

the third frame web axis intersects the second frame web axis at right angles at a third vertex associated with third frame web and to the second frame web and a third frame vertex region of the outer carrier frame at which the third frame web and the second frame web are integrally connected,

a plurality of substrate holding arms extend inwardly and upwardly from the outer carrier frame which overlap with the inner zone and form the substrate seat, which is located at a distance above the vertical extent of the carrier frame and is adapted to carry a plate-shaped substrate having a circular circumference and a diameter corresponding to a predetermined allowable diameter or within a predetermined allowable diameter range given by a predetermined allowable minimum diameter and a predetermined allowable maximum diameter,

the substrate seat defines a horizontal carrying plane which, in case that a plate-shaped substrate having a circular circumference and a diameter corresponding to the predetermined allowable diameter or the predetermined allowable maximum diameter is carried and held horizontally by the substrate seat, is coplanar with a lower surface of this plate-shaped substrate.

[0011] Accordingly, the outer carrier frames of the substrate carriers, in view of the above-described arrangement of the frame webs and the frame axes, have a generally or at least roughly quadratic or rectangular shape.

[0012] The disclosure of WO 2014/107818 A2 is incorporated herein by reference in its entirety.

[0013] The laid-open publication US 2017/0372930 A1, also originating from TEC-SEM AG and published on December 28, 2017, discloses substrate carriers of this kind and a substrate carrier stack of this kind which have additional characteristic features. As proposed in US 2017/0372930 A1, each substrate carrier of the proposed substrate carrier stack includes, in addition to the above-mentioned features, also the following features:

[0024] Each substrate carrier includes at its outer carrier frame at least one upper supporting formation and at least one lower supporting formation such that a lower substrate carrier of a respective pair of vertically adjacent substrate carriers of the substrate carrier stack supports with the at least one upper supporting formation the upper substrate carrier of the pair of vertically adjacent substrate carriers at the at least one lower supporting formation.

[0025] Each substrate carrier of the substrate carrier stack further includes the following features:

the outer carrier frame includes a first frame web extending along a first frame web axis, a second frame web extending along a second frame web axis, a third frame web extending along a third frame web axis, and a fourth frame web extending along a fourth frame web axis,

the first frame web axis intersects the fourth frame web axis at right angles at a first vertex associated with the first frame web and to the fourth frame web and a first frame vertex region of the outer carrier frame at which the first frame web and the fourth frame web are integrally connected,

the first frame web axis intersects the second frame web axis at right angles at a second vertex associated with the first frame web and to the second frame web and a second frame vertex region of the outer carrier frame at which the first frame web and the second frame web are integrally connected,

the third frame web axis intersects the fourth frame web axis at right angles at a fourth vertex associated with the third frame web and to the fourth frame web and a fourth frame vertex region of the outer carrier frame at which the third frame web and the fourth frame web are integrally connected,

the third frame web axis intersects the second frame web axis at right angles at a third vertex associated with third frame web and to the second frame web and a third frame vertex region of the outer carrier frame at which the third frame web and the second

wafers which are held by respective substrate carriers. If the substrate carrier stack is positioned differently, such as, on an inclined plane or even rotated about, e.g., 90 degrees, the frame plane of the outer carrier frame of a respective substrate carrier would not be a "horizontal" plane in a strict sense, and also some other indications relating to terms such as "horizontal" or "horizontally" and "vertical" or "vertically" would not apply in a strict sense. In view of these considerations, these indications should be understood to implicitly relate to an intrinsic Cartesian coordinate system of the substrate carrier stack, having one vertical axis and two horizontal axes, independently of an actual orientation of the substrate carrier stack with respect to a horizontal reference plane.

[0029] Concerning the frame web axes and the vertices it is to be noted, that the frame web axes are preferably to be assumed to extend at least partially within the respective associated frame web, but this is not mandatory. Further, it is not mandatory that the respective vertex is assumed to be located within the respective frame vertex region. Whether and to which extent such assumptions make sense will depend on the exact geometry of the frame web and the frame vertex regions and therewith the outer carrier frame, for example, which should have a roughly quadratic or rectangular shape. Generally one may assume that the frame web axes coincide with straight centroidal lines of the respective frame web. Depending on the shape of the frame webs and their extent in vertical direction, this assumption might have the consequence that the vertices are located above the respective associated frame vertex region of the outer frame web.

[0030] According to a preferred embodiment of the present invention, the frame vertex regions are vertically aligned with each other and coinciding with the lowermost portions of a respective substrate carrier. In such a case it would

[0064] In other words, the two substrate carriers of each pair of vertically adjacent substrate carriers of the substrate carrier stack are able to be rotated about a vertical rotation axis by 180 degrees relatively to each other to provide the substrate carrier stack. Preferably, certain features of the substrate carriers have a rotational symmetry of order two and certain features of the substrate carriers have a rotational symmetry of order one with respect to a rotation about a vertical rotation axis, such that the frame webs of a respective substrate carrier are able to be distinguished from each other.

[0065] Preferably, each substrate carrier of the substrate carrier stack includes at least one first positioning formation and at least one second positioning formation, wherein for each pair of vertically adjacent substrate carriers the at least one first positioning formation of the lower substrate carrier of this pair of vertically adjacent substrate carriers is engaged or engageable with the at least one second positioning formation of the upper substrate carrier of this pair of vertically adjacent substrate carriers, to safeguard or contribute to a proper relative positioning of the two substrate carriers of this pair of vertically adjacent substrate carriers.

[0066] Preferably, the first and second positioning formations are arranged and structured such that a respective first positioning formation, for example, one of a protrusion and an opening and a recess, of one substrate carrier is able to engage with a respective second positioning formation, for example the other of a protrusion and an opening or a recess, of another substrate carrier being the vertical adjacent substrate carrier located above or below in the substrate carrier stack, even if the substrate carrier stack includes only substrate carriers which are identically provided with the first and second positioning formations.

[0067] In particular, each substrate carrier of the substrate carrier stack is able to be identically provided with the at

substrate holding arm and a second substrate holding arm, which are provided at one of the first frame web and the second frame web of the frame webs, and a third substrate holding arm and a fourth substrate holding arm, which are provided at one of the third frame web and the fourth frame web of the frame webs, whose frame web axis extends parallel or substantially parallel to the frame web axis of the frame web at which the first substrate holding arm and the second substrate holding arm are provided.

[0075] A connection point of the first substrate holding arm, where the first substrate holding arm merges into the respective frame web, and a connection point of the fourth substrate holding arm, where the fourth substrate holding arm merges into the respective frame web, is able to have the same distance from the respective nearest frame vertex region, and a connection point of the second substrate holding arm, where the second substrate holding arm merges into the respective frame web, and a connection point of the third substrate holding arm, where the third substrate holding arm merges into the respective frame web, is able to have the same distance from the respective nearest frame vertex region. However, the distance of the connection points of the first substrate holding arm and the fourth substrate holding arm from the respective nearest frame vertex region are able to differ from the distance of the connection points of the second substrate holding arm and the third substrate holding arm from the respective nearest frame vertex region.

[0076] The proposed arrangements of the substrate holding arms discussed above enable or cause vertically adjacent neighboring substrate holding arms of vertically adjacent substrate carriers within the substrate carrier stack to not vertically overlap, so that a relatively small pitch, namely smaller vertical distances between the substrate seats within the substrate carrier stack, are able to be provided, resulting

vertically staggered projections.

[0081] Preferably, a first projection is provided at the first frame vertex region or at the fourth frame web near the first frame vertex region, and a fourth projection is provided at the fourth frame vertex region or at the fourth frame web near the fourth frame vertex region, the first and fourth projections protrude in the same horizontal direction, and a second projection is provided at the second frame vertex region or at the second frame web near the second frame vertex region, and a third projection is provided at the third frame vertex region or at the second frame web near the third frame vertex region, the second and third projections protrude in the same direction which is opposed to the horizontal direction in which the first and fourth projections protrude.

[0082] Alternatively, a first projection is provided at the first frame vertex region or at the first frame web near the first frame vertex region, and a second projection is provided at the second frame vertex region or at the first frame web near the second frame vertex region, the first and second projections protrude in the same horizontal direction, and a third projection is provided at the third frame vertex region or at the third frame web near the third frame vertex region, and a fourth projection is provided at the fourth frame vertex region or at the third frame web near the fourth frame vertex region, the third and fourth projections protrude in the same direction which is opposed to the horizontal direction in which the first and second projections protrude.

[0083] According to a preferred embodiment of the present invention, the first and fourth projections or the first and second projections are projections of a first type and the second and third projections or the third and fourth projections are projections of a second type, wherein a projection of the first type and a projection of the second type have different shapes or/and are positioned differently at or relatively to the

embodiment, the protrusions 150a, 150b and the openings or recesses 152a, 152b, and the engagement between the sealing ridges or sealing lips 204 and the associated upper sealing ring surface portions of the outer carrier frame 140, are the only portions or elements of contact or at least mutual form-fit engagement between vertically next neighboring substrate carriers 112 in the substrate carrier stack 110. Further, it is proposed that the positioning engagement between the positioning formations is an engagement which causes no vertically directed forces which act between next neighboring substrate carriers.

[0178] Preferably, the same is true for the engagement between the uppermost substrate carrier 112 and the cover 116 and for the engagement between the base 114 and the lowermost substrate carrier 112. Vertical forces preferably act between the respective elements of these two pairs of elements only via the respective sealing formations, an upper ring sealing surface portion of the base 114 and a lower ring sealing surface portion or - preferably - also a sealing ridge or sealing lip of the cover 116 according to the present preferred embodiment.

[0179] For the purging treatment of substrates 130 held by the substrate carriers 112 within the substrate carrier stack 110, horizontal purging gas flows between vertically neighboring substrates 130 are preferred, which emanate from the first vertical purging channels 170a and 170b and enter into the second vertical purging channels 172a and 172b, or emanate from the second vertical purging channels 172a and 172b and enter into the first vertical purging channels 170a and 170b, which are respectively defined by the inner openings 166a and 166b and 168a and 168b. The purging gas traverses the partition webs 160a and 160b on either side of the substrates, in particular at least the first and second arc-shaped portions 202a and 202b thereof. In the shown preferred embodiment, these partition webs on either side of the inner accommodation space include,

alternatingly, first partition webs 160a and second partition webs 160b, due to the relative rotational positioning of next adjacent substrate carriers, as described in the foregoing. This is able to be achieved in a simple manner by dimensioning the thicknesses of the partition webs such that there is a gap between next neighboring partition webs, in particular at least between next neighboring arc-shaped portions thereof.

[0180] However, instead, it is preferred to provide for longitudinal purging nozzles or line nozzles, which are able to be obtained by appropriately shaping the upper and lower surface of the respective partition web, such that a nozzle opening is obtained in a sectional view which tapers in the inward direction, such as shown in Fig. 17B. Preferably, the smallest opening width which defines the nozzle opening is provided at or very near to the inner edge of the partition webs. As shown in Fig. 17B, it is sufficient to suitably shape only one surface of the lower surface of the partition web of the upper substrate carrier and the upper surface of the partition web of lower substrate carrier. In view of the overall shape of the substrate carriers, it is preferred that the lower surface of the upper substrate carrier is shaped to provide the tapering, as shown in Fig. 17B, for example. By providing such longitudinal purging nozzles or line nozzles, the flowing speed of the purging gas emanating from the respective vertical purging channels is accelerated in the course of passing the partition webs, which helps to achieve laminar purging gas flows through the spaces between neighboring substrates.

[0181] Fig. 17B shows a cross-sectional side view of detail B in Fig. 17A, namely, medial regions of the arc-shaped portions 202a and 202b of the partition webs 160a and 160b with their connection portions 200a and 200b of the partition webs 160a and 160b, with neighboring edge portions of the substrate 130 stored within the corresponding substrate carrier stack. As shown in Fig. 17B, the vertical purging channels on one side of

the substrates 130 are horizontally connected by horizontal channels delimited by neighboring connection portions 200a and 200b of the stacked substrate carriers, so that a horizontal purging gas flow between next neighboring substrates is obtained also along the horizontal extent of these connection portions 200a and 202b. Corresponding line nozzle portions open inwardly towards the substrate carriers as shown in Fig. 17B. These line nozzles preferably extend along the complete extent of the arc-shaped sections 202a and 202b of the partition webs 160a and 160b and also over a substantial or complete extent of the two connection portions 200a and 200b at both ends of the arc-shaped portions which merge into and connect the arc-shaped portions with the respective frame web of the outer carrier frame 140.

[0182] Due to the substrate holding arms, which extend upwardly and inwardly from the upper edge of the outer carrier frame 140, a substrate 130 held by a respective substrate carrier 112 is preferably located not within the vertical extent of the arc-shaped portions 202a and 202b and the connecting portions 200b of the partition webs 160a and 160b of this substrate carrier, but at a vertical distance above these elements of the respective substrate carrier 112. The four respective edge sections of the substrates 130 shown in Fig. 17B are held by a respective one of four further substrate carriers, which are not shown in Fig. 17B and are located below the four shown substrate carriers in the substrate carrier stack. Fig. 17A shows eight substrates 130, namely the four substrates 130 indicated also in Fig. 17B as well as four additional substrates 130 which are held in the respective substrate seat of the four substrate carriers shown in Fig. 17B as well as in Fig. 17A.

[0183] The vertical distance between a respective substrate held in the seat of a substrate carrier and the upper edge or rim of the outer carrier frame 140 of the substrate carrier is able to vary among preferred embodiments of the present invention. For example, the distance between next neighboring

protrusions 150a, 150b and the openings or recesses 152a, 152b, such that adjacent substrate carriers in the substrate carrier stack have been rotated by 180° about a vertical axis of rotation, is illustrated in Fig. 18A. Three such substrate carriers are shown with appropriate alternate relative positioning, where the relative displacement of the three substrate carriers in the drawing plane shall symbolically represent a vertical displacement there between such as shown in Fig. 19 for four substrate carriers relatively positioned in this way. In Fig. 19, as well as in Fig. 18A, the location of the details C and B, as defined and shown in Figs. 12A, 12B, 12C, and 14 is indicated. In Fig. 19, a small variation of the position of the shown protrusion with respect to a sloping upper surface portion of the outer carrier frame 140 for the shown substrate carriers may be identified. In this respect, it is to be noticed that Fig. 19 is a view corresponding to the view direction given by arrow XIV in Fig. 12A or corresponding to the opposite view direction on the respective substrate carrier.

[0192] Fig. 18A and Fig. 19 show the relative arrangement of the substrate holding arms of vertically neighboring carriers, as achieved by the explained particular symmetric and asymmetric arrangement of the substrate holding arms. What is achieved is that the vertically next neighboring substrate holding arms, for example in Fig. 19, the substrate holding arms 132a and 132c, and the substrate holding arms 132b and 132d, do not vertically overlap and are located transversely displaced with respect to each other. This allows for a smaller pitch for the horizontal carrying planes of the substrate seats of the substrate carriers within the substrate carrier stack and therewith reduced vertical distances between next neighboring substrates held within the substrate carrier stack, if all substrate seats accommodate a respective substrate. Fig. 18A shows that two such next adjacent substrate holding arms do not overlap indeed due to their analogous orientation inwardly in a diagonal or

diametrical direction. This is also shown in Fig. 18B which shows the vertex regions 144b and 144d with neighboring sections including substrate holding arms 132b and 132d of plural substrate carriers which are properly stacked on each other.

[0193] Fig. 20 shows the frame vertex portions 144a and 144c of plural substrate carriers 112, which are properly stacked on each other. In particular, the mutual engagement of the protrusion 150a of a respective lower substrate carrier with the opening 152b of an upper substrate carrier can be seen as well as a transversely staggered arrangement of the interfacing projections 154a and 154c of adjacent substrate carriers within the substrate carrier stack. This enables a simplified interaction of external interfacing devices, such as movement devices with respective ones of the substrate carriers, since there is a relatively large vertical gap between vertically aligned interfacing projections, namely between vertically next neighboring interfacing projections 154a as well as between vertically next neighboring interfacing projections 154c.

[0194] According to the shown preferred embodiment, this transverse staggering of these interfacing projections at the four frame vertex regions of the stacked substrate carriers is able to be achieved with only one type of substrate carrier (no subtypes thereof), and the provision of the positioning formations, in the present case, the protrusions 150a, 150b and the openings or recesses 152a, 152b, safeguard a proper stacking of these substrate carriers 112 in the substrate carrier stack 110 with the required alternate relative rotational positions of the substrate carriers, so that the vertically neighboring holding arms are alternately transversely staggered and the vertically neighboring interfacing projections are alternately transversely staggered, as described above.

[0195] Fig. 21, Fig. 22A, and Fig. 22B show an example of a substrate carrier stack 110 according to the fifth preferred embodiment of the present invention. In the present case, well

112 at its sealing ridge or sealing lip 204 and forms a sealing surface. The weight of the substrate carriers 112 and the cover 116 of the substrate carrier stack 110 is supported via this sealing ridge or sealing lip 204, so that sealing is achieved.

[0202] Preferably, in order to enable the purging treatment of the substrates 130 within the substrate carrier stack 110, the base 114 is provided, at the lower side of the carrying plate 210, with an interfacing body 216 which is mounted to the carrying plate 210. The interfacing body includes an integrated purging gas entry connector or purging gas inlet and includes an integrated purging gas return connector or purging gas outlet. These connectors or inlet and outlet are connected via appropriate structures of the base 114 including openings in the carrying plates 210 with associated gas distribution structures or purging structures within the support base 212. These gas distribution structures or purging structures, which are able to include at least one of channels and chambers, are connected via a pair of inflow openings or inflow recesses 218a and 218b and a pair of return flow openings or return flow recesses 220a and 220b with an associated pair of vertical gas distribution channels or vertical purging channels of the substrate carrier stack, so that the purging gas entry connector or purging gas inlet is connected with one pair of these vertical channels and the purging gas return connector or purging gas outlet is connected to the other pair of these vertical channels.

[0203] As shown in Fig. 23, the inflow openings or recesses 218a and 218b which are open upwardly are able to have a rather similar shape as the openings 168a, 168b of the lowermost substrate carrier 112 stacked on the support base 212 to achieve or contribute to laminar purging flows. However, other shapes for the inflow openings or recesses are able to be chosen. One might consider the inflow openings or recesses 218a and 218b and the pairs of openings 168a, 168b and 166a, 166b and 168a, 168b and so forth of the substrate carriers 112 stacked on the support

base 212 and subsequently on each other to commonly belong to the pair of vertical gas distribution channels or vertical purging channels, through which the purging gas is supplied to the explained longitudinal nozzles or line nozzles (or generally longitudinal openings) defined by vertically adjacent partition web of pairs of vertically adjacent substrate carriers 112, so that the purging gas emanates horizontally towards and into the spaces between neighboring substrates held in the seat of a respective substrate carrier of the substrate carrier stack.

[0204] Also, for the return flow openings or return flow recesses 220a and 220b, shapes which are rather similar to the shape of the openings 166a, 166b of the lowermost substrate carrier 112 stacked on the support base 212, and deviate from the shape of these return flow openings or return flow recesses 220a and 220b shown in Fig. 23 are possible. One might consider the reflow openings or recesses 220a and 220b, and the further pairs of opening 166a, 166b and 168a, 168b and so forth of the substrate carriers 112 stacked on the support base 212 and subsequently on each other, to commonly belong to the pair of vertical gas distribution channels or vertical purging channels, into which the purging gas emanates via the explained longitudinal nozzles or line nozzles (or generally longitudinal openings) defined by vertically adjacent partition web of pairs of vertically adjacent substrate carriers 112, after having passed through the spaces between neighboring substrates held in the seat of a respective substrate carrier of the substrate carrier stack.

[0205] Accordingly, purging gas introduced into the substrate carrier stack via the purging gas entry connector or purging gas inlet of the interfacing body is supplied via the inflow openings or recesses 218a and 218b and one pair of the two pairs of vertical purging channels and a first set of the longitudinal nozzles or line nozzles (or generally longitudinal openings) to the substrates, and is returned and discharged from the

substrate carrier stack via a second set of the longitudinal nozzles or line nozzles (or generally longitudinal openings) and the other pair of the two pairs of vertical purging channels and the reflow openings or recesses 220a and 220b, and finally the purging gas return connector or purging gas outlet of the interfacing body.

[0206] The realization of the support base 212 in the form of two plate-shaped elements 212a and 212b, as schematically shown in Fig. 24, enables the manufacture of the support base 212 with the needed internal structures without much effort.

[0207] The base includes, on top of the support base 212, a cylindrical protrusion 214 having a circular cross section, which is able to be integrally formed with the support base 212 or its upper plate-shaped elements 212a or is able to be a separate element attached thereto. This cylindrical protrusion extends into the large opening 164 of the lowermost substrate carriers 112 and has a diameter which exactly or substantially corresponds to the diameter of the substrates 130 carried within the substrate carrier stack in a respective substrate seat. As shown in Fig. 25, the cylindrical protrusion 214 has a height such that the lowermost substrate 130 in the substrate carrier stack, which is held by the lowermost substrate carrier of the substrate carrier stack directly supported by the support basis 212, has purging conditions similar to the other substrate carriers within the substrate carrier stack. To this end, the distance between the upper planar surface of the cylindrical protrusion 214 and the lower surface of this substrate 130 corresponds exactly or substantially to the distance between the lower and upper surfaces of next neighboring substrates held within the substrate carrier stack, if all seats of the substrate carriers carry a respective substrate 130, and if the substrates have a thickness for which the substrate carriers 112 and therewith the substrate carrier stack 110 are optimized. In the case of the shown preferred embodiment, the lowermost three

which may also be denoted as partition ridges, include arc-shaped portions like the arc-shaped portions 202a and 202b of the partition webs and are provided with a respective set of vertically neighboring longitudinal openings 126 extending along the outer circumference of the inner accommodation space, analogous to the line nozzles or longitudinal openings defined by next neighboring partition webs of the substrate carriers, so that horizontal purging gas flows are able to emanate for the purging treatment of substrates also in the height range of the uppermost substrates held by the uppermost substrate carriers 112 of the substrate carrier stack 110, as illustrated in Fig. 28, along with Figs. 17A, 17B, and 25.

[0214] The four substrate carriers 112 shown in Fig. 28 are located in the substrate carrier stack above the substrate carriers of Fig. 17B and hold their respective substrate 130 via their substrate holding arms located within the larger recesses 228 of the cover 116. The smaller recesses 222a, 222b and 224a, 224b with the longitudinal openings or possibly line nozzles 226 in the partition walls 220a and 220b provide for horizontal purging gas flows through the spaces between next neighboring of the substrates 130 and also between the upper surface of the uppermost substrate carrier 112 and the lower surface of the cover within the large recess 228.

[0215] Using the base 114 and the cover 116, identical or substantially identical purging conditions for all substrates 130 within the substrate carrier stack 110 are able to be obtained. Preferably, the longitudinal openings or line nozzles from which the horizontal purging gas flows emanate towards the substrates and into which the purging gas enters after having passed the substrates are provided at equidistant vertical distances, wherein the respective line nozzle or longitudinal opening preferably is located at half height between the lower surface of an upper substrate 130 and the upper surface of a lower substrate 130, between the lower surface of the cover 116

within the recess 128 and the upper surface of the uppermost substrate 130 and between the lower surface of the lowermost substrate 130 and the upper surface of the cylindrical protrusion 214 of the base 114, again assuming substrates that have a thickness for which the substrate carriers 112 and therewith the substrate carrier stack 110 are optimized. However, the substrate carriers 112 and the substrate carrier stack 110 are also able to be used for the storage, handling, and treatment of substrates having other thicknesses.

[0216] It is to be noted that the cover 116 preferably includes horizontally extending interfacing projections 154a', 154b', 154c', and 154d', which are formed by interfacing sections 224a, 224b, 224c, and 224d protruding downwardly from a support surface 229 of a frame portion 227 of the cover 116. The frame portion 227 is supported on the outer carrier frame 140 of the uppermost substrate carrier 112. A lower ring surface strip of the frame portion 227 extending around the large recess 228 and a lower ring surface strip of the outer carrier frame 140 of the uppermost substrate carrier 112 extending around its inner zone 162 form sealing surfaces in mutual engagement to confine the purging gas within the substrate carrier stack 110. Alternatively, one of these surfaces is able to be replaced by a sealing lip or sealing ridge. Preferably, the cover 116 is provided with such a sealing lip or sealing ridge at its frame portion 227, analogous to the sealing lip or sealing ridge 204 of the substrate carriers 112.

[0217] To achieve a proper relative positioning of the cover on the uppermost substrate carrier 112 of the substrate carrier stack 110, one or a plurality of the interfacing sections 224a, 224b, 224c, and 224d are able to be provided with positioning formations analogous to the positioning formations of the substrate carriers. In the present case, the interfacing section 224a is provided with an opening or recess 152b' corresponding to the opening or recess 152b of a respective