas nozzle and the FOUP to some extent and the like, these structures are often overly complex, require complex connections therebetween, and need a complex installation structure for installation on the load plate. Further, the gas nozzle cannot be rapidly deployed and maintained in the cleaning apparatus, and when a sealed docking is performed between the FOUP and the gas nozzle using the rigid gas port component, the docking is difficult and time-consuming. These factors seriously affect the overall efficiency of wafer exchange through the load port.

[0004] In addition, a production workshop of a semiconductor factory is usually configured with a relatively large number of load ports, by which wafer exchange between

wafer processing equipment of the semiconductor factory and an automatic material handling system (AMHS) of the semiconductor factory is completed.

[0005] Therefore, the operational efficiency of the cleaning apparatus is an important factor for improving the overall efficiency of wafer exchange at the load port.

SUMMARY

[0006] In view of this, the present disclosure provides a cleaning apparatus and a gas nozzle device, a gas path device, a control method, an interface circuit and a control system thereof. By simplifying the structure of a gas nozzle body, the gas nozzle can be rapidly deployed and maintained in a load port, and the gas nozzle can provide better sealing performance and facilitate rapid sealed docking with a FOUP, which is beneficial for improving the operational efficiency of the cleaning apparatus, thereby improving the overall efficiency of wafer exchange at the load port.

[0007] The present disclosure provides a gas nozzle device of a cleaning apparatus, including: a gas port assembly, the gas port assembly being an integrally formed assembly enabling elastic deformation, and provided with an abutment portion, a connection portion, a first through hole, and a first recess. The first through hole extends from a middle of a top end surface of the abutment portion to a middle of a bottom end surface of the connection portion. The first recess is located on an outer side wall and between a lower end surface of the abutment portion and an upper end surface of the connection portion, and is an annular recess around an axis of the first through hole. The gas nozzle device further includes an upper assembly provided with a second recess, a second through hole, and a plurality of first connection holes for installation. The second recess is recessed downward from a middle of a top end of the upper assembly, and the second through hole extends from a middle of a bottom surface of the second recess to a bottom end surface of the upper assembly. The gas nozzle device further includes a lower assembly provided with a third recess, a fourth recess, a gas path connection hole for connecting a gas path, and a plurality of second connection holes for installation. The third recess is recessed downward from a middle of a top end of the lower assembly, the fourth recess is recessed downward from a middle of a bottom surface of the third recess, the gas path connection hole extends from a bottom surface of the fourth recess to a bottom end portion of the lower assembly, and the second connection holes are arranged to correspond to the first connection holes. The first connection holes and the second connection holes are configured for fixing the upper assembly and the lower assembly

on a FOUP load plate via a fastener. The abutment portion is configured for sealed docking with a docking port of a FOUP placed on the load plate. A first accommodation space is formed between a bottom surface of the upper assembly and the third recess, and the connection portion is accommodated in the first accommodation space in a compressed and deformed state, such that a bottom surface of the connection portion abuts against a bottom surface of the third recess, and the bottom surface of the upper assembly abuts against an upper end surface of the connection portion. The first recess serves as a second accommodation space to accommodate a partial structure of the upper assembly between the bottom surface of the second recess and the bottom end surface of the upper assembly.

[0008] The following beneficial effects are at least achieved by at least one of the above technical solutions adopted in the embodiments of the present disclosure.

[0009] By adopting the gas port assembly enabling elastic deformation (such as a soft gas port assembly made of silica gel or rubber) as a gas inlet/outlet assembly of the gas nozzle, and by providing the upper assembly and lower assembly having cylindrical structures to jointly form the accommodation spaces for achieving the sealing performance of the gas nozzle and an external mounting structure for mounting on the load plate, the gas nozzle can be firmly fixed on the load plate based on the external mounting structure constituted by the upper assembly and the lower assembly, and a lower connection end of the soft gas port assembly can be very conveniently and reliably press-fitted within an internal accommodation space formed between the upper assembly and the lower assembly having the cylindrical structures, and the abutment portion of the upper assembly cooperates with an upper end protruding portion of the soft gas port assembly to dock with a gas port of the FOUP. Therefore, the overall structure of the gas nozzle is simple, compact, and reliable, which not only facilitates rapid deployment and maintenance of the gas nozzle in the load port, but also enables a rapid sealed docking between the gas nozzle and the gas port of the FOUP with low docking difficulty and short time. Hence, the gas nozzle is very suitable for application in the cleaning apparatus of the load port in a semiconductor factory, thereby improving the operational efficiency of the cleaning apparatus in the load port, and ultimately improving the efficiency of wafer exchange through the load port.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] To illustrate the technical solutions in the embodiments of the present disclosure more clearly, the following briefly introduces the accompanying drawings required

for describing the embodiments. Apparently, the accompanying drawings in the following description show only some embodiments of the present disclosure, and for a person of ordinary skill in the art, other drawings can also be obtained from these accompanying drawings without creative effort.

[0011] FIG. 1 is a schematic structural diagram of a FOUP placed on a load plate according to the present disclosure.

[0012] FIG. 2 is a schematic structural diagram of a gas path according to the present disclosure.

[0013] FIG. 3 is a schematic structural diagram of a gas nozzle according to the present disclosure.

[0014] FIG. 4 is a schematic cross-sectional view of the gas nozzle according to the present disclosure.

[0015] FIG. 5 is a schematic cross-sectional view of a gas port assembly according to the present disclosure.

[0016] FIG. 6 is a schematic cross-sectional view of an upper assembly according to the present disclosure.

[0017] FIG. 7 is a schematic cross-sectional view of a lower assembly according to the present disclosure.

[0018] FIG. 8 is a schematic structural diagram of an interface circuit and system of a cleaning apparatus according to the present disclosure.

[0019] FIG. 9 is a schematic structural diagram of an interface circuit and system of a cleaning apparatus according to the present disclosure.

[0020] FIG. 10 is a schematic structural diagram of a digital input interface according to the present disclosure.

[0021] FIG. 11 is a schematic structural diagram of an analog input interface according to the present disclosure.

[0022] FIG. 12 is a schematic structural diagram of a dual-channel analog input interface according to the present disclosure.

[0023] FIG. 13 is a schematic structural diagram of a digital output interface according to the present disclosure.

[0024] FIG. 14 is a schematic structural diagram of an Input/Output (IO)-Link interface according to the present disclosure.

[0025] FIG. 15 is a schematic structural diagram of a secondary control circuit according to the present disclosure.

[0026] FIG. 16 is a circuit schematic diagram of a microcontroller and a peripheral circuit in a secondary control circuit according to the present disclosure.

[0027] FIG. 17 is a schematic structural diagram of an RS485 communication circuit in a secondary control circuit according to the present disclosure.

[0028] FIG. 18 is a schematic structural diagram of a power supply circuit in a secondary control circuit according to the present disclosure.

[0029] FIG. 19 is a schematic structural diagram of an EEPROM circuit in a secondary control circuit according to the present disclosure.

[0030] FIG. 20 is a schematic structural diagram of a primary control circuit according to the present disclosure.

[0031] FIG. 21 is a flow diagram of a control method for a cleaning apparatus according to the present disclosure.

[0032] FIG. 22 is a schematic diagram of a workflow of a primary control circuit according to the present disclosure.

[0033] FIG. 23 is a schematic diagram of an acquisition process of a primary control circuit according to the present disclosure.

[0034] FIG. 24 is a schematic diagram of a workflow of a primary control circuit according to the present disclosure.

[0035] FIG. 25 is a schematic diagram of an acquisition process of a primary control circuit according to the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0036] The embodiments of the present disclosure are described in detail below with reference to the accompanying drawings.

[0037] The embodiments of the present disclosure are described below through specific examples, and a person skilled in the art can easily understand other advantages and

effects of the present disclosure from the content disclosed in this specification. Apparently, the described embodiments are only a part, but not all, of the embodiments of the present disclosure. The present disclosure can also be implemented or applied through other different specific embodiments, and various details in this specification can also be modified or changed based on different viewpoints and applications without departing from the spirit of the present disclosure. It should be noted that, under the condition of no conflict, the following embodiments and features in the embodiments can be combined with each other. Based on the embodiments in the present disclosure, all other embodiments obtained by a person of ordinary skill in the art without making creative work fall within the scope of protection of the present disclosure.

[0038] It should be noted that various aspects of the embodiments within the scope of the appended claims are described below. It should be apparent that the aspects described herein can be embodied in a wide variety of forms, and any specific structure and/or function described herein is merely illustrative. Based on the present disclosure, a person skilled in the art should appreciate that an aspect described herein can be implemented independently of any other aspects, and two or more of these aspects can be combined in various ways. For example, an apparatus can be implemented and/or a method can be practiced using any number of the aspects set forth herein. In addition, an apparatus can be implemented and/or a method can be practiced using structures and/or functionalities in addition to one or more of the aspects set forth herein.

[0039] It should also be noted that the illustrations provided in the following embodiments only schematically illustrate the basic concept of the present disclosure, and only components related to the present disclosure are shown in the drawings rather than being drawn according to the number, shape, and size of components in actual implementation. The type, quantity, and proportion of each component in actual implementation can be arbitrarily changed, and the layout of components may also be more complex.

[0040] In addition, in the following description, specific details are provided to facilitate a thorough understanding of the examples. However, a person skilled in the art will understand that the described aspects can be practiced without these specific details.

[0041] Referring to the schematic diagrams of FIG. 1 and FIG. 2, the embodiments of the present disclosure provide a cleaning apparatus for cleaning a FOUP placed on a load plate in a load port.

[0042] In an example, the cleaning apparatus includes a gas nozzle device mounted on a load plate 10, such as a gas inlet nozzle 110 and a gas exhaust nozzle 120. The gas nozzle device is configured for sealed docking with a FOUP 20 placed on the load plate 10. The gas inlet nozzle 110 is configured to dock with an inflation port (not shown) at a bottom of the FOUP 20, and the gas exhaust nozzle 120 is configured to dock with an exhaust port (not shown) at the bottom of the FOUP 20. It should be noted that the gas nozzle device in this example can refer to the descriptions of the corresponding examples of the gas nozzle device below. In addition, at least one gas inlet nozzle 110 and at least one gas exhaust nozzle 120 are provided. For example, FIG. 1 illustrates two gas inlet nozzles 110 and two gas exhaust nozzles 120.

[0043] In an example, the cleaning apparatus includes a gas path device. The gas path device includes the gas nozzle device in the preceding example, gas paths correspondingly connected to the gas nozzle device, a sensor disposed on the gas paths, and a primary control circuit and a secondary control circuit. It should be noted that the gas path device in this example can refer to the descriptions of corresponding examples of the gas path device below.

[0044] In some embodiments, the load plate 10 is further provided with three positioning pins 102 correspondingly docked with positioning holes (not shown) on the FOUP 20 so that the FOUP 20 can be accurately placed at a target position on the load plate 10. The load plate 10 is further provided with a first position sensor 101 for detecting whether the FOUP 20 is placed in place.

[0045] Referring to the schematic diagrams of FIG. 3 and FIG. 4, the embodiments of the present disclosure provide a gas nozzle device of a cleaning apparatus, including: a gas port assembly 100 and a mounting structure 130. The mounting structure 130 includes an upper assembly 131 and a lower assembly 132. After clamping the gas port assembly 100, the upper assembly 131 and the lower assembly 132 are fixedly mounted on a load plate 10 via fixing screws 30.

[0046] In some embodiments, the gas port assembly 100 may have an overall cylindrical structure, and is a soft, integral component made of a flexible material (such as silica gel or rubber). As assembly components for installation, the upper assembly 131 and the lower assembly 132 may each be substantially cup-shaped. An edge portion of the upper assembly 131 and an edge portion of the lower assembly 132 are fixed together and fixed on

the load plate 10 by screws. In some embodiments, another type of fastener or fixing method may be adopted to install the upper assembly 131 and the lower assembly 132 on the load plate.

[0047] As illustrated in FIG. 5, the gas port assembly 100 is provided with an abutment portion 111, a connection portion 112, a first through hole 113, and a first recess 114. The first through hole 113 extends from a middle of a top end surface of the abutment portion 111 to a middle of a bottom end surface of the connection portion 112. The first recess 114 is located on an outer side wall and between a lower end surface of the abutment portion 111 and an upper end surface of the connection portion 112, and is an annular recess around an axis of the first through hole 113.

[0048] In some embodiments, a direction along a virtual central axis of the first through hole 113 of the gas port assembly 100 may be defined as a thickness direction. A thickness of the abutment portion 111 is set as H3, and a thickness of the connection portion 112 is set as H1. The specific setting values of H3 and H1 can be set according to actual needs, and are not limited herein.

[0049] In some embodiments, as illustrated in FIG. 6, the upper assembly 131 is provided with a second recess 133, a second through hole 134, and a plurality of first connection holes 1391 (such as screw holes) for installation. The second recess 133 is a recess recessed downward from a middle of a top end of the upper assembly 131, and the second through hole 134 extends from a middle of a bottom surface of the second recess 133 to a bottom end surface of the upper assembly 131.

[0050] In some embodiments, as illustrated in FIG. 7, the lower assembly 132 is provided with a third recess 137, a fourth recess 138, a gas path connection hole 136 (such as a threaded hole) for connecting a gas path, and a plurality of second connection holes 1392 (such as screw holes) for installation. The third recess 137 is a recess recessed downward from a middle of a top end of the lower assembly 132. The fourth recess 138 is a recess recessed downward from a middle of a bottom surface of the third recess 137. The gas path connection hole 136 is a threaded hole from a bottom surface of the fourth recess 138 to a bottom end portion of the lower assembly 132. The second connection holes 1392 are disposed corresponding to the first connection holes 1391.

[0051] Based on the configuration of the above components, the installation and use of the gas nozzle device are schematically described as follows.

[0052] The first connection holes 1391 and the second connection holes 1392 are jointly configured for fixing the mounting structure 130 (i.e., the upper assembly 131 and the lower assembly 132) on the load plate 10 for placing the FOUP 20 via fasteners (such as screws).

[0053] The abutment portion 111 is configured for sealed docking with a docking port (not shown) of the FOUP 20 placed on the load plate 10. In some embodiments, the docking port of the FOUP 20 can press down on the flexible abutment portion 111, thereby achieving a sealed connection through deformation of the abutment portion 111.

[0054] After a bottom surface of the upper assembly 131 abuts against a top surface of the lower assembly 132, a first accommodation space is formed between the bottom surface of the upper assembly 131 and the third recess 137. The first accommodation space is configured such that after the connection portion 112 passes through the second through hole 134, the connection portion 112 is compressed and deformed, so that a bottom surface of the connection portion 112 abuts against the bottom surface of the third recess 137, and the bottom surface of the upper assembly 131 abuts against the upper end surface of the connection portion 112. The first recess 114 serves as a second accommodation space to accommodate a partial structure of the upper assembly 131 between the bottom surface of the second recess 133 and the bottom end surface of the upper assembly 131.

[0055] In other words, the connection portion 112 at a lower part of the gas port assembly 100 is press-fitted between the upper assembly 131 and the lower assembly 132 which have cylindrical structures. The upper assembly 131 and the lower assembly 132 may be fixed on the load plate 10 by screws. Moreover, the gas port assembly 100 is soft, and a sealed connection between the gas port assembly 100, the upper assembly 131, and the lower assembly 132 can be achieved through the deformation of the gas port assembly 100. In some embodiments, the abutment portion 111 of the gas port assembly 100 may be configured to protrude from the upper end surface of the upper assembly 131, and after the abutment portion 111 is very conveniently docked with the FOUP 20, a sealed connection can be achieved through docking deformation. In addition, the gas path connection hole 136 (such as a threaded hole) disposed at a lower end of the lower assembly 132 may be conveniently connected to a ventilation pipe.

[0056] In some embodiments, the connection portion 112 has a height H1 in a natural state (when not installed). When the gas port assembly 100, the upper assembly 131, and the

lower assembly 132 are assembled together, a distance between an end surface of the upper assembly 131 abutting against the gas port assembly 100 and an end surface of the lower assembly 132 abutting against the gas port assembly 100 is denoted as D1. According to the requirement of achieving a sealed connection between the gas port assembly 100, the upper assembly 131 and the lower assembly 132 through deformation of the connection portion 112, the height H1 is greater than or equal to the distance D1, where the specific difference margin can be set according to the deformation amount required for the sealed connection, and is not limited.

[0057] In some embodiments, the lower assembly 132 is further provided with a first opening 135 recessed downward from a middle of a top end of the lower assembly 132 (e.g., a slant opening as illustrated in FIG. 7). The third recess 137 is further recessed downward from a bottom of the first opening 135. The first opening 135 is configured to accommodate a partial structure of the connection portion 112 that is compressed and deformed and/or the bottom surface of the upper assembly 131 abuts against the top surface of the lower assembly 132, which not only provides a more suitable deformation space for the deformation of the connection portion, but also can further improve the sealing connection characteristic among the upper assembly 131, the gas port assembly 100, and the lower assembly 132. It should be noted that the size, depth, etc. of the first opening 135 are not limited herein.

[0058] In some embodiments, the sealing connection performance and airflow flow performance can be further improved by setting the relative assembly relationship between the components.

[0059] As illustrated in FIG. 4, after the assembly between the upper assembly 131 and the lower assembly 132 is completed, an edge of the fourth recess 138 in the lower assembly 132 is aligned with an edge of the second through hole 134 in the upper assembly 131. The third recess 137 can provide a sufficient area to contact the connection portion 112, which is beneficial for improving the sealing performance.

[0060] Alternatively, in some embodiments, the edge of the fourth recess 138 protrudes inward in a radial direction relative to the edge of the second through hole 134 (i.e., a width of the fourth recess 138 is slightly smaller than a width of the second through hole 134). Thus, after the docking port of the FOUP 20 presses against the abutment portion 111 to complete the sealed docking, due to the inward protrusion of the fourth recess 138, the third recess 137 can provide more area to contact the connection portion 112, which is

beneficial for improving the sealing performance. Moreover, after the inward protrusion of the fourth recess 138, a gas flow passage formed by the inward protrusion of the fourth recess 138 is better matched with the first through hole 113, making the airflow smoother.

[0061] In some embodiments, when the abutment portion 111 of the gas port assembly 100 is not docked with the FOUP 20, a gap H4 exists between the lower end surface of the abutment portion 111 of the gas port assembly 100 and the upper end surface of the upper assembly 131. When the abutment portion 111 of the gas port assembly 100 is docked with the FOUP 20 and pressed down, the abutment portion 111 is pressed down until the lower end surface of the abutment portion 111 abuts against the upper end surface of the upper assembly 131. Therefore, the gap H4 can serve as a deformation space, ensuring that when connecting with the FOUP 20, the abutment portion 111 of the gas port assembly 100 steadily deforms and is airtightly docked with the FOUP 20.

[0062] Furthermore, before the abutment portion 111 is in sealed docking with the docking port of the FOUP 20, a first gap exists between the lower end surface of the abutment portion 111 and a top end surface of the upper assembly 131. The first gap serves as a deformation space, so that after the docking port of the FOUP 20 presses against the abutment portion 111 to complete the sealed docking, the abutment portion 111 and the upper assembly 131 can be configured such that the lower end surface of the abutment portion 111 is pressed down to abut against the top end surface of the upper assembly 131.

[0063] In some embodiments, by setting relative dimensions of the upper assembly 131, the gas port assembly 100, and the lower assembly 132, the deformation performance of the flexible gas port assembly 100 can be further improved, facilitating the gas nozzle to provide better sealing performance.

[0064] As illustrated in FIG. 4 to FIG. 6, a width D2 of the second recess 133, a width D3 of the abutment portion 111, and the first gap H4 are set to satisfy the following relationship: $(D2 - D3) > 2 \times H4$. Alternatively, the relationship can also be set to satisfy: $(D2 - D3) > H4$. Therefore, during the sealed docking in which the docking port of the FOUP 20 presses against the abutment portion 111, the second recess 133 can provide a deformation space for the abutment portion 111 along an axial direction and a radial direction of the first through hole 113.

[0065] In some examples, as illustrated in FIG. 6, the second recess 133 on the upper assembly 131 has a depth H2 and a width D2. When a lower part of the abutment portion 111

of the gas port assembly 100 is accommodated in the second recess 133, and the abutment portion 111 has a height H3 and a width D3, the following relationship of these dimensions can be set: the width D2 > the width D3, and the height H3 > the depth H2.

[0066] The foregoing structure allows the deformation space of the gas port assembly 100 in the radial direction to be more ample than that in the axial direction, and there is a certain deformation space in both directions, ensuring that the abutment portion 111 of the gas port assembly 100 steadily deforms in the foregoing two directions when connecting with the FOUP 20, thereby having better contact fit.

[0067] In some examples, as illustrated in FIG. 4, the first gap H4 may be set to be less than 2 mm. This gap can enable the first recess 114 to better serve as a buffer space to reduce a force when an upper side corner 115 of the first recess 114 abuts against an upper inner edge of the second through hole 134 in the upper assembly 131 during the sealed docking process in which the docking port of the FOUP 20 presses against the abutment portion 111.

[0068] For example, an upper inner edge of the through hole of the upper assembly 131 is close to an upper side corner of the annular recess of the gas port assembly 100, and a gap exists therebetween when the FOUP 20 is not placed. When the FOUP 20 is placed, the docking port of the FOUP 20 presses on the gas port assembly 100. Since the whole gas port assembly 100 is elastically deformable, the part at the annular recess (i.e., the first recess 114) of the gas port assembly 100 also receives a downward force, causing the upper side corner of the annular recess of the gas port assembly 100 to move downward during deformation. With the gap H4 serving as a buffer space, a protective effect can be provided to the corner position of the annular recess of the gas port assembly 100, reducing the force when this corner position abuts against the upper inner edge of the through hole of the upper assembly 131 since the gas port assembly 100 is pressed down, and thus the corner position is not easily punctured and damaged by the edge, which is beneficial for improving the structural life.

[0069] In some examples, as illustrated in FIG. 4, before the abutment portion 111 is in sealed docking with the docking port of the FOUP 20, a first height H5 exists between a top end surface of the abutment portion 111 and a top end surface of the upper assembly 131, and after the sealed docking between the abutment portion 111 and the docking port of the FOUP 20 is completed, a second height H6 (not shown) exists between the top end surface of

the abutment portion 111 and the top end surface of the upper assembly 131. The following relationship of these dimensions can be set: H5 > H6, and H5 > D2 - D3. In this way, the abutment portion 111 at the upper part of the gas port assembly 100 has good strength and an appropriate deformation space, so that the abutment portion 111 tightly docks with the inflation port or the exhaust port of the FOUP 20, maintaining good sealing contact. Meanwhile, the gas port assembly 100 and the upper assembly 131 have a compact assembly structure.

[0070] In a state where the FOUP 20 is not placed, a height by which the top end surface of the abutment portion 111 of the gas port assembly 100 protrudes from the upper end surface of the upper assembly 131 is the first height H5. In a state where the FOUP 20 is placed, the gas port assembly 100 is compressed and contracted so that a height difference between the top end surface of the abutment portion and the upper end surface of the upper assembly 131 is the second height H6. Usually, H5 can be set to 0 mm to 4 mm, and H6 can be set to larger than 0 mm. This not only facilitates the sealed docking of the FOUP 20, but also can further improve the sealing performance of the sealed docking.

[0071] In summary, the mounting structure of the load plate 10 and the gas nozzle is very compact, and the connection portion 112 of the gas port assembly 100 is reliably fixed between the upper assembly 131 and the lower assembly 132. The upper assembly 131 and the lower assembly 132 can be conveniently and firmly fixed on the load plate 10 by using general screws, so that the flexible gas nozzle is stably assembled on the load plate 10 and is not prone to air leakage or detachment.

[0072] Therefore, the gas nozzle device has a simple structure and good sealing performance, further facilitates operations such as installation and maintenance, and can be rapidly deployed and maintained in a load port, which is beneficial for improving efficiency.

[0073] Based on the same inventive concept, the present embodiment further provides a gas path device of a cleaning apparatus.

[0074] Referring to the foregoing schematic diagrams of FIG. 1 and FIG. 2, the gas path device of the cleaning apparatus includes: the load plate 10 disposed on the load port for placing the FOUP 20; a plurality of gas inlet nozzles 110 and a plurality of gas exhaust nozzles 120 mounted on the load plate 10, where each of the gas inlet nozzles 110 and the gas exhaust nozzles 120 may be the gas nozzle device of the cleaning apparatus according to any of the above embodiments (for details, refer to the foregoing examples); an inlet gas path

1210 connected to threaded holes of the gas inlet nozzles 110; and an exhaust gas path 1220 connected to threaded holes of the gas exhaust nozzles 120.

[0075] Both the inlet gas path 1210 and the exhaust gas path 1220 may be disposed in a space below the load plate 10, or mounted on a lower side of the load plate 10.

[0076] The inlet gas path 1210 is provided with a diaphragm valve 1211, a first throttle valve 1212, and a filter 1213 sequentially connected in series through a pipeline. A gas output end of the filter 1213 is connected to the gas inlet nozzle 110. At this time, clean gas can flow into the pipeline from the diaphragm valve 1211, pass through the first throttle valve 1212, the filter 1213, and the gas inlet nozzle 110, and then enter the interior of the FOUP 20.

[0077] In addition, the exhaust gas path 1220 is provided with a second throttle valve 1221 and a vacuum generator 1222 sequentially connected in series through a pipeline. A suction end of the vacuum generator 1222 is connected to the gas exhaust nozzle 120 through a pipeline, and a discharge end of the vacuum generator 1222 is connected to an exhaust pipeline. Intake air passing through the second throttle valve 1221 is input into the vacuum generator 1222 to adjust the working state of the vacuum generator 1222. Hence, gas in the FOUP 20 is sucked out to the exhaust pipeline when the vacuum generator 1222 is working.

[0078] In some embodiments, a corresponding sensor may be disposed on the gas path to perform sensing detection and data sampling on the airflow, so that the cleaning apparatus can obtain cleaning parameters in real time.

[0079] As illustrated in FIG. 2, a plurality of sensors are disposed on the gas path pipelines below the corresponding FOUP load plate 10 to perform sensing detection on the gas in the pipelines and output corresponding detection data.

[0080] For example, in the inlet gas path 1210: an inlet flow sensor 1214 is disposed on the gas path between the diaphragm valve 1211 and the first throttle valve 1212 to detect the gas flow from the diaphragm valve 1211 to the first throttle valve 1212; or, a mass flow controller (MFC, not shown) is connected between the diaphragm valve 1211 and the first throttle valve 1212.

[0081] For example, in the exhaust gas path 1220, a pressure sensor 1224 and a temperature and humidity sensor 1225 are disposed on the gas path between the gas exhaust nozzle 120 and the vacuum generator 1222 to detect the suction pressure from the gas

exhaust nozzle 120 to the vacuum generator 1222, and the temperature and humidity of the gas discharged from the FOUP 20.

[0082] As illustrated in FIG. 2, for one load plate 10 (corresponding to one cleaning apparatus), one secondary control circuit 220 is correspondingly provided. The secondary control circuit 220 is electrically connected to the foregoing sensors to collect information detected by the sensors. In some embodiments, a plurality of secondary control circuits 220 may be provided, where the secondary control circuit 220 is deployed corresponding to one FOUP load plate, and is electrically connected to a plurality of sensors to control operations of the sensors and collect detection data of the sensors. It should be noted that the number, deployment positions, etc. of the secondary control circuits 220 are not limited.

[0083] In some embodiments, the gas path device is provided with a primary control circuit 210 configured to remotely control the secondary control circuits 220. The primary control circuit 210 is deployed corresponding to a plurality of FOUP load plates. The primary control circuit 210 is communicatively connected to a plurality of the secondary control circuits 220, and is configured to control the operations of the secondary control circuits 220 and collect feedback data output by the secondary control circuits 220. The feedback data includes detection data of the sensors.

[0084] Therefore, secondary control circuits 220 of a plurality of cleaning apparatuses may be communicatively connected to one primary control circuit 210. The primary control circuit 210 communicates with a host computer, receives instructions or uploads data, and uploads the detection information to the host computer in time for monitoring. One host computer is connected to a plurality of primary control circuits 210, and one primary control circuit 210 is connected to a plurality of secondary control circuits 220, so that the interaction frequency of the host computer is reduced, and the waiting time for uploading is also reduced, improving the communication efficiency. In some embodiments, when a valve action needs to be controlled, the instruction can be sent to the secondary control circuit 220 in time to complete the corresponding control operation, improving the overall communication efficiency and execution efficiency of the instruction execution, which is beneficial for improving the work efficiency of the load port.

[0085] After in-depth research and improvement exploration on the cleaning apparatus, its externally provided interface circuit, and the external sensors and execution circuits that need to be connected thereto, as described in the above embodiments, a cleaning

apparatus interface circuit and a sampling control system thereof are proposed: one host computer 001 is connected to a plurality of primary control circuits 210, and one primary control circuit 210 is connected to a plurality of secondary control circuits 220. Further, different external interfaces (e.g., a first interface to an N-th interface, where N is a positive integer) are provided in the secondary control circuit 220 to satisfy the connection needs of external circuits 300 (e.g., a first circuit to an N-th circuit, such as sensors and execution circuits) of the cleaning apparatus in a one-to-many manner. Therefore, under the condition that the primary control circuit 210 can support the communication connection of the secondary control circuits 220 in a one-to-many manner, and the secondary control circuit 220 can support the communication connection of various external circuits (such as sensors, execution circuits, etc.) in a one-to-many manner, these external circuits (and even the corresponding secondary control circuits, primary control circuits, etc.) can all be flexibly deployed on site according to the needs of cleaning the FOUPs in a production link of a wafer fabrication production workshop. For example, a plurality of secondary control circuits may be disposed on different FOUP loading apparatuses, and the primary control circuit may be arranged adjacent to the secondary control circuits, or may be arranged at a position far away from the secondary control circuits.

[0086] In some embodiments, for a relatively large number of cleaning apparatuses, a plurality of primary control circuits 210 are provided, and each primary control circuit 210 is connected to a plurality of secondary control circuits 220. The secondary control circuit 220 can collect the working state information of the cleaning apparatus in time, and the primary control circuit 210 collects the information collected by the secondary control circuits 220 by means of querying, and can send collected information related to a plurality of cleaning apparatuses to the host computer at one time.

[0087] In some examples, the secondary control circuit 220 is provided with a plurality of digital output interfaces, and the digital output interfaces are configured for an execution circuit triggered and controlled by a digital quantity to be electrically connected to the secondary control circuit 220.

[0088] In some embodiments, the gas path device of the cleaning apparatus further includes: a solenoid valve 1223 disposed on the inlet gas path and correspondingly electrically connected to a digital output interface provided by the secondary control circuit. An input end of the solenoid valve 1223 is injected with gas. One output end of the solenoid valve 1223 is connected to a pneumatic control input end of the diaphragm valve 1211 to

control the action of the diaphragm valve 1211 under the control of the secondary control circuit. Another output end of the solenoid valve 1223 is connected to the second throttle valve 1221 on the exhaust gas path, so that the intake air is injected into the vacuum generator 1222 through the second throttle valve 1221 under the control of the secondary control circuit to adjust the operation of the vacuum generator 1222.

[0089] In some examples, the gas path device of the cleaning apparatus further includes: a plurality of mass flow controllers disposed on the corresponding inlet gas path or the exhaust gas path and correspondingly electrically connected to digital output interfaces provided by the secondary control circuit. A respective mass flow controller is configured to perform flow stabilization control on the gas flow of a respective gas path under the control of the secondary control circuit, so as to stabilize the gas flow of the respective gas path at a set value.

[0090] In some examples, the secondary control circuit is provided with a plurality of IO-Link interfaces, and the IO-Link interfaces are configured for an execution circuit or sensor based on the IO_Link protocol to be electrically connected to the secondary control circuit.

[0091] In some examples, the sensor include at least one of a temperature and humidity sensor, a position sensor, a clamp sensor, a flow sensor, and a pressure sensor.

[0092] A sensing portion of the temperature and humidity sensor is disposed in the exhaust gas path to detect the temperature and humidity of gas discharged from the FOUP. The position sensor is disposed on the FOUP load plate to detect whether the FOUP is placed at a preset position on the load plate. The clamp sensor is disposed in the FOUP load plate to detect whether a clamp hooks the FOUP on the load plate. The flow sensor is disposed on the inlet gas path to detect the flow of the intake gas. The pressure sensor is disposed on the exhaust gas path to detect the pressure of the exhaust gas.

[0093] In some examples, communication connection between the primary control circuit and the secondary control circuit includes RS485 remote communication.

[0094] In some examples, the foregoing primary control circuits and secondary control circuits may form interface circuits, so that the interface circuits can serve as interfaces for electrical connection in the cleaning apparatus, facilitating corresponding devices/circuits to be connected to the cleaning apparatus.

[0095] As illustrated in FIG. 8 and FIG. 9, the present embodiment provides a cleaning apparatus interface circuit 200 including: at least one primary control circuit 210 and a plurality of secondary control circuits 220. A respective secondary control circuit 220 includes a second control circuit 2206 and one or more of the following interface units electrically connected to the second control circuit 2206: an integrated circuit bus interface 2201, a digital input interface 2202, an analog input interface 2203, an IO-Link interface 2204, and a digital output interface 2205.

[0096] In some embodiments, the electrical connection between the primary control circuit 210 and the secondary control circuit 220 may be achieved based on a preset communication interface. Therefore, the primary control circuit 210 includes a first communication interface 2101, and correspondingly, the secondary control circuit 220 includes a second communication interface 2207. The second control circuit 2206 of the secondary control circuit 220 is communicatively electrically connected to the first communication interface 2101 in the primary control circuit 210 through the second communication interface 2207. It should be noted that the communication interface may be an RS485 industrial communication interface that supports remote connection, or may be another form of communication interface such as wired connection or wireless connection, which are not elaborated herein.

[0097] Therefore, based on the electrical connection of the control circuit to the secondary control circuits 220 in a one-to-many manner, and the electrical connection of the secondary control circuit 220 to the external circuits 300 in a one-to-many manner, since the electrical connection interfaces provided by the secondary control circuit 220 correspond to external circuits 300 to be deployed, these external circuits 300 can be electrically connected to the cleaning apparatus after on-site deployment in the wafer fabrication plant.

[0098] For example, for a first sensor 310 of an integrated circuit bus (I^2C), such as a temperature sensor, a humidity sensor or a temperature and humidity sensor, interfaces of these sensors are usually integrated circuit bus interfaces (I^2C interfaces). At this time, the secondary control circuit 220 provides a corresponding integrated circuit bus interface 2201 for electrical connection therewith. Therefore, with the integrated circuit bus interface 2201 provided by the secondary control circuit 220, a temperature sensor, a humidity sensor and the like can be flexibly deployed on site in the wafer fabrication plant according to actual application deployment, for example, the number and deployment positions of sensors can be flexibly increased or decreased.

[0099] For example, for a second sensor 320 of a digital quantity, such as a position sensor for detecting whether the FOUP is positioned in place, a clamp sensor for detecting whether a clamp is in place to hook the FOUP on the load plate, or other digital quantity detection sensors, interfaces of these sensors are usually digital interfaces (for example, outputting a digital signal "1" when a preset result is detected, otherwise outputting a digital signal "0"). At this time, the secondary control circuit 220 provides a corresponding digital input interface 2202 for electrical connection therewith. Therefore, with the digital input interface 2202 provided by the secondary control circuit 220, these detection sensors can be flexibly deployed on site in the wafer fabrication plant according to actual application deployment, for example, the number and deployment positions of the sensors can be flexibly increased or decreased.

[0100] For example, for a third sensor 330 of an analog quantity, such as a flow sensor for detecting inlet/exhaust flow, a pressure sensor for detecting inlet/exhaust pressure or other analog quantity detection sensors during the cleaning process of the FOUP (i.e., inflation, exhaust, etc.), the interfaces of these sensors are usually analog interfaces (for example, the gas flow is a continuous analog signal, and the pressure is a continuous analog signal). At this time, the secondary control circuit 220 provides the corresponding analog input interface 2203 for electrical connection therewith. Therefore, with the analog input interface 2203 provided by the secondary control circuit 220, these sensors can be flexibly deployed on site in the wafer fabrication plant according to actual application deployment, for example, the number and deployment positions of the sensors can be flexibly increased or decreased.

[0101] For example, for an external circuit of IO-Link, such as a fourth sensor 340 or a first execution circuit 350 (where the execution circuit may also be referred to as an executor, without distinction herein), the secondary control circuit 220 may provide a corresponding IO-Link interface 2204 for electrical connection therewith.

[0102] In some embodiments, with the support of the IO-Link interface 2204 provided by the secondary control circuit 220, in addition to simplifying the interfaces and wiring of the external circuits 300, an integrated parameter assignment and diagnosis channel function can be provided through the IO-Link interface, which is further beneficial for the cleaning apparatus to obtain additional data from a sensor/executor level, thereby generating meaningful added value. Therefore, with the support of the IO-Link interface, the cleaning

apparatus can well adapt to future Industry 4.0 applications, and the external circuits 300 can be more conveniently deployed flexibly on site in the wafer fabrication plant.

[0103] It should be noted that IO-Link is a point-to-point, serial digital communication protocol, whose purpose is to periodically exchange data between a sensor/executor and a controller (PLC). Moreover, a person skilled in the art should understand that the definitions related to the IO-Link protocol and its interface, etc., can be determined according to the IO-Link protocol standard (such as the international standard IEC 61131-9), which will not be elaborated herein. In addition, for the IO-Link sensor/executor, etc., a person skilled in the art can make a selection according to the actual needs of cleaning the FOUP in the wafer fabrication plant, which is not limited herein.

[0104] For example, for an execution circuit triggered and controlled based on a digital quantity (e.g., a second execution circuit 360 illustrated in FIG. 9), such as a switching circuit (e.g., an inlet solenoid valve and an exhaust solenoid valve) that needs to control inlet and exhaust during the cleaning process (i.e., inflation, exhaust, etc.) of the FOUP, the operation of these execution circuits is usually triggered and controlled by a digital quantity (for example, operating under the trigger of a digital signal "1", stopping operation under the trigger of a digital signal "0", etc.). Therefore, with the support of the electrical connection provided by the corresponding digital output interface 2205 in the secondary control circuit 220, these execution circuits can be flexibly deployed on site in the wafer fabrication plant according to actual application deployment, for example, the number and deployment positions of the executors can be flexibly increased or decreased.

[0105] It should be noted that, by providing corresponding interfaces via the secondary control circuit 220 in response to deployment needs of the wafer fabrication plant for these external circuits 300, it is possible to provide the secondary control circuits 220 with different interface types and interface quantities, and through these secondary control circuits 220 cooperating with the on-site deployment needs of these external circuits 300, flexible deployment can be achieved in a production workshop of the wafer fabrication plant according to actual production application needs.

[0106] In addition, the host computer 001 communicatively connected to the primary control circuit 210 may be a host computer that controls the cleaning apparatus to work, for example, a controller that triggers the cleaning apparatus to inflate and exhaust the FOUP. Therefore, the host computer 001 may be a controller disposed in the cleaning apparatus,

such as a control unit in the cleaning apparatus, or may be a controller arranged outside the cleaning apparatus, such as a controller in an automated material handling system (AMHS) of a semiconductor wafer fabrication plant. The host computer is not limited herein.

[0107] Therefore, in the interface circuit and sampling control system of the cleaning apparatus provided by the embodiments of the present disclosure, by dividing the interface circuit into a plurality of primary control circuits 210 and a plurality of secondary control circuits 220 correspondingly electrically connected to the primary control circuit 210, and further providing electrical connection interfaces for different external circuits 300 respectively through the secondary control circuits 220, and then electrically connecting the secondary control circuit 220 to external circuit units such as a sensor and an execution circuit, it is achieved that the external circuit units (and even the corresponding secondary control circuit 220, primary control circuit 210, etc.) can be flexibly deployed on site.

[0108] In some embodiments, the digital input interface 2202 may be an electrical interface based on a photoelectric isolator. Based on the photoelectric isolation, in addition to transmitting digital signals between the secondary control circuit 220 and the external circuit 300, there is a good isolation characteristic, and the circuits do not affect each other, simplifying the electrical connection relationship and being beneficial for improving circuit performance.

[0109] In some embodiments, as illustrated in FIG. 10, the digital input interface 2202 is an interface circuit with a photoelectric isolator U9A as the core. The digital input interface 2202 includes: an input interface DInput1, an output interface DI_1, a first resistor R1, a second resistor R2, a third resistor R3, a fourth resistor R4, a first capacitor C1, a second capacitor C2, and a photoelectric coupling circuit U9A.

[0110] The input interface DInput1 serves as an electrical connection interface of the second sensor 320 (see the foregoing schematic diagram of FIG. 9) and is electrically connected to one end of the first resistor R1. The other end of the first resistor R1 is electrically connected to a first input end (e.g., pin 1 shown in FIG. 10) of the photoelectric coupling circuit U9A. The first input end and a second input end of the photoelectric coupling circuit U9A are connected in parallel with the second resistor R2 and the first capacitor C1. The second input end (e.g., pin 2 shown in FIG. 10) of the photoelectric coupling circuit U9A is grounded. A first output end (e.g., pin 16 shown in FIG. 10) of the photoelectric coupling circuit U9A is connected to a first power supply VCC through the third resistor R3, and is

electrically connected to the output interface DI_1 through the fourth resistor R4. The second capacitor C2 is connected in parallel between the output interface DI_1 and the ground. At this time, the output interface DI_1 is electrically connected to the second control circuit 2206.

[0111] It should be noted that, for each digital-quantity external circuit 300, a corresponding digital input interface 2202 may be provided in the secondary control circuit 220, so that these external circuits 300 can be electrically connected to the secondary control circuit 220 through the digital input interface 2202. Therefore, a person skilled in the art should understand that, as shown in the schematic diagram of one channel of the digital input interface 2202 in FIG. 10, when the external circuit 300 requires multiple channels of the digital input interface 2202, the configuration can refer to the circuit form illustrated in the schematic diagram of FIG. 10, which are not elaborated.

[0112] In some embodiments, the analog input interface 2203 may be an electrical interface that performs signal conditioning based on an operational amplifier. By using an operational amplifier for signal conditioning, such as filtering, amplifying, and differential input to single-ended output, in addition to transmitting analog signals between the secondary control circuit 220 and the external circuit 300, there are good interconnection characteristics and isolation characteristics, and the circuits do not affect each other, simplifying the electrical connection relationship and improving the overall circuit performance.

[0113] As illustrated in FIG. 11, the analog input interface 2203 includes: a differential interface AI1+/AI1-, a first operational amplifier U11B, a second operational amplifier U11A, a fifth resistor R5, a sixth resistor R6, a seventh resistor R7, an eighth resistor R8, a ninth resistor R9, a tenth resistor R10, an eleventh resistor R11, a third capacitor C3, and a fourth capacitor C4.

[0114] The differential interface (the positive input terminal AI1+ and the negative input terminal AI1- as illustrated in FIG. 11) serves as an electrical connection interface of the third sensor 330 (see the foregoing schematic diagram of FIG. 9), and is respectively coupled to an inverting input terminal and a non-inverting input terminal of the first operational amplifier U11B through the fifth resistor R5 and the sixth resistor R6. The seventh resistor R7 is connected in parallel with the differential interface. The eighth resistor R8 is connected in parallel between the non-inverting input terminal of the first operational amplifier U11B and the ground. The ninth resistor R9 and the third capacitor C3 are

connected in parallel each other and then connected in series between the inverting input terminal and an output terminal of the first operational amplifier U11B. The tenth resistor R10 is connected in series between the output terminal of the first operational amplifier U11B and the non-inverting input terminal of the second operational amplifier U11A. The inverting input terminal and the output terminal of the second operational amplifier U11A are electrically connected to each other, and then is electrically connected to the second control circuit through the eleventh resistor R11. One end of the eleventh resistor R11 is coupled to the ground through the fourth capacitor C4, and a connection point between the eleventh resistor R11 and the fourth capacitor C4 serves as an output port AO1 for electrical connection with the second control circuit.

[0115] In some embodiments, with the first operational amplifier U11B as the core, a signal amplification and conditioning circuit for differential input and single-ended output is constituted. The fifth resistor R5, the sixth resistor R6, and the seventh resistor R7 constitute the interface of the differential input terminals. The eighth resistor, the ninth resistor R9, and the third capacitor C3 constitute a balancing branch for signal amplification and conditioning. With the second operational amplifier U11A as the core, a voltage follower is constituted. At the output terminal of the voltage follower, an electrical connection for signal driving is achieved between the secondary control circuit 220 and the input interface through an RC filtering and matching circuit (i.e., an RC circuit constituted by the eleventh resistor R11 and the fourth capacitor C4), which not only facilitates an electrical connection between the input interface and a post-stage circuit, but also causes a small impact of the circuits electrically connected at front and post stages on an analog signal, being beneficial for improving circuit performance.

[0116] It should be noted that, for each analog external circuit, a corresponding analog input interface 2203 may be provided in the secondary control circuit 220, so that these analog external circuits can be electrically connected to the secondary control circuit 220 through the analog input interface 2203. Therefore, a person skilled in the art should understand that, FIG. 11 illustrates a schematic diagram of one channel of the analog input interface 2203, and when the external circuit 300 requires multiple channels of the analog input interface 2203, the configuration can refer to the circuit form illustrated in the schematic diagram of FIG. 4, which are not elaborated.

[0117] In some embodiments, a resistor and a capacitor may be arranged at the input terminal of the operational amplifier of the follower, and these capacitors can be used to further condition the analog signal.

[0118] In some embodiments, as illustrated in FIG. 11, the analog input interface 2203 further includes: a twelfth resistor R12, a fifth capacitor C5, and a sixth capacitor C6. Therefore, in the foregoing example, the connection of the tenth resistor R10 in series between the output terminal of the first operational amplifier U11B and the non-inverting input terminal of the second operational amplifier U11A includes: the tenth resistor R10 is connected in series between the output terminal of the first operational amplifier U11B and one end of the twelfth resistor R12; the other end of the twelfth resistor R12 is connected to the non-inverting input terminal of the second operational amplifier U11A; the non-inverting input terminal of the second operational amplifier U11A is coupled to the ground through the fifth capacitor C5; and the sixth capacitor C6 is connected in parallel between the inverting input terminal and the non-inverting input terminal of the second operational amplifier U11A.

[0119] The twelfth resistor R12 and the fifth capacitor C5 constitute an RC circuit to condition the analog signal, and the non-inverting input terminal and the inverting input terminal of the voltage follower (i.e., the second operational amplifier U11A) are kept consistent by means of the sixth capacitor C6.

[0120] In some embodiments, an analog-to-digital converter may be adopted to convert the analog signal into a digital signal, which is beneficial for the second control circuit 2206 in the secondary control circuit to transmit to the primary control circuit 210.

[0121] In an example, the analog-to-digital conversion circuit may be disposed in the analog input interface 2203, which in turn simplifies the electrical connection relationship between the analog input interface 2203 and the second control circuit 2206, and is also beneficial for improving circuit performance.

[0122] In some embodiments, as illustrated in FIG. 12, the analog-to-digital conversion circuit includes an ADC conversion circuit having two channels. At this time, the conversion circuit may be electrically connected to the conditioning circuit having two channels in the foregoing example.

[0123] For each channel of the conditioning circuit, the inverting input terminal and the output terminal of the second operational amplifier U11A are electrically connected, and then coupled to an input terminal of an analog-to-digital converter through a resistor, and

thereafter an output terminal of the analog-to-digital converter is electrically connected to the second control circuit 2206.

[0124] In an implementation, a power supply terminal of the analog-to-digital converter (ADC) U10 may be filtered by a feedthrough capacitor C47, that is, after a power supply VDD passes through the feedthrough capacitor C47, a cleaner analog power supply AVDD (such as 5V DC) is formed. An analog negative input terminal of the analog-to-digital converter U10 is coupled to the ground through a resistor (e.g., a resistor R63 and a resistor R87 illustrated in FIG. 12).

[0125] It should be noted that an analog-to-digital converter (e.g., a number of bits, a conversion rate, etc.) can be selected according to application needs, and a connection manner between an output interface of the ADC and the second control circuit 2206 can be determined according to a specific interface of the ADC. For example, when the output interface of the ADC is a serial peripheral interface (SPI) (such as wirings of SS/SCK/MOSI/MISO illustrated in FIG. 12), these interfaces can be electrically connected to the second control circuit 2206 after being pulled up through resistors, and four pins of an output terminal of an analog-to-digital conversion chip are correspondingly connected to pins 33-36 of a microcontroller U3 to transmit signals, which is not limited herein.

[0126] In some embodiments, two channels of operational-amplifier-based analog signal conditioning circuits illustrated in FIG. 12 are the same as or similar to those illustrated in the foregoing FIG. 11, and schematic descriptions of functions and connection relationships, etc., of respective components in FIG. 12 will not be repeated.

[0127] Furthermore, the foregoing first operational amplifier U11B and second operational amplifier U11A may be a dual operational amplifier device, and a corresponding filtering capacitor (e.g., C59 and C60 illustrated in FIG. 12) is arranged at a power supply terminal of the operational amplifier.

[0128] In some embodiments, according to a driving signal required by an execution circuit (such as a solenoid valve) used in a cleaning process, a corresponding driving circuit may be further arranged in the digital output interface 2205 of the secondary control circuit 220 to provide the driving signal, so as to trigger the execution circuit to reliably execute a preset action.

[0129] As illustrated in FIG. 13, the digital output interface 2205 includes: an input interface DO1, an output interface VAL1, a first metal-oxide-semiconductor (MOS) transistor

Q1, a second MOS transistor Q2, a thirteenth resistor R13, a fourteenth resistor R14, a fifteenth resistor R15, a sixteenth resistor R17, and a seventh capacitor C7.

[0130] The input interface DO1 is electrically connected to the second control circuit 2206 (as schematically shown in FIG. 9). The input interface DO1 is connected to a gate of the first MOS transistor Q1. The gate of the first MOS transistor Q1 is coupled to the ground through the thirteenth resistor R13. A source of the first MOS transistor Q1 is grounded. A drain of the first MOS transistor Q1 is connected to one end of the fourteenth resistor R14. The other end of the fourteenth resistor R14 is connected to a gate of the second MOS transistor Q2. The gate of the second MOS transistor Q2 is coupled to a second power supply VIN (such as a 24V DC second power supply) through the fifteenth resistor R15. A drain of the second MOS transistor Q2 is connected to the second power supply VIN. A source of the second MOS transistor Q2 is coupled to the ground through the sixteenth resistor R16. The source of the second MOS transistor Q2 is connected to an output interface VAL1. The seventh capacitor C7 is connected in parallel with the sixteenth resistor R16.

[0131] In some embodiments, a grounding capacitor (i.e., C33 as shown in FIG. 13) may be coupled at the drain of the second MOS transistor, which can not only regulate and filter the power supply of the MOS transistor but also improve the transient characteristic when the MOS transistor switches, which is beneficial for improving the driving performance of the digital output interface 2205 to the external circuit 300.

[0132] In some embodiments, the output interface VAL1 may be coupled to the ground through a diode D6, where a cathode of the diode D6 is connected to the output interface VAL1, and an anode of the diode D6 is grounded. At this time, the diode D6 can provide a loop for the sixteenth resistor R16 and the seventh capacitor C6, and prevent the output interface VAL1 from being short-circuited to the ground, which is beneficial for improving the connection performance between the digital output interface 2205 and the external circuit 300.

[0133] In some embodiments, the IO-Link interface may be an electrical interface constituted by a device implementing the IO-Link protocol.

[0134] In some embodiments, referring to FIG. 14, a core circuit of the IO-Link interface is an IO_link unit U50. The IO_link unit U50 is provided with an IO_link_TX signal terminal, an IO_link_RX signal terminal, an IO_link_TXEN signal terminal, an IO_link_SCL signal terminal, an IO_link_SDA signal terminal, an IO_link_WU signal

terminal, an IO_link_MCLK signal terminal, an IO_link_EN signal terminal, an IO_link_L1 signal terminal, etc., which are respectively electrically connected to the second control circuit 2206.

[0135] An IO_link_CQ signal terminal of the IO_link unit U50 may be used to connect circuit units such as sensors and executors supporting IO_link. By providing the IO_link unit U50, the cleaning apparatus can have rich interface types, which can be flexibly selected/switched according to on-site needs, improving compatibility, especially better compatibility in the future Industry 4.0.

[0136] A person skilled in the art should understand that a corresponding device may be selected for the IO-link unit U50 according to application needs, which is not limited herein. Also, the resistors, capacitors, and other devices external to U50 are circuit devices used to cooperate with the operation of U50, and the specific parameter values can be determined according to the selection needs of U50, which will not be elaborated herein.

[0137] In any example provided by the embodiments of the present disclosure, the first sensor 310 may include a sensing sensor for sensing temperature and/or humidity during the cleaning process, and the sensing sensor may be an I2C sensor, such as a temperature sensor, a humidity sensor, a temperature and humidity sensor.

[0138] In any example provided by the embodiments of the present disclosure, the second sensor 320 may include a detection sensor for triggering detection, such as a position sensor and a clamp sensor. The output signal of the sensor is usually a digital signal, i.e., outputting a digital "1" when an object is detected, and outputting a digital "0" when no object is detected.

[0139] In some embodiments, the position sensor may be configured to detect the position of an object. In other words, the position sensor may be arranged at a certain fixed point or from a certain fixed point or position, and then provide position feedback at that position on whether the placement position of a preset object (such as a FOUP) is in place.

[0140] In some embodiments, the position sensor may be a micro-switch type sensor.

[0141] It should be noted that the position sensor may also be a sensor that provides a signal based on field detection, such as an electromagnetic field of an eddy current sensor, an electrostatic field of a capacitive sensor, and a magnetic induction field of a magnetoresistive, magnetoresistive-change, or Hall effect sensor, etc., which are not specifically limited herein.

[0142] In some embodiments, the clamp sensor may be configured to detect whether a clamp is in place, where the clamp may be a clamp on the load plate for temporarily hooking the FOUP.

[0143] In any example provided by the embodiments of the present disclosure, the third sensor 330 may include a flow sensor and/or a pressure sensor for inlet and exhaust detection. These sensors usually output analog signals, and may be connected to the analog input interface.

[0144] In any example provided by the embodiments of the present disclosure, the second execution circuit 2205 includes a solenoid valve.

[0145] In any example provided by the embodiments of the present disclosure, the secondary control circuit 220 may further provide a corresponding interface (not shown) for a mass flow controller (MFC), such as a digital interface (e.g., RS485).

[0146] It should be noted that the MFC not only has the function of a mass flow meter but can also automatically control the gas flow under an external signal trigger. Even if the system pressure fluctuates or the ambient temperature changes, the MFC can automatically stabilize the flow at a set value. In other words, the MFC is equivalent to a flow stabilization device. Therefore, by providing a corresponding digital interface (such as RS485) in the secondary control circuit 220, the MFC may be triggered for automatic flow stabilization control.

[0147] In some examples, based on the corresponding interfaces provided by the secondary control circuit 220, the foregoing various external circuits 300 may be flexibly deployed on site.

[0148] For example, a sensing portion of the temperature and humidity sensor 1225 is disposed in the exhaust gas path 1220 to detect the temperature and humidity of gas discharged from the FOUP. A signal output terminal of the temperature and humidity sensor 1225 is electrically connected to the integrated circuit bus interface 2201. Thus, the temperature and humidity sensor 1225 can detect the characteristics of the gas at the exhaust end, which facilitates the judgment of gas environment inside the FOUP in subsequent data processing. In some embodiments, the sensing portion of the temperature and humidity sensor 1225 is disposed on the exhaust gas path 1220 as close as possible to the gas exhaust nozzle 120.

[0149] For example, a FOUP position sensor is disposed on the load plate 10, where multiple position sensors may be provided to detect whether the FOUP is placed correctly and in place. The position sensor is electrically connected to the digital input interface. Similarly, the connection for a FOUP clamp sensor (not shown) is the same as that of the position sensor, and may be electrically connected to another channel of the digital input interface.

[0150] For example, the inlet flow sensor 1214 is disposed on the inlet gas path 1210 to detect the flow of the intake gas, and the exhaust pressure sensor 1224 is disposed on the exhaust gas path 1220 to detect the pressure of the exhaust gas. In addition, the inlet flow sensor 1214 and the exhaust pressure sensor 1224 are each correspondingly electrically connected to a corresponding analog input interface.

[0151] In some embodiments, the primary control circuit 210 and/or the secondary control circuit 220 may be a circuit structure with a microcontroller (MCU) as a core circuit. It should be noted that, even if a microcontroller circuit is used as the core of the control circuit, based on the interface circuits and interconnection relationships provided by the embodiments of the present disclosure, a person skilled in the art should be able to establish corresponding functions inside the microcontroller according to these circuits and interconnection relationships. Therefore, the microcontroller and its internal function settings are not specifically limited.

[0152] As illustrated in FIG. 15 to FIG. 16, the embodiments of the present disclosure provide an example of the secondary control circuit 220 with a microcontroller as the core control circuit. In the secondary control circuit 220, the second control circuit 2206 may be a microcontroller unit (MCU). Each interface circuit is respectively electrically connected to the MCU, and each external circuit 300 (such as a sensor and execution circuit) is correspondingly electrically connected to the electrical connection interface provided by the secondary control circuit 220.

[0153] For example, a digital-quantity sensor is electrically connected to the digital input interface circuit. The position sensor detecting the FOUP (sometimes also referred to as a position switch), the clamp sensor detecting whether the clamp hooks the FOUP, etc., are each electrically connected to the corresponding digital input interface, and the digital input interface circuit is connected to the MCU through a general purpose input/output (GPIO) of the MCU. Based on the foregoing examples, the input terminal Dinput1 in the digital input

interface 2202 may be connected to a position sensor, and the output terminal DI_1 in the digital input interface 2202 is electrically connected to pin 38 of the microcontroller U3 to input the detected digital signal into the microcontroller. Other position sensors are similarly set, and each connected to a corresponding pin of the microcontroller through a digital input interface 2202, which are not elaborated herein. Also, the connection for the FOUP clamp sensor is the same as that for the position sensor, and the FOUP may be connected to pin 40 of the microcontroller U3 through another digital input interface.

[0154] For example, an execution circuit triggered and controlled based on a digital quantity is electrically connected to the digital output interface 2205. Execution circuits such as an inlet solenoid valve and an exhaust solenoid valve are each electrically connected to the corresponding digital output interface 2205, and the digital output interface 2205 is electrically connected to the MCU through the GPIO of the MCU. Based on the foregoing examples, in one digital output interface 2205, each output terminal VAL1 correspondingly outputs a control signal for one valve (e.g., the inlet solenoid valve/exhaust solenoid valve), and a respective input terminal DO1 is connected to pin 55, 50, or 57 of the microcontroller U3.

[0155] For example, an analog-output sensor is electrically connected to the analog input interface 2203. Analog sensors such as an exhaust pressure sensor and an inlet flow sensor are respectively electrically connected to corresponding analog input interfaces 2203, and the analog input interface 2203 illustrated in the foregoing FIG. 11 is electrically connected to the MCU through an analog-to-digital converter (ADC) interface of the MCU itself, or the analog input interface 2203 illustrated in the foregoing FIG. 12 is electrically connected to the MCU through an SPI interface provided by the MCU. Based on the foregoing example where the ADC is external to the MCU, four pins of an output terminal of the analog-to-digital conversion chip U10 are correspondingly connected to pins 33-36 of the microcontroller U3 to transmit SPI2-NSS/SCK/MOSI/MISO signals respectively.

[0156] For example, an I2C temperature and humidity sensor is electrically connected to the integrated circuit bus interface 2201. I2C sensors such as a temperature sensor, a humidity sensor and a temperature and humidity sensor are each electrically connected to an I2C bus, and the integrated circuit bus interface 2201 is electrically connected to the MCU through an I2C interface provided by the MCU. Based on the foregoing examples, pins 29 and 30 of the microcontroller U3 are connected to the temperature and humidity sensor 1225 through the I2C interface.

[0157] For example, devices such as an IO-Link sensor and an executor are each electrically connected to the IO-Link interface circuit, and then the IO-Link interface circuit is electrically connected to an IO-Link interface in the MCU constituted by GPIOs or other pins. Based on the foregoing examples, pin 51 of the microcontroller U3 is coupled to the IO_link_TX signal terminal of the IO_link unit U50, pin 52 of the microcontroller U3 is coupled to the IO_link_RX signal terminal of the IO_link unit U50, pin 3 of the microcontroller U3 is coupled to the IO_link_TXEN signal terminal of the IO_link unit U50, pin 58 of the microcontroller U3 is coupled to the IO_link_SCL signal terminal of the IO_link unit U50, pin 59 of the microcontroller U3 is coupled to the IO_link_SDA signal terminal of the IO_link unit U50, pin 11 of the microcontroller U3 is coupled to the IO_link_WU signal terminal of the IO_link unit U50, pin 14 of the microcontroller U3 is coupled to the IO_link_MCLK signal terminal of the IO_link unit U50, pin 61 of the microcontroller U3 is coupled to the IO_link_EN signal terminal of the IO_link unit U50, and pin 62 of the microcontroller U3 is coupled to the IO_link_L1 signal terminal of the IO_link unit U50.

[0158] In some embodiments, as illustrated in FIG. 16, the microcontroller has corresponding peripheral circuits, such as a crystal oscillator circuit (e.g., a circuit composed of a crystal oscillator U5 and its peripheral circuits), a serial wire debug (SWD) debugging interface CN2 (e.g., a circuit composed of signals exSWDIO, exSWCLK, exPOWER, etc.), a debugging serial port P2 (e.g., a circuit composed of a connector Header3), a reset circuit (e.g., an RC reset circuit composed of R13 and C20 shown in FIG. 16), etc.

[0159] It should be noted that a person skilled in the art should be able to understand that the selection of each device in the peripheral circuits illustrated in FIG. 16 can be determined according to application needs, which is not limited or elaborated herein.

[0160] In some examples, as illustrated in FIG. 16, the secondary control circuit 220 may be provided with circuits such as a first indicator LED2 and a second indicator LED3, each connected to the microcontroller U3 and triggered to light up by the microcontroller U3. In some embodiments, the first indicator LED2 may be disposed on a device housing (not shown), so as to facilitate observing the working state of the control circuit when the device is running normally, and the second indicator LED3 may be disposed on a circuit board (not shown) to indicate the working state of the control circuit, especially when the first indicator LED2 is disconnected, so as to facilitate indicating the working state of the control circuit.

[0161] In some examples, as illustrated in FIG. 15 to FIG. 17, the secondary control circuit 220 may be provided with a first RS485 communication circuit. The first RS485 communication circuit is connected to pins 15-17 of the microcontroller U3 to transmit signals RXD1, RTS1, and TXD1. An output terminal of the first RS485 communication circuit is connected with a connection interface J1, so as to facilitate the communication connection with the primary control circuit 210.

[0162] In some examples, as illustrated in FIG. 15 to FIG. 17, the secondary control circuit 220 may be provided with a second RS485 communication circuit (e.g., an RS485 communication address module as shown in FIG. 17), whose configuration is the same as that of the first RS485 communication circuit. The second RS485 communication circuit is configured to connect to an MFC and communicate with the MFC. The second RS485 communication circuit is connected to pins 42, 43, and 45 of the microcontroller U3 to transmit signals RXD2, RTS2, and TXD2.

[0163] In some examples, as illustrated in FIG. 18, the secondary control circuit 220 further includes a power supply circuit. The power supply circuit includes a connection interface CN1, a common mode choke L2, a DC-DC conversion circuit U30, and a voltage regulator circuit U40 (low dropout regulator). The connection interface CN1 is used for inputting power, and is coupled to an input terminal of the common mode choke L2. An output terminal of the common mode choke L2 outputs a power supply (e.g., 24V), and is coupled to the DC-DC conversion circuit U30. An output terminal of the DC-DC conversion circuit U30 outputs VDD (e.g., 5V), and is coupled to the voltage regulator circuit U40, which outputs a power supply VCC (e.g., 3.3V).

[0164] In some examples, as illustrated in FIG. 15, FIG. 16, and FIG. 19, the secondary control circuit 220 may be provided with an electrically erasable programmable read-only memory (EEPROM) circuit for storing programs/data. The EEPROM circuit is a circuit unit with an EEPROM chip U6 as the core, and is coupled to pins 58 and 59 of the microcontroller U3 through corresponding resistors.

[0165] It should be noted that the control circuit of the primary control circuit (i.e., the first control circuit 2102 as schematically shown in the foregoing FIG. 9) may be configured with reference to the circuit form of the secondary control circuit 220 taking a microcontroller as the core.

[0166] Referring to the schematic diagram of FIG. 20, in the primary control circuit 210, the first control circuit 2102 takes a microcontroller as the core, and when the communication interface is in the RS485 form, an RS485 communication circuit is provided. In some embodiments, functional units such as an onboard EEPROM, an SWD debugging interface, an RSS485 communication address module, and a power supply circuit may be further provided. For details, reference can be made to the related schematic content of the secondary control circuit 220, which will not be elaborated further.

[0167] Based on the same inventive concept, the embodiments of the present disclosure further provide a control method for a cleaning apparatus, which is configured to control the gas path device of the cleaning apparatus according to any one of the embodiments of the present disclosure.

[0168] As illustrated in FIG. 21, the control method for the cleaning apparatus includes operations described below.

[0169] Operation S1: receiving an instruction from a host computer through a primary control circuit, where the instruction includes an action execution instruction and a query instruction, the action execution instruction is configured to instruct the cleaning apparatus to execute a preset control action, and the query instruction is configured to instruct the cleaning apparatus to report collected working data to the host computer.

[0170] Operation S2: making a judgement based on the instruction, where in response to the instruction being the query instruction, executing operation S3, and in response to the instruction being the action execution instruction, executing operation S4.

[0171] Operation S3: reporting, by the primary control circuit, the currently collected working data to the host computer, the working data including at least one of sensor detection data collected by a secondary control circuit from a sensor, working state data of the secondary control circuit, and working state data of the primary control circuit.

[0172] Operation S4: sending, by the primary control circuit, a preset control instruction to a corresponding secondary control circuit, so that the corresponding secondary control circuit executes a corresponding circuit control action according to the preset control instruction.

[0173] In some examples, the control method for the cleaning apparatus further includes: after completing the execution of the above instruction, or when no instruction is received, controlling whether to start executing a state collection process corresponding to the

primary control circuit based on whether a timing time is valid, where within the timing time, the collection process is started to be executed, and beyond the timing time, the collection process is not started to be executed, and an indication unit is controlled to indicate a corresponding working state.

[0174] In some examples, the state collection process executed by the primary control circuit is to periodically poll information collected and stored by the secondary control circuit, and upload the information to the host computer.

[0175] In some examples, the control method for the cleaning apparatus further includes: after completing the execution of the above instruction, or when no instruction is received, controlling whether to start executing a state collection process corresponding to the secondary control circuit based on whether a timing time is valid, where within the timing time, the collection process is started to be executed, and beyond the timing time, the collection process is not started to be executed, and an indication unit is controlled to indicate a corresponding working state.

[0176] The following provides another example description of the workflows and sampling processes of the primary control circuit and the secondary control circuit.

[0177] As illustrated in FIG. 22 to FIG. 25, based on the workflows and data collection processes of the primary control circuit and the secondary control circuit, the following monitoring control is performed on the cleaning apparatus.

[0178] After the primary control circuit receives the instruction, the following operations are performed.

[0179] In response to the instruction being a query instruction, the working state of the cleaning apparatus currently collected by the primary control circuit is reported to the host computer.

[0180] In response to the instruction being an action execution instruction, such as the above instruction to control the solenoid valve to open the valve, a control instruction is sent to the secondary control circuit to cause a corresponding controlled component to open the valve. The primary control circuit stores the working state (opening/closed) of the solenoid valve, and updates the stored working state according to the responsive information after the control action. For the MFC, a flow control value parameter is further included, and after the foregoing update operation is completed, the current working state information of the component is reported to the host computer. In addition to the state information related to the

control action, the working state information of the target cleaning apparatus collected by the primary control circuit is also synchronously reported to the host computer.

[0181] After completing the execution of the above instruction, or when no instruction is received, the primary control circuit executes a state collection process, and controls whether to start the execution based on whether the timing time is valid. Within the timing time (valid), the collection process is started to be executed, and beyond the timing time (invalid), an indicator is controlled to indicate timeout/abnormality. The foregoing collection process may be configured to be executed periodically when no instruction is received.

[0182] The state collection process of the primary control circuit is to periodically poll and query the information collected and stored by the secondary control circuit, and upload the information to the host computer.

[0183] The primary control circuit may also report, according to an instruction of the host computer, the information collected and stored by the primary control circuit. When the primary control circuit performs a query and responds, a timeout timer T0 is set, and when relevant information is not queried within the timeout period, a timeout/alarm may be reported.

[0184] The device is further provided with a clamp (FOUP latch) and a clamp sensor (FOUP clamp sensor) corresponding to the latch, the clamp sensor being connected to the secondary control circuit.

[0185] The state collection process of the secondary control circuit is to receive the working state information of the cleaning apparatus, specifically including: a state of the solenoid valve, obtained detection information of the above-mentioned pressure sensor, flow sensor, temperature and humidity sensor, position sensor, and clamp sensor, and real-time gas flow information of an MFC. For the MFC, a response time T1 is set, and when relevant information is not collected within a timeout period, a timeout/alarm may be reported.

[0186] After the secondary control circuit receives the instruction, the following operations are performed.

[0187] In response to the instruction being a query instruction, the working state of the cleaning apparatus currently collected by the secondary control circuit is reported to the primary control circuit.

[0188] In response to the instruction being an action execution instruction, for example, to open two output terminals of the solenoid valve, a control instruction is sent to the solenoid valve to open the solenoid valve, the state information of the solenoid valve of the secondary control circuit is updated, and the execution result is responded to the primary control circuit. Various currently collected detection information may also be synchronously reported to the primary control circuit.

[0189] When the secondary control circuit executes the state collection process, the process also controls whether to start execution based on whether a timing time is valid. For details, reference can be made to the foregoing description of the primary control circuit. Upon a timeout/abnormality, an indicator connected to the primary control circuit is controlled to indicate the state.

[0190] In the present disclosure, for the same or similar parts among the various embodiments, reference can be made to each other. Each embodiment focuses on the differences from other embodiments. In particular, for the embodiments described later, the description is relatively simple, and for related parts, reference can be made to the partial descriptions of the foregoing embodiments.

[0191] The above description is only specific implementation modes of the present disclosure, but the scope of protection of the present disclosure is not limited thereto. Any changes or substitutions that can be easily conceived by a person skilled in the art within the technical scope disclosed by the present disclosure should fall within the scope of protection of the present disclosure. Therefore, the scope of protection of the present disclosure should be subject to the scope of protection of the claims.

CLAIMS

1. A gas nozzle device of a cleaning apparatus, comprising:

a gas port assembly, the gas port assembly being an integrally formed assembly enabling elastic deformation and provided with an abutment portion, a connection portion, a first through hole, and a first recess, wherein the first through hole extends from a middle of a top end surface of the abutment portion to a middle of a bottom end surface of the connection portion, and the first recess is located on an outer side wall and between a lower end surface of the abutment portion and an upper end surface of the connection portion, and is an annular recess around an axis of the first through hole;

an upper assembly, provided with a second recess, a second through hole, and a plurality of first connection holes for installation, wherein the second recess is recessed downward from a middle of a top end of the upper assembly, and the second through hole extends from a middle of a bottom surface of the second recess to a bottom end surface of the upper assembly; and

a lower assembly, provided with a third recess, a fourth recess, a gas path connection hole for connecting a gas path, and a plurality of second connection holes for installation, wherein the third recess is recessed downward from a middle of a top end of the lower assembly, the fourth recess is recessed downward from a middle of a bottom surface of the third recess, the gas path connection hole extends from a bottom surface of the fourth recess to a bottom end portion of the lower assembly, and the plurality of second connection holes are disposed corresponding to the plurality of first connection holes;

wherein:

the first connection holes and the second connection holes are configured to fix the upper assembly and the lower assembly on a front open unified pod (FOUP) load plate via fasteners, and the abutment portion is configured for sealed docking with a docking port of a FOUP placed on the FOUP load plate; and

a first accommodation space is formed between a bottom surface of the upper assembly and the third recess, the connection portion is accommodated in the first accommodation space in a compressed and deformed state such that a bottom surface of the connection portion abuts against a bottom surface of the third recess, and the bottom surface of the upper assembly abuts against the upper end surface of the connection portion, and the first recess serves as a second accommodation space to accommodate a partial structure of the upper

assembly between the bottom surface of the second recess and the bottom end surface of the upper assembly.

2. The gas nozzle device of the cleaning apparatus according to claim 1, wherein the lower assembly is further provided with a first opening recessed downward from the middle of the top end of the lower assembly, and the third recess is further recessed downward from a bottom of the first opening, wherein the first opening is configured to accommodate a portion of the connection portion that is compressed and deformed; and/or

wherein the bottom surface of the upper assembly abuts against a top surface of the lower assembly.

3. The gas nozzle device of the cleaning apparatus according to claim 1 or 2, wherein after the upper assembly and the lower assembly are assembled, an edge of the fourth recess in the lower assembly is aligned with an edge of the second through hole in the upper assembly, or an edge of the fourth recess protrudes inward in a radial direction relative to an edge of the second through hole; and

wherein the fourth recess serves as a gas flow passage.

4. The gas nozzle device of the cleaning apparatus according to any one of claims 1 to 3, wherein before the abutment portion is in sealed docking with the docking port of the FOUP, a first gap exists between the lower end surface of the abutment portion and a top end surface of the upper assembly, and serves as a deformation space, so that after the docking port of the FOUP presses against the abutment portion to complete the sealed docking, the lower end surface of the abutment portion is pressed down to abut against the top end surface of the upper assembly.

5. The gas nozzle device of the cleaning apparatus according to claim 4, wherein (D2 - D3) > 2 × H4 or (D2 - D3) > H4, so that during the sealed docking in which the docking port of the FOUP presses against the abutment portion, the second recess provides a deformation space for the abutment portion along an axial direction and a radial direction of the first through hole, wherein D2 represents a width of the second recess, D3 represents a width of the abutment portion, and H4 represent the first gap; and/or

wherein H5 > H6, and H5 > D2 - D3, wherein H5 represents a first height between the top end surface of the abutment portion and the top end surface of the upper assembly before the abutment portion is in sealed docking with the docking port of the FOUP, and H6 represents a second height between the top end surface of the abutment portion and the top

end surface of the upper assembly after the sealed docking between the abutment portion and the docking port of the FOUP is completed; and/or

wherein the first gap is less than 2 mm so that during the sealed docking in which the docking port of the FOUP presses against the abutment portion, the first recess serves as a buffer space to reduce a force when an upper side corner of the first recess abuts against an upper inner edge of the second through hole in the upper assembly.

6. A gas path device of a cleaning apparatus, comprising:

a plurality of gas inlet nozzles and a plurality of gas exhaust nozzles disposed on a respective FOUP load plate of a plurality of FOUP load plates, wherein a respective gas inlet nozzle and/or a respective gas exhaust nozzle includes the gas nozzle device of the cleaning apparatus according to any one of claims 1 to 5;

an inlet gas path connected to a threaded hole in the respective gas inlet nozzle, and an exhaust gas path connected to a threaded hole in the respective gas exhaust nozzle, wherein:

the inlet gas path and the exhaust gas path are each arranged below the FOUP load plate;

the inlet gas path is provided with a diaphragm valve, a first throttle valve, and a filter sequentially connected in series through a pipeline;

a gas output end of the filter is connected to the respective gas inlet nozzle, and clean gas flows into the pipeline from the diaphragm valve, passes through the first throttle valve, the filter, and the respective gas inlet nozzle, and then enters an interior of the FOUP;

the exhaust gas path is provided with a second throttle valve and a vacuum generator sequentially connected in series through a pipeline;

a suction end of the vacuum generator is connected to the respective gas exhaust nozzle, a discharge end of the vacuum generator is connected to an exhaust pipeline, and intake air passing through the second throttle valve is input into the vacuum generator to adjust a working state of the vacuum generator, so that gas in the FOUP is sucked out to the exhaust pipeline when the vacuum generator is working;

a plurality of sensors, disposed on gas path pipelines below the respective FOUP load plate and configured to perform sensing detection on the gas in the gas path pipelines and output corresponding detection data;

a plurality of secondary control circuits, wherein a respective secondary control circuit of the plurality of secondary control circuits is deployed corresponding to the respective FOUP load plate, and is electrically connected to the plurality of sensors and configured to control operations of the sensors and collect detection data of the plurality of sensors; and

a primary control circuit, deployed corresponding to the plurality of FOUP load plates, wherein the primary control circuit is communicatively connected to the plurality of the secondary control circuits, and is configured to control operations of the plurality of secondary control circuits and collect feedback data output by the plurality of secondary control circuits, the feedback data including the detection data of the plurality of sensors.

7. The gas path device of the cleaning apparatus according to claim 6, wherein the respective secondary control circuit is provided with a plurality of digital output interfaces configured for an execution circuit triggered and controlled by a digital quantity to be electrically connected to the respective secondary control circuit;

wherein the gas path device of the cleaning apparatus further comprises a solenoid valve disposed on the inlet gas path and correspondingly electrically connected to a respective digital output interface provided by the respective secondary control circuit, wherein an input end of the solenoid valve is injected with gas, one output end of the solenoid valve is connected to a pneumatic control input end of the diaphragm valve to control an action of the diaphragm valve under a control of the respective secondary control circuit, and another output end of the solenoid valve is connected to the second throttle valve on the exhaust gas path, so that intake air is injected into the vacuum generator through the second throttle valve under the control of the respective secondary control circuit to adjust operation of the vacuum generator; and/or

wherein the gas path device of the cleaning apparatus further comprises a plurality of mass flow controllers disposed on the inlet gas path or the exhaust gas path and correspondingly electrically connected to a digital output interface provided by the respective secondary control circuit, wherein the plurality of mass flow controllers are configured to perform flow stabilization control on a gas flow in the inlet gas path or the exhaust gas path under a control of the respective secondary control circuit, so as to stabilize the gas flow at a set value.

8. The gas path device of the cleaning apparatus according to claim 6 or 7, wherein the respective secondary control circuit is provided with a plurality of IO-Link interfaces

configured for an execution circuit or sensor based on an IO-Link protocol to be electrically connected to the respective secondary control circuit;

wherein the plurality of sensors include at least one of a temperature and humidity sensor, a position sensor, a clamp sensor, a flow sensor, and a pressure sensor;

wherein a sensing portion of the temperature and humidity sensor is disposed in the exhaust gas path to detect a temperature and humidity of gas discharged from the FOUP; and/or

wherein the position sensor is disposed on the FOUP load plate to detect whether the FOUP is placed at a preset position on the FOUP load plate; and/or

wherein the clamp sensor is disposed in the FOUP load plate to detect whether a clamp hooks the FOUP; and/or

wherein the flow sensor is disposed on the inlet gas path to detect a flow of an intake gas; and/or

wherein the pressure sensor is disposed on the exhaust gas path to detect a pressure of an exhaust gas; and/or

wherein a communication connection between the primary control circuit and the respective secondary control circuit includes RS485 remote communication.

9. A control method for a cleaning apparatus, configured to control the gas path device of the cleaning apparatus according to any one of claims 6 to 8, the control method for the cleaning apparatus comprising:

receiving an instruction from a host computer through the primary control circuit, wherein the instruction includes an action execution instruction and a query instruction, the action execution instruction is configured to instruct the cleaning apparatus to execute a preset control action, and the query instruction is configured to instruct the cleaning apparatus to report collected working data to the host computer;

in response to the instruction being the query instruction, reporting, by the primary control circuit, the currently collected working data to the host computer, the working data including at least one of: sensor detection data collected by the respective secondary control circuit from a sensor, working state data of the respective secondary control circuit, and working state data of the primary control circuit; and

in response to the instruction being the action execution instruction, sending, by the primary control circuit, a preset control instruction to the respective secondary control circuit, so that the respective secondary control circuit executes a corresponding circuit control action according to the preset control instruction.

10. The control method for the cleaning apparatus according to claim 9, further comprising:

after completing the execution of the instruction, or when no instruction is received, controlling whether to start executing a state collection process corresponding to the primary control circuit based on whether a timing time is valid;

in response to being within the timing time, starting to execute the state collection process; and

in response to being beyond the timing time, not starting to execute the state collection process, and controlling an indication unit to indicate a corresponding working state;

wherein the state collection process executed by the primary control circuit is to periodically poll information collected and stored by the respective secondary control circuit, and upload the information to the host computer, and

wherein the control method for the cleaning apparatus further comprises:

after completing the execution of the instruction, or when no instruction is received, controlling whether to start executing a state collection process corresponding to the respective secondary control circuit based on whether a timing time is valid;

in response to being within the timing time, starting to execute the state collection process; and

in response to being beyond the timing time, not starting to execute the state collection process, and controlling an indication unit to indicate a corresponding working state.

11. An interface circuit of a cleaning apparatus, comprising:

at least one primary control circuit, a respective primary control circuit of the at least one primary control circuit being the primary control circuit in the gas path device of the cleaning apparatus according to any one of claims 6 to 8; and

the plurality of secondary control circuits in the gas path device of the cleaning apparatus according to any one of claims 6 to 8,

wherein the respective primary control circuit includes a first control circuit and a first communication interface communicatively connected to the first control circuit;

wherein the respective secondary control circuit includes a second control circuit, a second communication interface communicatively connected to the second control circuit, and at least one of the following interface units respectively communicatively connected to the second control circuit: an integrated circuit bus interface, a digital input interface, an analog input interface, an IO-link interface, and a digital output interface;

wherein the first communication interface of the respective first control circuit is communicatively connected to the second communication interfaces of the plurality of second control circuits;

wherein the integrated circuit bus interface is configured to provide a communication connection interface for a first sensor supporting the integrated circuit bus, the digital input interface is configured to provide a communication connection interface for a second sensor supporting digital output, the analog input interface is configured to provide a communication connection interface for a third sensor supporting analog output, the IO-link interface is configured to provide a communication connection interface for a fourth sensor and/or a first execution circuit supporting an IO-link protocol, and the digital output interface is configured to provide a communication connection interface for a second execution circuit triggered and controlled by a digital quantity.

12. The interface circuit of the cleaning apparatus according to claim 11, wherein the digital input interface includes: an input interface, an output interface, a first resistor, a second resistor, a third resistor, a fourth resistor, a first capacitor, a second capacitor, and a photoelectric coupling circuit;

wherein the input interface is configured to provide a communication connection interface for the second sensor, and is electrically connected to one end of the first resistor, another end of the first resistor is electrically connected to a first input end of the photoelectric coupling circuit, the first input end and a second input end of the photoelectric coupling circuit are connected in parallel with the second resistor and the first capacitor, the second input end of the photoelectric coupling circuit is grounded, a first output end of the photoelectric coupling circuit is connected to a first power supply through the third resistor and is electrically connected to the output interface through the fourth resistor, the second

capacitor is connected in parallel between the output interface and the ground, and the output interface is communicatively connected to the second control circuit.

13. The interface circuit of the cleaning apparatus according to claim 11 or 12, wherein the analog input interface includes: a differential interface, a first operational amplifier, a second operational amplifier, a fifth resistor, a sixth resistor, a seventh resistor, an eighth resistor, a ninth resistor, a tenth resistor, an eleventh resistor, a third capacitor, and a fourth capacitor;

wherein the differential interface is configured to provide a communication connection interface for the third sensor, two pins of the differential interface are respectively coupled to an inverting input terminal and a non-inverting input terminal of the first operational amplifier through the fifth resistor and the sixth resistor, the seventh resistor is connected in parallel with the two pins of the differential interface, the eighth resistor is connected in parallel between the non-inverting input terminal of the first operational amplifier and the ground, the ninth resistor and the third capacitor are connected in parallel and then connected in series between the inverting input terminal and an output terminal of the first operational amplifier, the tenth resistor is connected in series between the output terminal of the first operational amplifier and a non-inverting input terminal of the second operational amplifier, an inverting input terminal and an output terminal of the second operational amplifier are electrically connected, the output terminal of the second operational amplifier is communicatively connected to the second control circuit through the eleventh resistor, and one end of the eleventh resistor that is electrically connected to the second control circuit is coupled to the ground through the fourth capacitor;

wherein the analog input interface further includes: a twelfth resistor, a fifth capacitor, and a sixth capacitor;

wherein one end of the twelfth resistor is connected in series between the non-inverting input terminal of the second operational amplifier and the tenth resistor, the non-inverting input terminal of the second operational amplifier is coupled to the ground through the fifth capacitor, and the sixth capacitor is connected in parallel between the inverting input terminal and the non-inverting input terminal of the second operational amplifier; and

wherein the analog input interface further includes: an analog-to-digital conversion circuit, wherein the output terminal of the second operational amplifier is coupled to an input terminal of the analog-to-digital converter through the eleventh resistor, and an output

terminal of the analog-to-digital converter is communicatively connected to the second control circuit.

14. The interface circuit of the cleaning apparatus according to any one of claims 11 to 13, wherein the digital output interface includes: an input interface, an output interface, a first metal-oxide-semiconductor (MOS) transistor, a second MOS transistor, a thirteenth resistor, a fourteenth resistor, a fifteenth resistor, a sixteenth resistor, and a seventh capacitor;

wherein the input interface is communicatively connected to the second control circuit, the input interface is connected to a gate of the first MOS transistor, the gate of the first MOS transistor is coupled to the ground through the thirteenth resistor, a source of the first MOS transistor is grounded, a drain of the first MOS transistor is connected to one end of the fourteenth resistor, another end of the fourteenth resistor is connected to a gate of the second MOS transistor, the gate of the second MOS transistor is coupled to a second power supply through the fifteenth resistor, a drain of the second MOS transistor is connected to the second power supply, a source of the second MOS transistor is coupled to the ground through the sixteenth resistor, the source of the second MOS transistor is connected to the output interface, and the seventh capacitor is connected in parallel with the sixteenth resistor.

15. The interface circuit of the cleaning apparatus according to any one of claims 11 to 14, wherein:

the first sensor includes a temperature and humidity sensor; and/or

the second sensor includes a position sensor and/or a clamp sensor; and/or

the third sensor includes a flow sensor and/or a pressure sensor; and/or

the second execution circuit comprises a solenoid valve; and/or

the second control circuit is communicatively connectable to a mass flow controller.