outflow through the valve. The process gas is usually fed in on a side of the process chamber opposite the evacuation opening.

Besides the gas concentration and the atmospheric pressure, a distribution of the process gas that is as homogeneous as possible at least in the region of the substrate to be machined is advantageous. A most symmetrical possible flow of gas through the process chamber, i.e. both when feeding in gas and when evacuating, can be helpful for this.

US 6,994,311 B2 discloses a vacuum regulating valve with the aim of establishing a symmetrical flow through an opening in an open valve position. The valve plate is suspended centrally on a guide (valve rod) and can be guided axially, so that a volume flow through the opening can be set as a function of the distance between the valve plate and the valve seat. However, one disadvantage of this solution is that, in order to provide the guide for the valve plate, a mechanical connection must be present in the centre of the valve opening. This mechanical connection eliminates the symmetry of the flow at least in parts and leads to turbulence at the connection elements.

Summary

In an aspect, the present disclosure refers to a vacuum machining system, comprising

- a vacuum chamber which defines an evacuable internal volume for generating a vacuum and for machining a substrate in the internal volume, and
- a vacuum regulating valve for regulating a volume flow or mass flow of a fluid flowing through the vacuum chamber and for interrupting a flow path of the fluid in a gas-tight manner, said valve having
  - a first valve seat, which has a first valve opening defining a first opening axis and a first sealing surface extending around the first valve opening, and

- a first valve plate with a first contact surface corresponding to the first sealing surface, and
- a drive unit, which is designed in such a way and is coupled to the first valve plate in such a way that the latter can be moved at least from
- an open position, in which the first valve plate and the first valve seat are not in contact with each other, to
- a closed position, in which sealing contact between the first sealing surface and the first contact surface exists via a sealing element located therebetween and the first valve opening is thereby closed in a gas-tight manner,

and back again,

characterized in that

- the first valve seat is arranged within the vacuum chamber and divides the vacuum chamber into a main process chamber for machining the substrate and into a secondary process chamber,
- the first sealing surface extends orthogonally to the first opening axis and points in the direction of the secondary process chamber, and
- the first valve plate is movably arranged in the secondary process chamber.

In an example, an object of the present disclosure is therefore to provide a vacuum regulating valve and vacuum machining system which, on the one hand, precisely regulates or sets the valve opening and thus a flow through the opening and, on the other hand, provides a homogeneous fluid distribution in a process chamber.

In particular, one example is to provide the above improvements while achieving comparatively short movement times of the valve closure.

A further example is to provide a machining system which precisely regulates a fluid flow and provides a comparatively small process volume.

These examples are achieved by implementing the features of the independent claims. Features that further develop the invention

in an alternative or advantageous manner are to be found in the dependent claims.

The disclosure relates, in an example, to a design of a vacuum machining system which comprises at least one vacuum chamber or process chamber and a vacuum valve, in particular a vacuum regulating valve. The vacuum valve provides for an improved flow of process fluid through and out of a process volume with regard to the homogeneity of the flow behaviour. At the same time, a movement time for changing from an open state to a closed state (or vice versa) can be significantly improved, i.e. reduced. By virtue of the design according to the example, the vacuum chamber is divided into a main chamber and into a secondary chamber by means of the valve, the valve being arranged within the vacuum chamber.

The aforementioned advantages and improvements are in particular provided by dividing a single valve opening, as known to date in the prior art, into a plurality of valve sub-openings of the vacuum valve. The sub-openings are preferably arranged symmetrically around a central valve axis. Each valve sub-opening is provided by a respective valve seat and is surrounded by a respective sealing surface. The sum of the areas of the plurality of valve sub-openings yields the area of the total valve opening.

The total valve opening cross-section results from the sum of the opening cross-sections of the plurality of valve sub-openings, wherein the opening cross-section depends on the respective open state of the valve sub-openings, i.e. on the flow area exposed by the respective valve closure.

The valve seats form in particular a lower boundary of the main process chamber and an upper boundary of the secondary process chamber. A seal for establishing a gas-tight closure of the main process chamber is preferably provided on the underside of the valve seats, that is to say not in the main process chamber but rather in the secondary process chamber. The valve plates for

closing the openings are accordingly located in the secondary process chamber and can be moved in this chamber along a movement axis. As an alternative or in addition, the seal may be provided on the valve plates.

Since the valve plates together with the drive components are arranged in or on the secondary process chamber, a fluid flow in or through the main chamber is not influenced by the valve. As a result, an improved symmetrical (through-)flow and thus an improved substrate machining can take place in the main process chamber.

The valve seats are preferably arranged around the central chuck in such a way that fluid can flow around the chuck with a homogeneous flow distribution.

The disclosure thus relates, in an example, to a vacuum machining system for machining, in particular by means of deposition (ALD, atomic layer deposition/epitaxy) or etching (ALE, atomic layer etching), a substrate or workpiece, in particular a semiconductor.

The vacuum machining system comprises a vacuum chamber which defines an evacuable internal volume for generating a vacuum and for machining a substrate in the internal volume. The vacuum machining system additionally comprises a vacuum regulating valve for regulating a volume flow or mass flow of a fluid flowing through the vacuum chamber and for interrupting a flow path of the fluid in a gas-tight manner.

The vacuum regulating valve has at least a first valve seat, which has a first valve opening defining a first opening axis and a first sealing surface extending around the first valve opening, and at least a first valve plate with a first contact surface corresponding to the first sealing surface.

The vacuum machining system comprises at least one drive unit, which is designed in such a way and is coupled to the first

valve plate in such a way that said valve plate can be moved at least from an open position to a closed position and back again (for example in a motorized manner). In the open position, the first valve plate and the first valve seat are not in contact with each other. In the closed position, sealing contact between the first sealing surface and the first contact surface exists via a sealing element located therebetween, the first valve opening thereby being closed in a gas-tight manner.

According to the disclosure, in an example, the first valve seat is arranged within the vacuum chamber and divides the vacuum chamber into a main process chamber for machining the substrate and into a secondary process chamber. The first sealing surface extends orthogonally to the first opening axis and points in the direction of the secondary process chamber, in particular parallel to the first opening axis. The first valve plate is movably arranged in the secondary process chamber.

In one example, the vacuum regulating valve may have a second valve seat, which has a second valve opening defining a second opening axis and a second sealing surface extending around the second valve opening, and a second valve plate with a second contact surface corresponding to the second sealing surface. The second valve seat may be arranged within the vacuum chamber and, together with the first valve seat, may divide the vacuum chamber into the main process chamber and the secondary process chamber. The second sealing surface extends orthogonally to the second opening axis and points in the direction of the secondary process chamber, in particular parallel to the second opening axis. The second valve plate may be movably arranged in the secondary process chamber.

As a result, a total valve opening of the vacuum regulating valve may be formed at least by the first valve opening as a first valve sub-opening and the second valve opening as a second valve sub-opening.

Providing at least two groups, each comprising at least one valve seat and one valve closure (valve plate), permits a symmetrical arrangement around a centre of the vacuum valve. Consequently, on the one hand a symmetrical volume flow through the valve can be provided, and on the other hand comparatively quick actuation (i.e. quick movement of the valve closures due to the comparatively low individual masses of the valve closures) can be provided, with the possibility of very flexible regulation of the volume flow, i.e. also reaching a comparatively large total opening cross-section from a closed position (and vice versa) within a short time.

In one example, the vacuum regulating valve may have a third valve seat, which has a third valve opening defining a third opening axis and a third sealing surface extending around the third valve opening. A third valve plate with a third contact surface corresponding to the third sealing surface may accordingly be provided.

The third valve seat may be arranged within the vacuum chamber and, together with the first and second valve seat, may divide the vacuum chamber into the main process chamber and the secondary process chamber. The third sealing surface may extend orthogonally to the third opening axis and may point in the direction of the secondary process chamber, in particular parallel to the third opening axis. The third valve plate may be movably arranged in the secondary process chamber.

In this case, the total valve opening may additionally be formed by the third valve opening as a third valve sub-opening.

By arranging a third combination or further combinations of valve seat and valve plate, the symmetry of the total valve opening around a central axis of the valve can be maintained or enhanced, and thus the symmetry of the volume flow (concentrically) through the valve can be further improved.

In particular, the drive unit may be coupled to the second and third valve plate in such a way that the coupled valve plates can be moved at least from a respective open position, in which the respective valve plate and the respective valve seat are not in contact with each other, to a closed position, in which axially sealing contact between the respective sealing surface and the respective contact surface exists via a respective sealing element located therebetween and the respective valve sub-opening is thereby closed in a gas-tight manner, and back again.

The drive unit may be designed, for example, as an actuator or electric motor, in particular a linear motor or stepper motor.

In one example, the vacuum regulating valve may have a coupling arrangement, which coupling arrangement mechanically couples the first valve plate to the second valve plate, and in particular to the third valve plate, in such a way and is connected to the drive unit in such a way that the respective valve plates can be jointly moved by means of the drive unit. The coupling arrangement may be implemented, for example, using a shaft, joints (for example universal joints), bearings and/or transmissions.

Thus, by means of a mechanical solution for example, some or all coupled valve plates can be moved simultaneously. In particular, a homogeneous and symmetrical fluid flow through the valve can thus be achieved in that an equal opening cross-section is provided for all the openings right from when the valve sub-opening is first opened, and the flow through all the openings is equal with regard to the volume flow or mass flow and then remains equal.

According to a further example, the drive unit may have at least a first and a second, in particular a third, drive component, in particular respective motors. The first drive component may be coupled to the first valve plate and the second drive component may be coupled to the second valve plate, and

in particular the third drive component may be coupled to the third valve plate.

In contrast to the preceding example, in this variant each of the valve plates can be actuated and moved individually. This permits greater flexibility with regard to setting the flow behaviour through the valve and in particular through the main process chamber. For example, it is thus possible to compensate for asymmetries of the volume flow caused by machining devices present in the process chamber or caused by an asymmetrical arrangement of fluid inlets. Such compensation can be achieved by providing different opening cross-sections for the individual valve sub-openings.

In particular, the flow behaviour within the chamber can be set in such a way that it is possible to compensate for an asymmetric flow caused for example by a device in the chamber for machining a substrate. The flow would accordingly take place in an inhomogeneous manner through the process chamber if using a conventional valve. Because the outflow behaviour can be set by means of the valve according to the invention, the outflow of fluid can counteract the asymmetrical flow through the chamber and thus ultimately result in a flow through the chamber that is symmetrical overall. The flow through the valve may in this case accordingly take place in an asymmetrical manner (non-centric, i.e. asymmetrical in relation to a central axis). By way of example, there may be different flow velocities on different (for example opposite) sides of the valve.

In one example, the drive unit, in particular the respective drive components, and at least the first valve plate (or also the second, the third or more valve plates) may be designed and coupled in such a way that at least the first of the valve plates can be moved along a first movement axis, and the first movement axis extends transversely relative to the first opening axis. It will be understood that the number of valve plates preferably corresponds to the number of valve seats, i.e. a valve may have

a plurality of (more than three) valve seats and a corresponding number of valve plates.

According to one example, the main process chamber may enclose a main internal volume and the secondary process chamber may enclose a secondary internal volume, the main internal volume being larger than the secondary internal volume.

In one example, the vacuum machining system may have an electrostatic holding device, in particular a chuck, arranged in the main process chamber.

The vacuum regulating valve may in particular have at least the first valve seat and at least two further valve seats, and the valve seats may define a first valve opening and at least two further valve openings. The valve seats may be arranged symmetrically around the electrostatic holding device.

In one example, the valve seats and/or the valve openings may be ring-segment-shaped and may be arranged in such a way that respective inner arcs or outer arcs of the ring-segment-shaped valve seats and/or valve openings lie on a common circle.

The chuck may for example be round and/or may define a circular surface as a holding surface for a substrate. Due to the overall ring-shaped arrangement of the valve opening around the chuck, a correspondingly optimized fluid flow behaviour around and over the chuck can be achieved.

In one example, the first and the second valve sub-opening, in particular the third valve sub-opening, may be arranged symmetrically around a central axis of the vacuum regulating valve, the central axis extending through a valve centre and in particular forming a central axis of the flow channel. Due to its geometry, the valve may define on the one hand a flow path for a fluid, and thus on the other hand a bounded flow channel for the fluid. The central axis lies in particular in the middle of this channel and extends along the extension of the channel.

A centre of the chuck support surface lies in particular on the central axis.

By means of a valve according to the disclosure, the flows mentioned above can advantageously be regulated, i.e. even at very low pressures and while providing and maintaining a substantially symmetrical and laminar flow.

The vacuum machining system may in particular comprise a control unit, in particular a regulating unit, wherein the drive unit (and the drive components thereof) can be actuated on the basis of a control signal provided by the control unit, in particular on the basis of a regulating variable.

In particular, each drive component of the drive unit may be able to be actuated individually by means of an (individual) control signal.

In one example, the control unit may have a flow functionality configured in such a way that, upon execution thereof, at least one of the valve plates coupled to the drive unit is moved to an intermediate position between the open position and the closed position.

In particular, the at least one coupled valve plate may be able to be moved linearly along a movement axis and a distance between the contact surface of said valve plate and the corresponding sealing surface in the intermediate position may be smaller than in the open position and greater than in the closed position.

According to one example, the vacuum regulating valve may have at least the first and the second valve seat, the first and the second valve plate, as well as the first drive component, which is coupled to the first valve plate, and the second drive component, which is coupled to the second valve plate. The flow functionality may in this case be configured in such a way that the valve plates can be individually positioned between the

fluid flow through the main process chamber can be provided as a function of the flow information. For example, when there is an uneven fluid distribution in one of the process chambers or when there is a spatially uneven inflow of fluid into the main process chamber, this can be achieved by setting and/or dynamically adjusting different opening cross-sections for the individual valve sub-openings. However, this can also be achieved, for example, by setting equal opening cross-sections for the valve sub-openings if the fluid distribution or the fluid inflow is homogeneous.

In one example, the positioning of the valve plates can be individually dynamically adjusted and thus the fluid flow through the main process chamber can be continuously regulated. If the fluid distribution in the process chamber changes, for example if a new or different process gas is added, the valve plate positions can be adjusted during or before a machining process.

In one example, a defined flow behaviour can be set and/or regulated by the vacuum regulating valve, in particular by the at least two valve sub-openings, in particular wherein the flow behaviour can be set by the vacuum regulating valve in an asymmetric manner with respect to a central axis of the vacuum regulating valve and the central axis extends through a valve centre.

In one example, if there is an inhomogeneous fluid flow through the main process chamber, a symmetrical fluid flow can be set by executing the flow functionality.

The vacuum machining system comprises in particular at least one sensor unit, which is designed in such a way that the flow information can be detected by means of the sensor unit, in particular a pressure sensor or a sensor for chemically analysing a gas composition.

In one example, the flow path may connect the main process chamber and the secondary process chamber, wherein the main process chamber can be separated from the secondary process chamber in a gas-tight manner by the vacuum regulating valve, i.e. the flow path can be closed.

According to one example, the first valve seat and the second valve seat may be arranged in a common plane. Alternatively, the first valve seat and the second valve seat may be arranged at an angle relative to each other in such a way that the plane defined by the first sealing surface and the plane defined by the second sealing surface enclose a defined angle. The valve seats may for example be oriented in such a way that the defined sealing planes each comprise one side face of a virtual pyramid.

In one example, the orientation may be such that the opening axes defined by the respective valve opening of a valve seat intersect, in particular intersect at a common point of intersection. The common point of intersection lies in particular on the central axis of the valve.

According to one example, the drive unit comprises at least one motor and at least one guide component, in particular a valve rod or guide rod, which can be moved along a movement axis in a manner controlled by the at least one motor, wherein the valve plate with the guide component can be moved relative to the valve seat.

The position of the movement axis is in particular defined by the extension of the guide component, which for example is designed and referred to as a push rod, valve rod or guide rod, and/or by the linear movement direction provided by the drive unit.

In one example, the vacuum machining system or the vacuum regulating valve may have a separating device for separating a process atmosphere area from an external atmosphere area. In