Description

Loading and unloading cycle for a CVD reactor system

Technical Field

[0001] The invention relates to a method for simultaneously treating multiple substrates in at least one process chamber of a process chamber assembly, wherein multiple sets, each comprising a number n of substrate carriers, each configured to carry at least one substrate, wherein the multiple sets of substrate carriers can be used cyclically, and in doing so, unprocessed substrate carriers are sequentially loaded with substrates to be processed, introduced into the at least one process chamber of the process chamber assembly, treated in the at least one process chamber at a first elevated temperature, whereby the unprocessed substrates are processed into processed substrates and the unprocessed substrate carriers become processed substrate carriers, are removed from the process chamber at a second elevated temperature, are cooled to a reduced temperature, and are separated from the processed substrates, and an apparatus for carrying out such a method.

Prior Art

[0002] US 2020/0354828 A1 describes an apparatus and a method for depositing semiconductor layers on substrates carried by substrate carriers in at least one process chamber of an MOCVD reactor. A cleaning chamber is provided in which the substrate carriers can be cleaned prior to the deposition process. In various storage chambers, cleaned and processed substrate carriers as well as unprocessed and processed substrates are stored separately from one another, wherein the storage chamber for cleaned substrate carriers can also be cooled.

[0003] US 2022/0333271 A1 discloses a device for treating substrates mounted on ring-shaped substrate carriers in a process chamber, in particular for the deposition of SiC. The unprocessed and processed substrates can be stored outside the process chamber together in a single storage chamber or separately from one another in two storage chambers. In addition, a third storage chamber is provided in which, in the event of an abnormal

situation, substrates with substrate carriers can be stored. After a deposition process, a substrate carrier with one or more substrates can be cooled in a cooling device.

[0004] US 10,790,174 B2 describes a device for transporting substrates, comprising a first storage chamber in which unprocessed substrates are stored and a second storage chamber into which the processed substrates are transferred from a process chamber.

[0005] US 2022/0076976 A1 describes an automated method for depositing thin films. To increase throughput, the heating, processing, and cooling of the substrates are decoupled. For this purpose, a heating chamber, a processing chamber, and a cooling chamber are used, in each of which a substrate carrier loaded with substrates can be treated simultaneously.

[0006] US 2005/0187647 A1 discloses the use of two sets of substrate carriers that are coated in temporally overlapping deposition processes.

[0007] The invention addresses, in particular, the problem that existing methods for the simultaneous treatment of multiple substrates carried by substrate carriers in a process chamber of a CVD reactor result in excessive downtime. In existing CVD systems, after a treatment of the substrates, the substrate carriers are removed individually from the process chamber together with the substrates in a first step. Removal takes place at temperatures of several hundred degrees Celsius. At these temperatures, a separate cooling step is required for each substrate to enable further processing of the substrates. This can be done either before separating the substrate from the substrate carrier or after separation. Therefore, after each removal of a substrate-substrate carrier pair, the pair must first be separated, and the substrate must then be cooled in a designated cooling station. This results in long cooling times, particularly for substrates with high thermal capacity, such as sapphire. After cooling is complete, the substrate is placed in a storage chamber and the substrate carrier is returned to the process chamber. These process steps are repeated until all processed substrates are stored in the storage chamber and all processed substrate carriers are stored in the process chamber. Subsequently, the processed substrate carriers, which, if the treatment involves the deposition of a layer,

have a parasitic coating, are cleaned in the CVD process chamber. For a subsequent treatment, the cleaned substrate carriers are removed individually from the process chamber, loaded with an unprocessed substrate, and then returned to the process chamber. During the cooling phase when unloading the reactor and during the loading of cleaned substrate carriers with unprocessed substrates, the CVD reactor is unproductive. The time during which the CVD reactor is unproductive is multiplied by the number of substrates. In practice, this leads to considerable downtime, thereby significantly reducing the overall productivity of the CVD reactor.

Summary of the Invention

[0008] The invention is based on the objective of providing a method that minimizes the effort required for the simultaneous treatment of multiple substrates in a CVD reactor assembly and maximizes the utilization of the CVD reactor, as well as providing a device for implementing such a method.

[0009] The problem is solved by the invention specified in the claims, wherein the subclaims represent advantageous further developments of the invention claimed in the associated claims.

[0010] First and foremost, a process chamber arrangement, preferably a CVD system, comprising at least one process chamber is provided, which has a total of n storage locations for storing one substrate carrier each, where n is a natural number. Here, each substrate carrier is configured to carry at least one substrate. The unprocessed substrate carriers are loaded one after another with unprocessed substrates until n substrate carriers are each loaded with one unprocessed substrate.

[0011] Loading may take place in a first separation device. After loading, the unprocessed substrate carriers carrying the unprocessed substrates are fed one after another into the process chamber assembly. Subsequently, the substrates are treated in the process chamber at a first elevated temperature. In this process, the unprocessed substrates are processed into processed substrates, and the unprocessed substrate carriers

become processed substrate carriers. During this thermal treat, one or more layers may be deposited on the substrates. Preferably, the deposition process is an MOCVD process in which III-V layers are deposited on the substrate using starting materials from Groups III and V. However, II-VI and/or IV-IV layers, such as SiC layers, may also be deposited.

[0012] After the thermal treatment, the processed substrate carriers bearing the processed substrates are sequentially removed from the process chamber at a second elevated temperature. After removal, the processed substrate carriers bearing the processed substrates are cooled to a reduced temperature and separated from the processed substrates.

[0013] A second separation device may be used to separate the substrates from the substrate carriers. The same separation device may also be used for loading the substrate carriers with substrates and for separating the substrate carriers from the substrates. The separation devices may be arranged in a transfer chamber connected to the process chamber assembly or may be connected thereto. Preferably, the separation of substrate carriers and substrates takes place after cooling.

[0014] After thermal treatment and removal from the process chamber assembly, the substrate carriers bearing the processed substrates can be transferred to a storage chamber assembly and cooled there to the reduced temperature. Two storage chamber assemblies may be used, each comprising one or more storage chambers. The storage chamber assemblies may be arranged within the transfer chamber or connected thereto. In the storage chambers of a first storage chamber assembly with m1 storage locations, only unprocessed substrate carriers, with or without unprocessed substrates, may be stored. In the storage chambers of a second storage chamber with m2 storage locations, only processed substrate carriers, with or without substrates, may be stored.

[0015] The processed substrate carriers holding the processed substrates in the second storage chamber assembly, or the cleaned substrate carriers in the first storage chamber assembly, can be cooled either actively by a cooling element located in each of the

second storage chamber assemblies, or passively by a storage chamber maintained at ambient temperature.

[0016] The first and/or second storage chamber assembly may contain an inert gas atmosphere, such as a nitrogen atmosphere. The pressure in the first and/or second storage chamber assembly can be varied between vacuum and atmospheric pressure.

[0017] The storage of processed and unprocessed substrate carriers, with or without substrates, may also take place in the same storage chamber assembly, in a single storage chamber, or in separate storage chambers. Separate storage of unprocessed and processed substrate carriers prevents contamination of unprocessed components.

[0018] After the processed substrate carriers carrying the processed substrates have been cooled down in the storage chamber assembly, the processed substrates can be separated from the processed substrate carriers in the separation device. After separation, the processed substrate carriers can be returned to the storage chamber assembly. The removed processed substrates can be transported out of the system individually or collected in groups within a first carrier element, such as a Front Opening Universal Pod.

[0019] Before loading the unprocessed substrate carriers with unprocessed substrates, the unprocessed substrates can be transported into the CVD system individually or collected in groups within a second carrier element, such as a Front Opening Universal Pod. For loading, the unprocessed substrates are removed one by one from the second carrier element and loaded onto the unprocessed substrate carriers in the first separation device. These are first removed one by one from the storage chamber assembly and brought into the first separation device. After loading unprocessed substrate carriers with unprocessed substrates, the unprocessed substrate carriers carrying the unprocessed substrates can be returned to the storage chamber.

[0020] After the processed substrate carriers carrying the processed substrates have been removed, a cleaning step can be performed in the at least one process chamber of

the process chamber assembly, during which processed substrate carriers without substrates are present in the process chamber. During this cleaning step, the processed substrate carriers are cleaned to become unprocessed substrate carriers.

[0021] After the cleaning step, the unprocessed substrate carriers can be removed from the process chamber and transferred to the first storage chamber assembly.

[0022] Decoupling the cooling and separation of the substrates and substrate carriers from the treatment step in the process chamber increases the productivity of the system, since during these intermediate steps the process chamber assembly can already perform a subsequent treatment step or a cleaning step.

[0023] Loading the unprocessed substrate carriers with unprocessed substrates and separating the processed substrate carriers and the processed substrates is preferably performed during the treatment step or the cleaning step. The order of loading and separation may be reversed.

[0024] Loading and unloading can be performed using a gripper. The gripper has a capacity that allows it to transport one or more substrate carriers simultaneously. Preferably, the gripper has a capacity that allows it to carry exactly one substrate carrier.

[0025] In a first embodiment of the invention, the simultaneous use of at least, but preferably exactly, three sets of substrate carriers is provided. Each substrate carrier set may comprise a number n of substrate carriers. Here, a first set of the multiple sets of substrate carriers may be treated in the at least one process chamber of the process chamber assembly. A second set, comprising unprocessed substrate carriers carrying unprocessed substrates, may be arranged in at least one of the storage chamber assemblies. A third set, comprising processed substrate carriers carrying no substrates, may be arranged in the same or a different storage chamber assembly. The multiple sets of substrate carriers may be used cyclically.

[0026] After thermal treatment of the first set and removal of the first set from the process chamber, the first set can be transferred to the storage chamber assembly and cooled there to the reduced temperature together with the processed substrates. After removal of the first set from the process chamber, the third set of processed substrate carriers can be cleaned in the process chamber.

[0027] In a second embodiment of the invention, it is provided that unprocessed substrate carriers carrying unprocessed substrates are stored in the first storage chamber assembly prior to thermal treatment, and that unprocessed substrate carriers without substrates are stored there after cleaning. Furthermore, it is provided that, in the second storage chamber arrangement, processed substrate carriers carrying processed substrates are cooled from the second elevated temperature to the reduced temperature after thermal treatment, and that processed substrate carriers without substrates are stored prior to cleaning. The cooling of the processed substrate carriers carrying processed substrates in the second storage chamber assembly may take place during a thermal treatment of unprocessed substrate carriers carrying unprocessed substrates.

[0028] In a third embodiment of the invention, the number of storage locations m1 in the first storage chamber assembly and the number m2 of storage locations in the second storage chamber assembly are greater than the number n. Furthermore, the substrate carriers removed from the process chamber are placed directly into vacant storage locations in the first and second storage chamber assemblies. Due to the surplus of storage locations m_1 , m_2 in the storage chambers compared to the substrate storage locations n in the process chamber arrangement, after cleaning in the process chamber arrangement, the unprocessed substrate carriers carrying the unprocessed substrates can be alternately removed from the first storage chamber arrangement in place of the cleaned substrate carriers and transferred to the process chamber arrangement. Similarly, after thermal treat, the processed substrate carriers without substrates can be alternately removed from the second storage chamber assembly in exchange for the processed substrate carriers carrying the processed substrates and brought into the process chamber assembly.

[0029] In all variants of the invention, substrate carriers removed from the process chamber may first be temporarily stored at an intermediate storage location before being transferred to the one or more storage chamber assemblies.

[0030] The method according to the invention can be carried out using a device that has a process chamber assembly comprising at least one process chamber, but optionally also multiple process chambers, in which n substrates mounted on substrate carriers can be treated. The substrate carriers may be arranged on a susceptor. The process chamber may be connected to a gas-tightly sealed transfer chamber. The transfer chamber may in turn be connected to further chambers that are gas-tightly sealed from the environment. In a first storage chamber arrangement with m1 storage locations for storing one substrate carrier each, unprocessed substrate carriers with and/or without unprocessed substrates can be stored, and in a second storage chamber arrangement with m2 storage locations, processed substrate carriers with and/or without processed substrates can be stored. In one embodiment of the invention, the first and second storage chamber assemblies may each comprise a single storage chamber. However, the storage chamber assemblies may also each comprise multiple storage chambers. To minimize the storage space, the substrate carriers may be arranged vertically one above the other in the storage chambers. For the alternating loading and unloading of the storage chamber assembly, it is necessary that the storage chamber assembly have at least, preferably exactly, one more substrate carrier storage location than the process chamber assemblies. The number m1 of storage locations in the first storage chamber assembly and the number m2 of the second storage chamber assembly may be greater than the number n of substrate storage locations in the process chamber assembly. At least three sets of substrate carriers, each comprising n substrate carriers, may be used. Each substrate carrier is configured to carry at least one substrate. If the process chamber assembly comprises more than one process chamber, the substrate carrier storage capacity of the individual process chambers may be the same or different. The use of at least three sets of substrate carriers extends their service life, i.e., the time until the substrate carrier sets in use must be replaced with new substrate carrier sets. The substrate carriers can carry one or more, for example, three substrates.

[0031] The apparatus further comprises a loading and unloading lock that can be purged with an ultra-pure gas and evacuated. Through this, objects, such as substrates and/or substrate carriers, can be transferred into and out of the system. A handling device is arranged in the transfer chamber, preferably centrally. This comprises a gripping element with one or more gripping heads for gripping objects, such as substrates and substrate carriers or other objects used in the processing of substrates. The gripping element may be mounted on an arm so as to be pivotable about an axis. By vertically moving the gripping element, the gripping head can grasp the substrate carriers and/or substrates arranged vertically one above the other in the storage chambers. For this purpose, the storage chambers have openings that can be closed with gates. Using the gripping element, the substrate carriers of one of the sets can be removed from the process chamber one after another, and after each substrate carrier is removed, a substrate carrier from another set can be brought into the process chamber.

[0032] The device comprises one or more loading and/or separation units in which substrates and substrate carriers can be separated and/or brought together. A first separation device can be used to separate unprocessed substrates and unprocessed substrate carriers. A second separation device can be used to separate processed substrates and processed substrate carriers. However, the same separation device can also be used to separate unprocessed and processed substrates and substrate carriers.

[0033] Furthermore, the device may include an alignment device that aligns unprocessed or processed substrates into a predetermined position.

[0034] To perform the method of the invention automatically, a programmed or programmable electronic control system is provided. This can, in particular, control the gripping elements and the gates.

[0035] In a further embodiment, the device may comprise a process chamber arrangement comprising multiple process chambers connected to a common transfer chamber. With such a device, multiple processes can be carried out in parallel; for example, in multiple process chambers, each of which is associated with a CVD reactor,

a treatment step or a cleaning step may be performed in each chamber. However, it is also possible to perform a cleaning step and a treatment step alternately in an even number of process chambers, each of which is assigned to a CVD reactor. In such a process, the alternations can take place simultaneously. However, it may also be provided that the treatment steps and/or the cleaning steps are carried out in such a phase-shifted manner relative to one another that the alternations of the cleaned substrate carriers or the alternations of the coated substrate carriers occur with a time delay. Furthermore, it may be provided that a substrate carrier carries multiple substrates. A substrate carrier that carries only one substrate may have the known ring shape, so that a fork-like gripping arm can engage under a ring projection of the substrate carrier. However, it may also be provided that an overall ring-shaped substrate carrier has three or more openings, each having an opening edge on which the edge of a substrate rests. It is also possible to use multiple gripping arms. This is particularly advantageous when, in operation with a process chamber arrangement comprising two process chambers, the coated substrate carriers and the cleaned substrate carriers are to be exchanged stepwise simultaneously.

Brief Description of the Drawings

[0036] Examples of the invention are described below with reference to the accompanying drawings. They show:

Fig. 1 shows, schematically in the form of a top view or a cross-section, a device for the simultaneous treatment of multiple substrates 1, 9 in a process chamber 4 of a CVD reactor 3, comprising a first storage chamber 6 for unprocessed substrate carriers 2 with and without unprocessed substrates 1, and a second storage chamber 7 for processed substrate carriers 8 with and without processed substrates 9;

Fig. 2 a second embodiment according to Fig. 1 with two process chambers 4;

Fig. 3 a third embodiment according to Fig. 1 with three process chambers 4 and two transfer chambers 15, 15';

Fig. 4 a schematic representation of an embodiment of the method according to the invention and the essential elements of the apparatus according to the invention, wherein the first storage chamber arrangement 19 comprises a first storage chamber 6 and the second storage chamber arrangement 20 comprises a second storage chamber 7 with a total substrate carrier storage capacity of m_1 =9 and m_2 =9;

Fig. 5 a schematic representation according to Figure 4, wherein the substrate carrier storage capacity of the first storage chamber arrangement 19 is m_1 =10 and the substrate carrier storage capacity of the second storage chamber arrangement 20 is m_2 =11;

Fig. 6 a schematic representation according to Figure 4, wherein the process chamber assembly 21 comprises two process chambers 4 and the second storage chamber arrangement 20 comprises two storage chambers 7, 7’ with a total of m_2= 17 substrate carrier storage locations;

Fig. 7 a schematic representation according to Figure 4, wherein the process chamber assembly 21 comprises three process chambers 4, and the first storage chamber arrangement 19 and the second storage chamber arrangement 20 each comprise three storage chambers 6, 6', 6", 7, 7', 7", which are arranged within a storage housing 29;

Fig. 8 a schematic representation of an embodiment of the method according to the invention and the device according to the invention with three sets of substrate carriers used cyclically, wherein a state within a process cycle is depicted in which processed substrate carriers 8 loaded with processed substrates 9 are separated from one another in a separation device 13 arranged in the transfer chamber 15 while processed substrate carriers 8 are being cleaned in the process chamber 4;

Fig. 9 a schematic representation according to Figure 8, showing a state within a process cycle during the cleaning step, in which cleaned substrate carriers 2 stored in the first storage chamber 6 are loaded with unprocessed substrates 1 from a support element 26 in the separation device 13;

Fig. 10 a schematic representation according to Figure 8, showing a state within a process cycle following the cleaning step, in which the cleaned substrate carriers 2 are transferred from the process chamber 4 to the first storage chamber 6, and the unprocessed substrate carriers 2 loaded with unprocessed substrates 1 are transferred from the first storage chamber to the process chamber 4;

Fig. 11 a schematic representation according to Figure 8, showing a state within a process cycle following a coating process in the process chamber 4, in which processed substrate carriers 8 carrying processed substrates 9 stored in the process chamber 4 are transferred to the second storage chamber 7, and processed/substrate carriers 8 to be cleaned stored in the second storage chamber 7 are transferred to the process chamber 4.

Description of the Embodiments

[0037] Fig. 1 shows a plan view of an embodiment of the device according to the invention, comprising a process chamber 4 arranged within a CVD reactor 3, into which reactive gases can be fed to deposit a layer on a substrate 1. The CVD reactor 3 is connected to a transfer chamber 15 via a loading and unloading opening 12, which can be moved from an open state to a closed state. The transfer chamber 15 may contain an anhydrous and oxygen-free atmosphere. The pressure in the transfer chamber can be in a range between vacuum (50 mbar and less) and atmospheric pressure (1000 mbar). Inside the transfer chamber 15 is a gripping element 10, which includes a gripper 11 with which a substrate carrier 2, 8 and/or a substrate 1, 9 can be transported. A susceptor 5, which can be heated by a heating device, may be arranged in the process chamber 4. A substrate carrier 2, 8,

with or without a substrate 1, 9, can be placed on the susceptor 5 using the gripping element 10 through the loading and unloading opening 12.

[0038] A first storage chamber 6 and a second storage chamber 7 are each connected to the transfer chamber 15 via a loading and unloading opening 12. In the first storage chamber 6, the cleaned substrate carriers 2, with and/or without unprocessed substrates 1, can be stored vertically one above the other. In the second storage chamber 7, processed substrate carriers 8 can be stored with and/or without processed substrates 9. Using the gripping element 10, the substrate carriers 2, 8 with and without substrates 1, 9 can be individually removed from the storage chambers 6, 7 or placed into the storage chambers 6, 7.

[0039] To separate the processed substrates 9 from the processed substrate carriers 8 and to load the cleaned substrate carriers 2 with unprocessed substrates 1, the substrates or substrate carriers are transferred into a separation module 13 connected to the transfer chamber 15 via a loading and unloading opening 12 using the gripping element 10. Multiple separation modules 13, 13’ may also be connected to a transfer chamber 15. When loading the cleaned substrate carriers 2, the unprocessed substrates 1 can be aligned on the cleaned substrate carriers 2 in a predetermined position.

[0040] Substrates 1, 9 and substrate carriers 2, 8 can be fed into the transfer chamber 15 from the outside or removed from the system via a loading and unloading airlock 27 connected to the transfer chamber 15.

[0041] A control system 17, which includes a control computer and a storage 18, can control all units of the device. The control system 17 is capable of controlling the gripping element 10, which includes a gripper 11, or controlling the gates used to open or close the loading and unloading openings 12. A program is stored in the storage 18, according to which the control computer automatically performs a treatment process for one or more substrates 1 or a cleaning process for one or more processed substrate carriers 8. The cleaning of the processed substrate carriers 8 takes place in the process chamber 4.

[0042] Prior to a treatment process, the process chamber 4 must be loaded with substrate carriers 2 that have previously been cleaned in the process chamber 4. These are transferred individually from the process chamber 4 to the first storage chamber 6 by means of the gripping element 10. Following the removal of a cleaned substrate carrier 2 from the process chamber, a cleaned substrate carrier 2 carrying an unprocessed substrate 1 is transferred from the first storage chamber 6 into the process chamber 4. The loading and unloading of the process chamber 4 takes place alternately until the process chamber 4 is fully loaded with the cleaned substrate carriers 2 carrying the unprocessed substrates 1 from the first storage chamber 6. This is followed by the treatment of the substrates 1 in the process chamber 4.

[0043] The treatment of the substrates 1 may involve coating the substrates 1 with at least one semiconductor layer, for which process gases are fed into the process chamber 4. The process chamber 4 is heated to a process temperature at which a chemical reaction takes place within a gas phase in the process chamber 4 or on the surface of the substrates 1, resulting in the deposition of a layer—in particular a single-crystalline layer—on the surface of the substrate 1. Consequently, the substrate carriers 2 and other surfaces in the process chamber 4 are also coated. These coatings are parasitic and therefore undesirable.

[0044] During the treatment, the cleaned substrate carriers 2 are transferred individually from the first storage chamber 6 to the separation module 13. There, the substrate carriers 2 are loaded with unprocessed substrates 1 and subsequently returned to the first storage chamber 6. The ring-shaped substrate carriers 2 essentially serve as support elements for handling the substrates 1 with the gripping elements 10 without causing damage. Such a ring is described, for example, in DE 10 2018 113 400 A1. A device for separating substrates and substrate carriers, or for loading a substrate carrier with substrates, is described in DE 10 2012 111 167 A1.

[0045] After a treatment process, the processed substrate carriers 8 carrying the processed substrates 9 are individually transferred from the process chamber 4 to the second storage chamber 7 by means of the gripping element 10. Subsequently, a processed substrate carrier 8 without a substrate is transferred from the second storage

chamber 7 into the process chamber 4 using the gripping element 10. This is repeated until the process chamber 4 is completely filled with processed substrate carriers 8 from the second storage chamber 7. The cleaned substrate carriers 8 are then cleaned in the process chamber 4. During this process, a chlorine-containing gas is introduced at an elevated temperature, which removes any coatings remaining on the surface of the substrate carriers 8 and the process chamber 4 from previous coating steps performed there.

[0046] During cleaning, the substrate carriers 8 bearing the processed substrates 9 are individually transferred from the second storage chamber 7 into the separation module 13 using the gripping element 10 and separated there. Subsequently, the processed substrates 9 are conveyed out of the system through the loading and unloading lock 27. The processed substrate carriers are returned to the second storage chamber 7.

[0047] After cleaning, the cleaning gas is vented from the process chamber 4, and after one or more rinses of the process chamber 4, the cleaned substrate carriers 2 are individually transferred from the process chamber 4 to the first storage chamber 6 using the gripping element 10. This is followed by the previously described alternating loading and unloading of the process chamber 4 with cleaned substrate carriers 2 carrying unprocessed substrates 1 and the cleaned substrate carriers 2.

[0048] The embodiment shown in Figure 2 differs from the embodiment shown in Figure 1 essentially in that two CVD reactors 3 are connected to the transfer chamber 15, with each CVD reactor 3 having a respective process chamber 4, each of which has a respective susceptor 5. However, a CVD reactor 3 may also comprise multiple process chambers 4. Different treatment processes can be carried out simultaneously in the CVD reactors 3. Furthermore, the second storage chamber arrangement 20 comprises two second storage chambers 7′, which are arranged in different storage housings 29, 29′ and are each connected to the transfer chamber 15. However, the storage capacity can also be increased by vertically arranging multiple storage chambers 7, 7’ within a storage housing 29. By arranging separate storage chambers 7, 7’ within a storage chamber assembly 20, processed substrate carriers 8 with and without processed substrates 9 can

be stored separately from one another from the various process chambers 4. This prevents unwanted contamination, for example, during different coating processes using different materials. In Figure 2, the separation module 13 is arranged in the transfer chamber 15, in contrast to the embodiment shown in Figure 1.

[0049] In the embodiment shown in Figure 3, three CVD reactors 3 are provided, each connected to a transfer chamber 15. A further transfer chamber 15’ is connected to this transfer chamber 15 via a connecting opening 16. Four storage chambers 6, 6', 7, 7' are provided, wherein the cleaned substrate carriers 2, with and without unprocessed substrates 1, are stored in two storage chambers 6, 6', and the processed substrate carriers 8, with and without processed substrates 9, are stored in two storage chambers 7, 7'. The separation module 13, like the storage chambers 6, 6', 7, 7', is connected to the second transfer chamber 15' via a respective loading and unloading opening 12.

[0050] Figures 4 through 11 schematically illustrate the method of the invention and the essential elements of the apparatus of the invention in various embodiments. The substrate carriers 2, 8 are annular in shape here. However, they may also be circular in shape.

[0051] The embodiment shown in Figure 4 comprises a process chamber assembly 21 with a process chamber 4 having n=8 substrate carrier storage area 22, a first storage chamber arrangement 19 with a first storage chamber 6, and a second storage chamber arrangement 20 with a second storage chamber 7. Both storage chamber arrangements 19 and 20 have the same storage chamber capacity of $m_1 = m_2 = 9$.

[0052] During the unloading and loading of the first storage chamber 6, a cleaned substrate carrier 2 is transferred from the process chamber to the first storage chamber 6, and subsequently, a cleaned substrate carrier 2 carrying an unprocessed substrate 1 is transferred from the first storage chamber 6 to the process chamber 4. This step is repeated until the process chamber 4 is completely loaded with substrate carriers 2 carrying unprocessed substrates 1 and all cleaned substrate carriers 2 have been transferred from the process chamber 4 to the first storage chamber 6. The first storage chamber 6 has eight

substrate storage locations 23, which are loaded with the cleaned substrate carriers 2, each carrying a substrate 1. Another substrate carrier storage location 23’ is empty.

[0053] The gripper, not shown in Figure 4, places the cleaned substrate carrier 2 previously removed from the process chamber 4 onto the empty substrate carrier storage location 23'. The gripper, which no longer carries a substrate carrier, can then grasp one of the substrate carriers 2 lying on one of the substrate carrier storage locations 23 and carrying a substrate 1 to be processed, in order to place it in the process chamber 4 onto the substrate carrier storage location 22 that has become vacant there.

[0054] During the unloading and loading of the second storage chamber 7, a processed substrate carrier 8 carrying a processed substrate 9 is transferred from the process chamber 4 into the second storage chamber 7, and subsequently a processed substrate carrier 8 is brought from the second storage chamber 7 into the process chamber 4. Analogous to the unloading and loading of the first storage chamber, this step is repeated until all processed substrate carriers 8 carrying processed substrates 9 have been transferred from the process chamber 4 to the second storage chamber 7, or until the process chamber 4 is completely loaded with processed/substrate carriers 8 to be cleaned.

[0055] Here, too, all n=8 substrate carrier storage locations 22 of the process chamber 4—for example, substrate carrier storage locations 22 arranged on a susceptor 5—are each occupied by a substrate carrier 8 carrying a processed substrate 9. Using the gripper (not shown), one of these processed substrate carriers 8 carrying a processed substrate 9 is removed from its substrate carrier storage location 22 and placed on the free substrate carrier storage location 24’ of the second storage chamber arrangement 20 or the second storage chamber 7. The gripper, now free, can grasp a substrate carrier 8 to be cleaned from one of the substrate carrier storage locations 24 in order to place it on the now-free substrate carrier storage location 22 in the process chamber 4.

[0056] The embodiment shown in Figure 5 also features a process chamber assembly 21 with a process chamber 4 having a total of n=8 substrate carrier storage locations, which are alternately unloaded and loaded by two storage chambers 6, 7, wherein the

transport capacity of the gripping element 10 (not shown) corresponds to two substrate carriers 2, 8 when unloading and loading the first storage chamber 6, and to three substrate carriers 2, 8 when unloading and loading the second storage chamber 7.

[0057] In this embodiment, two grippers with different gripping capacities are used. A first, non-shown gripper loads and unloads the first storage chamber 6, whereby two cleaned substrate carriers 2 are simultaneously removed from the process chamber 4 and placed on the two free substrate carrier storage locations 23’ of the storage chamber 6. The gripper that is then free can grasp two substrate carriers 2, each carrying an unprocessed substrate 1, from the substrate carrier storage locations 23 and place them on the two free substrate carrier storage locations 22 of the process chamber 4.

[0058] The second gripper, which is used to load and unload the second storage chamber 7, has a gripping capacity of three. The gripper can simultaneously transport three processed substrate carriers 8 from the process chamber 4 to the second storage chamber 7 and place the processed substrate carriers 8 there in the free substrate carrier storage locations 24'. It can then remove three substrate carriers 2 requiring cleaning from the storage locations 24 to bring them to the three free storage locations 22 of the process chamber 4.

[0059] In the embodiment shown in Figure 6, the CVD reactor assembly 3 comprises a process chamber assembly 21 with two process chambers 4 and a total of n=16 substrate carrier storage positions. Unlike the embodiments shown in Figure 2, the second storage chamber arrangement 20 comprises two second storage chambers 7, 7’ arranged vertically one above the other, with a total of m_2 =17 substrate carrier storage locations, whereas the first storage chamber arrangement 19, as in the previous embodiments, comprises only a first storage chamber 6 with a total of m_1 =17. The transport capacity of the gripping element 10 (not shown) is the same when unloading and loading the first and second storage chamber assemblies ($m_{1,2}$ =1). However, both process chambers 4 are loaded with cleaned substrate carriers 2 carrying unprocessed substrates 1 from the single first storage chamber 6 of the first storage chamber arrangement 19. The cleaned substrate

carriers 2 from both process chambers 4 are also stored in the single first storage chamber 6.

[0060] Figure 7 shows a further embodiment with a process chamber assembly 21 comprising three process chambers 4 with a total of n=24 substrate carrier storage locations. Unlike in the previous embodiments, the first storage chamber arrangement 19 and the second storage chamber arrangement 20 are arranged together in a storage housing 29. The storage chamber arrangements 19, 20 each have a total of $m_1 = m_2 = 25$ substrate carrier storage slots, with one free substrate carrier storage location 23', 24' present in each of the two storage chamber arrangements 19, 20.

[0061] The embodiments illustrate the use of first storage chambers 6 and second storage chambers 7, wherein one or more first storage chambers 6 form a first storage chamber arrangement 19 and one or more second storage chambers 7 form a second storage chamber assembly 20. One or more process chambers 4 form a process chamber assembly 21.

[0062] The process chamber assembly 21 has a predetermined number of n substrate carrier storage locations, each of which is completely filled with substrate carriers 2, 8 during cleaning or processing.

[0063] The first storage chamber assembly 19 and the second storage chamber assembly 20 each have a number of occupied substrate carrier storage locations 23, 24 corresponding to the total number of substrate carrier storage locations 22 in the process chamber assembly 21.

[0064] There are thus $3 \cdot n$ substrate carriers, with n substrate carriers arranged in the process chamber assembly 21, n substrate carriers in the first storage chamber arrangement 19, and a further n substrate carriers in the second storage chamber arrangement 20.

[0065] In addition to the n substrate carrier storage locations 23, 24, each loaded with substrate carriers 2, 8, the first storage chamber arrangement 19 and the second storage chamber arrangement 20 have additional empty substrate carrier storage locations 23', 24'. Their number corresponds to the number of substrate carriers that can be transported simultaneously by a gripper.

[0066] The invention relates in particular to a device and a method for depositing a sequence of layers, wherein the sequence of layers may in particular be a sequence of III.-V.-layers, wherein the sequence of layers is a transistor structure, a laser diode, a light-emitting diode, or another diode structure. The invention further relates to a device or a method for depositing a II.-VI.-layer or a II.-VI.-structure, wherein the II.-VI.-structure may be a two-dimensional structure. To carry out the method, either reactive gases containing elements of the III. and V. main groups or reactive gases containing elements of the II. and VI. main groups are used.

[0067] Compared to the prior art, the following features in particular are considered especially advantageous: Two storage chambers 6, 7 are provided, which differ in that only cleaned substrate carriers 2 with and without substrates 1 are arranged in one storage chamber 6, and only processed substrate carriers 8 with and without substrates 9 are arranged in the other storage chamber 7. The number m_1, $m_2$of storage locations 23, 23', 24, 24' held in the storage chambers 6, 7 need only be one greater than the capacity of the process chamber 4 of the CVD reactor 3. A device complex consists of a CVD reactor 3 and two storage chambers. An additional process chamber 4 may be provided. In the two process chambers 4, coating or cleaning preferably takes place simultaneously. However, this second process chamber 4 can be used alternately with the first process chamber 4 either for coating or for cleaning the substrate carriers 2, 8. In this case, treatment of the substrates 1 can be performed alternately in the first process chamber 4, while cleaning of the processed substrate carriers 8 can be performed simultaneously or in a staggered manner in the second process chamber 4. For the temporary storage of the processed substrate carriers 8 and for the temporary storage of the cleaned substrate carriers 2, the same various storage chambers 6, 7 or different various storage chambers 6’, 7’ may be used, respectively. Temporary storage of the substrate carriers 2, 8 with or without

substrate 1, 9 may also take place at a temporary storage location 28. The intermediate storage location 28 may be arranged in the transfer chamber 15, 15’ (see Figures 8 through 11).

[0068] Preferably, three sets of substrate carriers are assigned to each process chamber 4. When using only one process chamber 4, virtually the entire cycle time is available for separating the processed substrates 9 from the processed substrate carriers 8 or for loading the unprocessed/cleaned substrate carriers 2 with unprocessed substrates 1. When using two process chambers 4 and a gripping element 10, this time is reduced accordingly by the time required to separate the processed substrates 2 from the processed substrate carriers 8 or to load the unprocessed substrate carriers 2 with unprocessed substrates 1 from the second process chamber 4. In such a process, which is carried out, for example, using an arrangement according to Figure 2, a coating process is performed in one of the process chambers 4 and a cleaning process is performed in the other process chamber 4 in alternating cycles. The device need only have a first storage chamber 6 for the cleaned substrate carriers 2 and a second storage chamber 7 for the processed substrate carriers 8. While the cleaned substrate carriers 2 from one process chamber 4 are exchanged for substrate carriers 2 carrying cleaned, uncoated substrates 1, the processed substrate carriers 8 loaded with processed substrates 9 from the other process chamber 4 are exchanged for processed substrate carriers 8 without substrates 9. After simultaneous coating and cleaning, or simultaneous coating, or simultaneous cleaning in the various process chambers 4, the process continues in the same manner. In the drawings, each substrate carrier 2, 8 can be loaded with only one substrate 1, 9 at a time. In embodiments not shown, each substrate carrier 2, 8 may also carry multiple substrates 1, 9.

[0069] Figures 8 through 11 illustrate a further embodiment, wherein the apparatus for the simultaneous treatment of multiple substrates 1 is located in a process chamber 4 of a CVD reactor 3—which, for example, has n=8 storage positions—using three sets of substrate carriers at different stages of a process cycle comprising a cleaning and coating process. A transfer chamber 15 is connected to the reactor chamber 4. Adjacent to the transfer chamber 15 are a first storage chamber 6, arranged in a storage housing 29, and a second storage chamber 7 for storing unprocessed substrate carriers 2 and processed

substrate carriers 8 with and without substrates 1, 9. Carrier elements 26, 26’ are each connected to the transfer chamber 15 for storing unprocessed substrates 1 and processed substrates 9. Two separation devices 13, 13’ are arranged within the transfer chamber 15. A first separation device 13 is used to load unprocessed substrate carriers 2 with unprocessed substrates 1. A second separation device 13’ is used for the separation of processed substrates 9 and processed substrate carriers 8. The separation devices 13, 13’ are also used as an intermediate storage location for processed substrate carriers 8 carrying processed substrates 9 removed from the reactor chamber 4 and cleaned substrate carriers 2.

[0070] A process cycle is explained below using Figures 8 through 11 as examples.

[0071] Starting from an initial situation in which the process chamber 4 is loaded with, for example, n = 8 processed substrate carriers 8 to be cleaned, and in which the first storage chamber 6 stores unprocessed/cleaned substrate carriers 2 without unprocessed substrates 1 are stored, and in the second storage chamber 7, processed substrate carriers 8 without substrates 9 are stored, a cleaning process is initiated.

[0072] During the cleaning process, the processed substrates 9 stored on the processed substrate carriers 8 in the second storage chamber 7 are separated from the substrate carriers 8 and transferred to the carrier element 26'. In this process, a processed substrate carrier 8 loaded with a processed substrate 9 is first transferred from the second storage chamber 7 to the separation device 13, where the processed substrate 9 is separated from the processed substrate carrier 8. The processed substrate 9 is then transferred to the alignment element 14. This stage within the process cycle is schematically illustrated in Figure 8. From there, the processed substrate 9 is transferred to an intermediate storage location 28, where the substrate 9 cools down. While the substrate 9 is cooling, the unprocessed substrate carrier 8 is removed from the separation device 13 and returned to the second storage chamber 7. Subsequently, the cooled processed substrate 9 is transferred to the carrier element 26'. These steps are repeated until all processed substrates 9 from the second storage chamber 7 are stored in the carrier element 26' and

the corresponding processed substrate carriers 8 are stored in the second storage chamber 7.

[0073] Following the unloading of the processed substrates 9, the unprocessed substrate carriers 2 stored in the first storage chamber 6 are loaded with unprocessed substrates 1 stored in the carrier element 26, also during the cleaning step. In this process, a cleaned substrate carrier 2 is first transferred from the first storage chamber 6 to the separation device 13 by means of the gripping element 10. Subsequently, an unprocessed substrate 1 is removed from the carrier element 26 and transferred to the alignment element 14, where the substrate 1 is positioned in a predetermined orientation. The unprocessed substrate carrier 2 is then loaded with this aligned substrate 1 in the separation device 13. This state within the process cycle is schematically illustrated in Figure 9. Subsequently, the unprocessed substrate carrier 2 loaded with the unprocessed, aligned substrate 1 is returned to the first storage chamber 6. These steps are repeated until all unprocessed substrate carriers 2 stored in the first storage chamber 6 are loaded with the unprocessed substrates 1 stored in the carrier element 26.

[0074] After completion of the cleaning step in the process chamber 4, the cleaned substrate carriers 2 are exchanged from the process chamber 4 for the unprocessed substrate carriers 2 loaded with unprocessed substrates 1 from the first storage chamber 6. First, a cleaned substrate carrier 2 is transferred from the process chamber 4 to the separation device 13'. Thereafter, an unprocessed substrate carrier 2 loaded with an unprocessed substrate 1 is loaded from the first storage chamber 6 into the process chamber 4 onto the now-vacant storage location 22. This status within of the process cycle is schematically illustrated in Figure 10. Subsequently, the cleaned substrate carrier 2 is transferred from the separation device 13‘ to the first storage chamber 6. These steps are repeated until all cleaned substrate carriers 2 are stored in the first storage chamber 6 and the process chamber 4 is fully loaded with unprocessed substrate carriers 2 loaded with unprocessed substrates 1 from the first storage chamber 6.

[0075] Following the loading of the process chamber 4 with unprocessed substrates 1 stored on the unprocessed substrate carriers 2, a coating process is initiated.

[0076] During the coating process, the carrier element 26 can be loaded with new unprocessed substrates 1 or exchanged for another carrier element 26 loaded with unprocessed substrates 1. The carrier element 29’ loaded with the processed substrates 9 can also be exchanged during the coating process for another unloaded carrier element 26’ or the processed substrates 9 can be removed from the carrier element 26’.

[0077] Following the coating process, the substrates 9 coated in the process chamber are transferred to the second storage chamber 7 while still resting on the processed substrate carriers 8, and the process chamber 4 is loaded with the processed substrate carriers 9 stored in the second storage chamber 7. In this process, a processed substrate 9 resting on a processed substrate carrier 8 is first transferred from the reactor chamber to the separation device 13'. This stage within the process cycle is schematically illustrated in Figure 11. Thereafter, a processed substrate carrier 8 is transferred from the second storage chamber 7 into the process chamber 4 to the now-vacant storage location 22. Subsequently, the processed substrate carrier 8 loaded with a processed substrate 9 and stored in the separation device 13‘ is transferred to the second storage chamber 7. These steps are repeated until the process chamber 4 is completely loaded with the processed substrate carriers 8 from the second storage chamber 7 and all processed substrate carriers 8 loaded with processed substrates 9 have been moved from the process chamber 4 to the storage chamber 7.

List of Reference Numbers

1	Unprocessed substrate
2	Cleaned/unprocessed substrate carrier
3	CVD reactor
4	Process chamber
5	Susceptor
6	First storage chamber
6’	First storage chamber
6’’	First storage chamber
7	Second storage chamber
7’	Second storage chamber
7’’	Second storage chamber
8	Processed substrate carriers
9	Processed substrate
10	Gripping element
11	Gripper
12	Loading and unloading opening
13	Separation device
13‘	Separation device
14	Alignment element
15	Transfer chamber
15’	Transfer chamber
16	Connection opening
17	Control
18	Storage
19	First storage chamber arrangement
20	Second storage chamber arrangement
21	Process chamber assembly
22	Substrate carrier storage location
23	Substrate carrier storage location
23’	Substrate carrier storage location
24	Substrate carrier storage location
24’	Substrate carrier storage location
25	Substrate storage location
26	Carrier element
26’	Carrier element
27	Loading and unloading airlock
28	Intermediate storage location
29	Storage housing
29’	Storage housing
29’’	Storage housing
29’’’	Storage housing

Claims

1. A method for the simultaneous treatment of multiple substrates (1, 9) in at least one process chamber (4) of a process chamber assembly (21), wherein unprocessed substrate carriers (2) are loaded with substrates (1) to be processed, are introduced into the at least one process chamber (4) of the process chamber assembly (21), are treated in the at least one process chamber (4) at a first elevated temperature, wherein the unprocessed substrates (1) are processed into processed substrates (9) and the unprocessed substrate carriers (2) become processed substrate carriers (8), are removed from the process chamber (4) at a second elevated temperature, wherein unprocessed substrate carriers (2, 8), each carrying an unprocessed substrate (1), are arranged in at least one first storage chamber (6), and the processed substrate carriers (8), each carrying a processed substrate (1, 9), are removed one after another from the at least one process chamber (4) at the second temperature after the substrates (1, 9) they carry have been processed, and are then transferred to a second storage chamber (7), where they are cooled to a reduced temperature together with the processed substrates (9).

2. A method according to claim 1, characterized in that, by means of a gripping element (10), during loading of the at least one process chamber (4) of the process chamber assembly (21), a substrate carrier (2, 8) of the set of substrate carriers (2, 8) located in the process chamber (4) is removed from a storage location (22) of a susceptor (5) by means of a gripping element (10), and subsequently a substrate carrier (2, 8) from another set of substrate carriers (2, 8) is transferred from the storage chamber (6, 7) to the storage location (22).

3. A method according to claim 1, characterized in that only unprocessed substrate carriers (2), with or without unprocessed substrates (1), are stored in the first storage chamber (6), and only processed substrate carriers (8), with or without processed substrates (9), are stored in the second storage chamber (7).

4. A method according to claim 1, characterized in that, during the treatment of substrate carriers (2) carrying unprocessed substrates (1), or during the cleaning of processed substrate carriers (8) which do not carry substrates (9), the processed substrates (9) are removed from the processed substrate carriers (8) that have been cooled to the reduced temperature.

5. A method according to claim 1, characterized in that, during the treatment of unprocessed substrate carriers (2) carrying unprocessed substrates (1), or during the cleaning of other processed substrate carriers (9), unprocessed substrate carriers (2) are loaded with unprocessed substrates (1).

6. Apparatus for carrying out a method according to one of the preceding claims, comprising at least one process chamber assembly (21) having a process chamber (4), comprising a plurality of substrate carriers (2, 8), wherein each of the substrate carriers (2, 8) is configured to carry at least one substrate (1, 9), wherein the process chamber (4) comprises storage locations (22) for a number n of substrate carriers (2, 8), comprising at least a first storage chamber (6) in which either unprocessed substrates (1) carried by unprocessed substrate carriers (2) or unprocessed substrate carriers (2) carrying no substrates (1) are arranged, and comprising at least a second storage chamber (7), in which either processed substrates (9) carried by processed substrate carriers (8) or processed substrate carriers (8) carrying no substrates (9) are arranged, wherein the second storage chamber (8, 9) comprises a cooling element with which the substrate carriers (8) carrying the processed substrates can be cooled down.

7. Apparatus according to claim 6, characterized by a control unit (17) comprising a control computer and a storage (18), and capable of controlling a gripper (11) of a gripping element to perform a process according to any one of claims 1 to 5.