

Process For Producing Parts, And A Vacuum Treatment System

W098/58099 is attached to this description as a description of the process.

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The present invention relates to a process for producing parts as electronic, opto-electronic, optical or micromechanical components or as intermediate products therefore by using at least one plasma-assisted treatment step, in which reactive gas or reactive gas mixture admitted to a process space is activated by means of
10 a low-energy plasma discharge with ion energy E on the surface of the part of

$$0 \text{ eV} < E \leq 15 \text{ eV}$$

in accordance with the generic term of Claim 1.

Furthermore, the invention relates to a process for producing a virtual substrate
15 or a component thereof, preferably on a silicon germanium basis, comprising at least one cleaning step, according to the preamble of Claim 28. In addition, the invention relates to vacuum treatment system in accordance with the general terms of Claims 29 and 30 respectively.

20 The present invention basically relates to the production of parts for which the same demands are to be made as during the coating of parts with an epitaxial layer.



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From W098/58099 (enclosed) by the same applicant, processes as well as systems of the initially mentioned type are known. As a plasma-assisted treatment step, in which reactive gas or reactive gas mixture admitted to a process space is activated by means of a low-energy plasma discharge with ions of the ion energy E on the surface of the part of

$$0 \text{ eV} < E \leq 15 \text{ eV},$$

is described in detail and only the coating of a work piece of a quality sufficient for the epitaxy is described and claimed there. The plasma generated by the low-energy plasma discharge is essentially composed of electrons, single and multiple charged ions and neutral particles (atoms, dissociated molecules) as well as excited but non-ionized neutral particles. The energy range

$$0 \text{ eV} < E \leq 15 \text{ eV}$$

of the single ionized ions is characteristic of the plasma described herein. 15eV represents the so-called sputtering threshold, above which, when the ions act upon the substrate, damage may occur there. Even up to 100 eV, electrons contribute essentially only to the heating of the substrate. It is also known that, particularly in the case of the DC low voltage plasma generating arrangement particularly preferred in this case – as will be explained in the following – the above-mentioned energy range of the single-charged ions simultaneously limits in the upward direction the energy range of the neutral particles existing in the plasma as well as excited neutral particles. The reason is that the neutral particles obtain their significant energy contribution by impacts with the ions.

Also, a vacuum treatment system for the above-mentioned coating is explained in detail W098/58099 and has a vacuum chamber, a work piece carrier in the vacuum chamber, a plasma generating arrangement for generating a plasma in the chamber as well as a gas inlet arrangement in the chamber which is
5 connected with a gas tank arrangement with at least one reactive gas. The plasma generating arrangement is described specifically as a low-voltage plasma generating arrangement: A cathode chamber communicates by way of a diaphragm with the process space. A hot cathode is mounted in the cathode chamber; an anode arrangement is present in the process space. Having a
10 physically downward orientation, the work piece carrier is arranged in an electrically insulated manner.

The principle of this low-voltage plasma generating arrangement is far preferred for the processes described herein over also known other plasma generating
15 processes (such as microwave plasma), because it is capable of obtaining the above-mentioned energy characteristics in a preferred manner.

Thus, on the one hand, the present invention is based on processes and a system of this type; on the other hand, among others, the process described in
20 International Patent Document W098/58099 is to be implemented also according to the present application, although – as will be explained in the following – while meeting additional criteria according to the object of the present invention.

The reason is that it is an object of the present invention to provide a process and a system of the above-mentioned type whose industrial suitability is significantly increased with respect to economic criteria, particularly with respect to higher up-times and higher throughput.

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During the required high up-times, the high purity of the system has to be ensured for the above-mentioned processes. In addition, optimal integration ability of the process steps and of the system into the automated production process should be achieved.

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With respect to the process of the initially mentioned type, this object is achieved in that the process atmosphere during the plasma-assisted treatment step is separated from the interior wall of a vacuum recipient exposed to the environment. The basic recognition is in this case that a functional separation, on the one hand, of structures which ensure the required vacuum-related pressure condition with respect to the ambient pressure and, on the other hand, of structures which are directly exposed to the treatment process will achieve the above-mentioned object.

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According to W098/58099, the interior surface of the vacuum chamber, normally made of stainless steel or Inox, is exposed directly to the process atmosphere. During the plasma-assisted treatment step, specifically during the coating of work piece or part by means of the low-energy plasma discharge, the vacuum chamber wall and thus the interior surface will heat up. Because of various

effects, such as the absorption behavior of the interior surface during the preceding process exposures, if used in industrial manufacturing, this results in an intolerable contamination of the treatment step process atmosphere or in the formation of intolerable partial background gas pressures. Background gas in a process atmosphere in this case are those gas portions, which originate neither from the plasma discharge working gas, such as argon, nor from the admitted reactive gas or reactive gas mixture, nor from their gaseous reaction products. As a result of the approach according to the invention, it will now be possible to minimize the influence upon the process by the vacuum recipient wall.

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In accordance with the wording of Claim 2, the process according to the invention is used in a greatly preferred manner (a) for coating the part or (b) for changing the material composition of the part to a defined penetration depth, or (c) for etching the surface of the part, particularly for etching of structure. In all mentioned cases, it is absolutely necessary to maintain process conditions required for the growth of epitaxial layers, within the scope of the production processes endeavored according to the invention. As a result of the change of the material composition according to the invention mentioned in (b), this addresses the implantation of material into a given target material.

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Furthermore, a cleaning step in accordance with Claim 3 is proposed, which is carried out a plasma-assisted treatment step according to the invention, or a cleaning step in accordance with Claim 4 in addition to a plasma-assisted treatment step according to the invention.

In a preferred embodiment of the process of the invention, a virtual substrate is produced in accordance with the wording of Claim 5. A virtual substrate is a semiconductor wafer, which, in contrast to a wafer consisting of a generally mono-crystalline semiconductor material, has a special layer construction but
5 functionally is also used as a starting material for semiconductor components.

A semiconductor material "A", for example, mono-crystalline silicon in the form of a wafer, is used as the starting substrate. A buffer layer is applied thereto which consists of preferably continuously changing portions of semiconductor "A" and
10 another semiconductor "B", the progression normally being from a high "A" portions and little "B" to a high "B" portions and little "A". This is called a "graded buffer layer". The structure of this buffer layer is full of defects. On the buffer layer, a cover layer is grown which has a composition corresponding essentially to that of the uppermost buffer layer zone. The purpose is the achieving of a low-
15 defect, no-dislocation mixed crystalline layer. These three components – the base or substrate, the buffer layer and the cover layer form the virtual substrate. As known to a person skilled in the art, the application of additional intermediate layers is also possible. The actual useful layer is applied to the virtual substrate and has the composition required for the characteristics of the semiconductor
20 material to be achieved. A mixture of two semiconductors can again be used as the useful layer material, but also a layer consisting of a pure semiconductor, for instance "B". As a rule, this layer is so thin that no dislocations will occur on it but the stress in this layer is maintained (band gap engineering). The epitaxial growth of this useful layer can be combined with the construction of the virtual

substrate. However, prefabricated virtual substrates can also be subsequently provided with the useful layer. In accordance with the invention and the wording of Claim 5, the base or the mentioned substrate is first subjected to a plasma-assisted cleaning, in contrast to previous processes, in which wet cleanings were used within the scope of the production of virtual substrates. Then, the hetero-epitaxial buffer layer is deposited as well as, if required, the above-mentioned cover layer. Optionally, according to the invention, the useful layer, which is to be used, is also deposited then, or, after the depositing of the buffer layer, changing over into the cover layer, the actually finished virtual substrate is made available for a deposition of the useful layer, which will take place later.

It should be pointed out already at this stage that, within the framework of known production processes for virtual substrates (including MBE – molecular beam epitaxy, UHVCVD – ultra high vacuum CVD, ALD – atomic layer deposition, among others), the replacement of the wet-chemical cleaning steps by a plasma-assisted cleaning step in low-energy plasma by itself is also considered to be inventive and results in significant production-technical advantages.

With regard to this please also refer to the production process in accordance with Claim 28.

In the course of the addressed industrial manufacturing, it is generally often necessary to subject the parts which subsequently are to be treated by the above-mentioned plasma-assisted treatment steps (a), (b), (c) first to a cleaning,

for example, with respect to ambient-atmosphere-caused surface contaminations.

Furthermore, after each of the above-mentioned plasma treatment steps (a), (b),
5 (c), a cleaning step may be required, for example, for cleaning contamination materials or gases released during the etching.

In an embodiment of the cleaning process, reactive gases (hydrogen, hydrogen – noble gas mixtures) can be used which may impair the materials used for
10 encapsulating the process atmosphere.

It is therefore also suggested according to Claim 4 to provide such cleaning steps either a relatively low-cost metallic encapsulation, or to limit the cleaning process atmosphere directly by the interior wall of the vacuum recipient exposed to the
15 environment.

The reason is that, for the above-mentioned treatment steps (a), (b), (c) of the parts, as will be explained in the following, non-metallic boundaries of the process atmosphere are considerably preferable; that is, materials which are
20 inert with respect to the used plasma-activated reactive gases. However, in this cleaning step, it must also be ensured that the cleaned surfaces of the part are accessible to the subsequent treatment in an unimpaired manner just as if this treatment were the depositing of epitaxial layers. Therefore in the case of the

plasma-chemical cleaning step of the part as well, the above-mentioned low-energy plasma with the specified ion energy is used on the surface of the part.

Furthermore it is suggested in accordance with Claim 6 that part, which arrive in
5 the process space in question one after the other that is, in a serial time
sequence, are subjected to at least one of the above-mentioned plasma-assisted
treatment steps and that after the implementation of a pre-defined number of
such treatment steps they are subjected to another plasma-assisted step in the
above-mentioned process space, specifically a process space cleaning step,
10 without a part being introduced into the process space or a substrate dummy
being used. This process space cleaning step is preferably implemented in at
least two partial steps: First the etching; then the cleaning off of etching residues;
the latter preferably in a plasma, containing hydrogen, inert gas or a mixture
thereof.

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In the light of the object of the invention, particularly with regard to the
implementation for high up-times, the process space in question is therefore
cleaned in a plasma-assisted manner, after a pre-defined number of treatment
steps have taken place. In a process space, parts are normally either processed
20 or cleaned according to (a) or (b) or (c), be it in accordance with the wording of
Claim 3 or be it, if necessary, in accordance with Claim 4. However, a case may
also occur in which, in a single process space under consideration, in a
programmed sequence, sequentially, the coating, etching or, the change of the

material composition or - in this case according to Claim 3 - the cleaning of the part is carried out.

The separation of the process atmosphere from the vacuum recipient wall
5 provided for according to the invention permits the subjecting of the process space or of the part to a plasma-chemical cleaning, using reactive gases, to which the vacuum chamber wall must not be exposed. The fact that a process space under consideration, after a pre-defined or definable number of treatment steps of parts can be subjected to a plasma-assisted self-cleaning and then is
10 immediately available again for the treatment of parts, drastically increases the up-time for the continuous operation. This is compared, for example, with the case that the process space has to be cleaned according to W098/58099.

Summarizing the previous statements, it is therefore demonstrated that, by
15 means of the production process according to the invention, with respect to quality demands to be made on epitaxy, the coating, the changing of the material composition of the part, the etching of structures on the part or its cleaning can be carried out while avoiding wet-chemical cleaning steps, and that between such treatment steps, a self-cleaning of the process space can be carried out,
20 simply by changing process parameters, particularly of the admitted reactive gases. The same process can also be used for cleaning the parts in the course of their production according to the invention in that the separation of the process atmosphere and the vacuum recipient is changed or omitted.

According to the wording of Claim 7, the part is preferably subjected in a locally separated manner to at least two of the above-mentioned plasma-assisted treatment steps and the transport in-between takes place in a vacuum.

According to Claim 8, this preferably takes place in a linear movement from one treatment step to the next, in the manner of a linear system or along a circular path, in the manner of a circular system known by the name of "cluster system". There, treatment stations grouped around a circular transport system in a programmed, optionally freely programmable manner are provided with parts or work pieces by the circular transport system.

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In a greatly preferred embodiment – Claim 9 - of the process according to the invention, the separation between the process atmosphere and the vacuum recipient wall surface is effected by limiting the process space by means of a surface, which, in the original condition, is chemically inert with respect to the plasma-activated reactive gas or reactive gas mixture, preferably by means of a dielectric or graphitic surface.

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During the operation, that is particularly during the coating (a), the changing of the material composition (b), or the etching (c), particularly the etching of a structure, or also the cleaning, material is deposited on this surface. However, this material is not or only tolerably process-contaminating. Specifically when, in the same process space under consideration, identical treatment steps are carried out on parts occurring in series, it is even desirable to coat the preferably dielectric or graphitic separating surface which, as mentioned above, is inert in its

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new condition, with the above-mentioned reaction product materials, however, only to the extent that the resulting coating also adheres in a secured manner to the above-mentioned surface.

- 5 The provision of the required inert, preferably dielectric surface can take place in such way that a structure forming an inert, preferably dielectric surface, is applied directly to the interior surface of the vacuum recipient, whether as a coating with such a material, or by the mounting of self-supporting wall parts with such an inward-facing surface directly onto the interior vacuum recipient wall.

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In a greatly preferred embodiment, however, the inert surface, in accordance with Claim 10, is placed at a distance from the interior wall of the vacuum recipient at least along predominant surface sections. This approach has significant advantages under the aspect of the exchangeability of a separating wall structure also with respect to being service-friendly, and under the aspect of a specific pre-

15 setting of the surface temperatures.

- In accordance with the wording of Claim 11, the process space and the above-mentioned intermediate space can be pumped identically or differently. Among
- 20 other things, this may permit the implementation of an atmosphere in the intermediate space, which results in desired thermal conduction ratios between the vacuum recipient wall and the above-mentioned surface. If, in this case, a gas of a high thermal conduction capacity, such as helium, is admitted to this intermediate space, and/or, at least temporarily, a higher pressure than in the

process space is implemented in this intermediate space, the heat conduction in this intermediate space is increased in comparison with that in the process space, which may make it possible to keep the surface at the desired temperatures. It should be remembered that below a defined vacuum pressure, the thermal conduction decreases with the pressure and naturally depends on the thermal capacity of the contained gas in question.

Preferred materials for the surface in its new state are specified in Claim 12. It should be stressed that when the surface made of an inert, preferably dielectric material is mentioned, this initially exclusively addresses the surface material of the surface facing the process space. This surface is preferably formed by that of a separating wall. This surface may be coated, for example it may have a metallic construction facing the vacuum recipient, with an inert surface facing the process space or the process atmosphere. In this sense, according to the wording of Claim 12, the surface can therefore be formed by a layered structure, permitting also the use of diamond-like materials or of diamonds.

It is known that, in plasma-chemical processes, the coating rate always increases with rising temperatures (and the acted-upon plasma intensity). As mentioned above, it may be highly desirable to coat the surface facing the process space with reaction products of the plasma-activated reactive gas corresponding to the respective process. However, in that case, considerable attention must be paid to avoiding any peeling-off of such a coating. This knowledge can be implemented in such way that by controlling the temperature of the above-

mentioned surface, the coating rate of the above-mentioned surface is minimized during the implementation of the plasma-assisted treatment step. This results, for example, in the possibility of selecting this interference coating rate to be significantly smaller than the effective rate on the part, and thus to subject the process space to the self-cleaning cycle only after a relatively large number of completed treatments of parts. There, the above-mentioned coating will be removed before its thickness has reached a critical value, for example, with respect to peeling-off.

- 10 In this case, the effective rate on the part, depending on the treatment, is understood by us as the coating rate, the penetration rate, the etching rate, and the cleaning rate.

- With regard to the object to be achieved according to the invention it is also
15 sensible to pay considerable attention to the degree of automation of the process and the system. In accordance with the wording of Claim 13, it is therefore proposed that a feeding opening for the part be provided in the above-mentioned surface, and that the feeding opening for the treatment of the part be closed by the part and/or by a carrier for the part, at least to such an extent that the escape
20 of charge carriers from the process space is prevented.

As another preferred embodiment, the low-energy plasma discharge in accordance with Claim 14 is used with an electron source with an electron energy of ≤ 100 eV, preferably ≤ 50 eV, particularly preferably implemented with

a DC discharge; in this case, preferably according to Claim 15, by means of a thermionic cathode, preferably a directly heated thermionic cathode. In a particularly preferred manner, the treated surface of the part is exposed directly to the plasma.

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In accordance with Claim 16 it is furthermore preferred that at least two locally displaced anodes are provided in the process space for the plasma discharge. Each of these anodes can preferably be heated separately. By controlling the electric potentials applied thereto and/or their temperature, the plasma density
10 distribution in the process space can be adjusted or controlled dynamically and/or statically. We understand a static adjustment as an adjustment, which is set and is kept stationary at least during one treatment step. We understand a dynamic adjustment as an adjustment, in which at least one of the above
15 parameters is changed with respect to the time is changed during the treatment step, whether in the sense of a sweep, periodically, or a-periodically corresponding to defined curve shape in an oscillating manner, or in the form of any linear or non-linear ramp function, during the treatment step. Particularly by means of the approach mentioned last, it becomes possible to take into account the conditions, which change during a process step in the process space, and act
20 upon these in a compensating manner or also achieve a desired time variation of the plasma density on the surface of the part.

In accordance with the wording of Claim 17, a magnetic field is furthermore generated preferably in the process space, which magnetic field, analogous to

the above-mentioned parameters anode potential and/or anode temperature, stationary or dynamically, sets or controls the plasma density distribution on the surface of the part. As a result of the controlled time variation of the magnetic field, the plasma density distribution along the surface of the part can be

5 changed, particularly preferably as if the part were to move periodically in stationary distributed plasma. Because of such a sweep of the magnetic field and the oscillating change of the plasma density along the surface of the stationary held part, the same effect is achieved as if the part were to be moved in an oscillating or rotating manner, but particularly advantageously with respect

10 to the vacuum, without moving parts.

As a result of the fact that – in accordance with Claim 18 - the reactive gas is admitted to the process atmosphere in a distributed manner, preferably with an inflow direction essentially parallel to the part surface, and further preferably, with

15 jet-in points, which are equidistant from the part surface, an optimal exposure of the surface of the part to the plasma-activated reactive gas is achieved, and an optimal utilization of admitted fresh reactive gas, in the sense of an inverse operating ratio, specifically of the quotient of fresh reactive gas admitted per time unit to still fresh reactive gas pumped out per time unit.

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For achieving effects as a result of the above-mentioned treatment steps, particularly according to (a), (b), (c) or the cleaning of the part according to Claim 3, of a quality required for depositing epitaxial layers, the partial pressure of

background gases, as defined above, is kept at no more than 10^{-8} mbar, preferably at maximally 10^{-9} mbar, according to Claim 19.

The above-mentioned at least one plasma-assisted treatment step of the process according to the invention, in a preferred first embodiment, is the depositing of a homo- or hetero-epitaxial layer. Also preferably, in accordance with Claim 21 such a layer is deposited as a silicon germanium layer.

Also, in accordance with Claim 22, an essentially disk-shaped part is produced as the part.

In accordance with the wording of Claim 23, as a further preferred embodiment, the part subjected to the treatment is a silicon wafer or a wafer consisting of a compound semiconductor, preferably of gallium arsenide, indium phosphide, silicon carbide or of glass. On the basis of the production process in accordance with the invention, Claim 24 specifies preferred deposited layer materials.

In an extremely important embodiment of the production process in accordance with the invention, in accordance with Claim 25 virtual substrates of the above-mentioned type are produced, which preferably contain silicon germanium.

In another preferred embodiment of the production process in accordance with the invention, in accordance with Claim 26, parts, particularly the above-

mentioned essentially flat or disk-shaped parts, are produced with diameters of at least 150 mm, preferably of at least 200 mm, preferably even of at least 300 mm.

In another preferred embodiment of the production process of the invention

- 5 according to Claim 27, the coating of parts is implemented at a coating rate of at least 60 nm/Min.

- In connection with virtual substrates, particularly on a silicon germanium basis, normally wet-chemical cleaning processes are used nowadays, be this in order to
- 10 clean the surface of a finished virtual substrate for additional treatment steps, be this in order to clean the surface of an already epitaxially coated substrate for the subsequent preparation of a virtual substrate, be this in order to clean the substrate, suitable for epitaxial growth before growing the buffer layer. Within the scope of the present invention, it was now recognized that, as a result of the use
- 15 of the above-mentioned low-energy plasma for a plasma-assisted cleaning step, the cleaning is implemented in such a way that the subsequent implementation of the production of virtual substrates or of the production of components based on virtual substrates, can take place without any problems. On the one hand this, that is the bypassing of wet-chemical cleaning processes through the use of a
- 20 plasma-assisted cleaning process, always results in an outstanding advantage and, in addition, this knowledge permits the integration of such a plasma-assisted cleaning process into the production process of virtual substrates and of components based thereon. In accordance with the wording of Claim 28, a process for producing a virtual substrate or a component on the base of a virtual

substrate, preferably on a silicon germanium basis, is therefore proposed, which comprises at least one cleaning step, which is plasma-assisted and during which the work piece is exposed to reactive gas or a reactive gas mixture admitted to a process space. This is activated by means of a low-energy plasma discharge
5 with ion energy at the surface of the part of a maximum of 15 eV.

The surprising success, which the inventors achieved by means of this dry cleaning process in connection with extremely difficult surfaces, is attributed to the use of the low-energy plasma, as defined.

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In Claims 29 and 30 a vacuum treatment system according to the invention is specified, which is particularly suitable for carrying out the process according to one of the above-mentioned aspects: In accordance with Claim 29 the interior wall surface of the process chamber in the new condition is realised of a material,
15 preferably of a dielectric material, which is inert with respect to the plasma-activated reactive gas or reactive gas mixture; according to Claim 30, the process chamber comprising the process space is set off toward the inside from the vacuum chamber wall, that is, is realised at a distance. Preferred embodiments of the vacuum treatment system in accordance with the invention
20 are specified in the following in Claims 42 to 60.

The invention will now be explained by means of figures:

Fig. 1 shows a schematic view of a first embodiment of a process module according to the invention for carrying out the process according to the invention;

5 Fig. 2 shows a representation analogous to that of Figure 1 of a preferred embodiment of the process module according to Figure 1 for carrying out the process according to the invention;

10 Fig. 3 shows a representation analogous to Figures 1 and 2 respectively of another process module type according to the invention for carrying out processes according to the invention, specifically cleaning according to the invention;

15 Fig. 4 shows a representation analogous to Figures 1 to 3, a modification of the process module illustrated in Figure 3 for carrying out processes according to the invention, specifically cleaning according to the invention,

20 Fig. 5 shows a simplified view of a preferred embodiment of a process module in accordance with the invention according to Figure 2, which can be changed into a process module according to Figures 3 or 4 for carrying out the processes according to the invention;

Fig. 6, with respect to a diaphragm axis A of the process module according to Figure 5, shows a view of the local and time-related modulation, caused by the control, of magnetic field components parallel to the axis A, above a plane E, perpendicular to the diaphragm axis A;

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Fig. 7 shows a schematic view of the passage coating of a process module according to one of Figures 1 to 5 with work pieces and, above the time axis, its self-cleaning after a defined number of implemented treatment steps or as required;

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Fig. 8 shows a view of the combination of process modules according to Figures 1 to 5 in an inline passage system; and

Fig. 9 shows a simplified top view of the combination of process modules according to Figures 1 to 5 into a circular or cluster system, particularly for the production according to the invention of virtual substrates and of components on the basis of virtual substrates.

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Fig. 1 is a schematic view of a process module Type I according to the invention
 20 A chamber wall 1 of a vacuum recipient 3 encloses a process space PR, wherein plasma is generated. In the process space PR a substrate carrier 5 is provided and a feeder line 7 communicates, on the one hand, with the process space PR and, on the other hand, with a reactive gas tank arrangement 9. By way of a pump connection 11, as schematically illustrated by means of the vacuum pump

13, the process space PR is pumped down to the pressure of a maximum of 10^{-8} mbar, preferably a maximum of 10^{-9} mbar, required for carrying out the production process according to the invention. The construction of the recipient meets UHV requirements (for example, metallically sealed vacuum tank, bakeable). The by far predominant surface area of the surface of the chamber wall 1 facing the process space PR, which normally consists of stainless steel or Inox, is produced of a material, which is inert with respect to the plasma-activated reactive gas in tank 9. According to the embodiment of the Type I process module illustrated in Figure 1, for this purpose, the chamber wall 1 is coated on the inside with the above-mentioned inert material, or, on the chamber wall 1 wall parts are mounted on the inside at least with interior surfaces made of the above-mentioned inert material. In Figure 1, this coating or these inert material surfaces have the reference number 15. After the pumping-down of the process space PR to the above-mentioned required partial background gas pressure, while working gas, such as argon, is admitted, the low-energy plasma required according to the invention is generated in the process space PR, which plasma, in the area of the substrate carrier 5 or of a part deposited thereon, results in ion energies E of

$$0 \text{ eV} < E \leq 15 \text{ eV}$$

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As the material of the surface 15 facing the process space PR, preferably a dielectric material, preferably at least one of the materials listed in the following Group G is used:

Quartz, graphite, silicon carbide, silicon nitride, aluminum oxide, titanium oxide, tantalum oxide, niobium oxide, zirconium oxide, diamond-like carbon or diamond, the latter surface materials being used as coating materials.

- 5 In a representation analogous to that of Figure 1, Figure 2 schematically shows a preferred embodiment of the Type I process module in accordance with the invention according to Figure 1. For the parts already described in Figure 1, the same reference numbers are used in it. In difference to the embodiment according to Figure 1, in the embodiment of Figure 2, the process space PR is
- 10 limited by a process space wall 14 spaced away along predominant sections of the chamber wall 1, furthermore preferably made of stainless steel or Inox. At least its surface 15a facing the process space PR consists of the material, preferably a dielectric material, which is inert with respect to the plasma-activated reactive gas in the tank arrangement 9, for this furthermore particularly preferably
- 15 made of at least one of the above-mentioned materials of Group G.

The wall 14, which actually forms a process space casing within the vacuum chamber together with the wall 1, may consist of the material forming the surface 15a, or the inert material forming the surface 15a is built up, for example, stacked

20 up in layers, on a carrying wall (not shown) which faces the wall 1, the latter of which, because it is not exposed to the process space PR, can then be constructed, for example, of stainless steel or Inox. By means of the pump connection 11 and the pump 13 respectively, the process space PR is pumped down to the partial background gas pressure explained in conjunction with

Figure 1, while, for example and as illustrated in Figure 2, the intermediate space ZW between the vacuum chamber wall 1 and the casing 14 is pumped down by way of a separate pump connection 11a by the same or by another vacuum pump.

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An expert will easily recognize that, even when the same pump 13 is used for pumping down both spaces, specifically the process space PR and the intermediate space ZW, corresponding controllable throttling elements are installed in the assigned pump connection pieces 11 and 11a respectively. With regard to the low-energy plasma, which is used for carrying out the process according to the invention on the module according to Figure 2, the pre-conditions apply, which were established in conjunction with the module explained in Figure 1. The process space casing provided in the embodiment of Figure 2 and formed by the wall 14 is preferably designed to be exchangeable in the recipient 3a.

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Analogous to the representations of Figures 1 and 2, Figure 3 shows a process module of the Type II_e which, compared with that illustrated in Figure 2, differs only in that the surface 15b enclosing the process space PR does not meet the inertness requirements explained in conjunction with the process module according to Figure 2, and in the case of which the wall 14a, for example like the wall 1, is produced of stainless steel or Inox or another metal. With regard to set partial background gas pressures, ion energies in the area of the substrate carrier, the explanations apply, which were made concerning Figures 1 and 2

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The normally metallic wall 14a is also exchangeable, so that the process module Type II_e according to Figure 3 can easily be changed into a process module Type I according to Figure 2 and vice versa.

- 5 Irrespective of the processes implemented thereon, the process module structures according to Figures 1 to 3 correspond to the invention.

In a representation analogous to Figures 1 to 3, Figure 4 shows another process module Type II_{ne}, which does not correspond to the invention. In contrast to the process modules explained by means of Figures 1 to 3, in the case of Type II_{ne},
 10 the process space is limited by the process chamber wall 1 with a surface, which consists, for example, of stainless steel or Inox. If this process module, the structure of which does not correspond to the invention, is, however, used according to the invention, that is, a process according to the invention is carried out by means of this process module, or such a module is used within the scope
 15 of a process according to the invention, the data indicated for Type I and Type II_e modules apply with respect to the set partial background gas pressure and the plasma.

- 20 It can easily be seen that the Type I, Type II_e and Type II_{ne} modules can be converted to one another by the corresponding removal or installation of the corresponding process space casing 14, 15b.

Figure 5 illustrates a preferred embodiment of the Type I process module according to Figure 2. In this case, it should be pointed out, that all measures originating from the module according to Figure 2 preferably used additionally or specifically preferred on the module according to Figure 5, can be used on the principal module according to Figure 2 individually or in arbitrary partial combinations.

As will be demonstrated, in a preferred embodiment, the Type I process module illustrated in Figure 5 can easily be converted into a Type II_e module or into a Type II_{ne} module. The recipient wall 101 of the process module according to Figure 5, preferably made of stainless steel or Inox, centrally, preferably on its upper frontal plate 103, carries an electron source 105 for co-generating the plasma discharge in the process space PR. Although, within the scope of the ion energies required in principle according to the invention in the substrate carrier area, other plasmas, such as microwave plasmas can also be used, an electron source, such as the electron source 105, is preferably used, which emits electrons with an electron energy of a maximum of 100 eV, preferably of a maximum of 50 eV. In a preferred embodiment, the plasma discharge is implemented as a DC discharge. The electron source 105 according to Figure 5 is preferably constructed with a thermionic cathode, preferably a directly heated thermionic cathode 107, installed in a cathode chamber 109 with a cathode chamber wall that is electronically insulated from the recipient wall 101, 103. The cathode chamber communicates by way of a diaphragm 111 with the process space PR. The working gas, such as argon, is preferably (not shown) admitted

into the cathode chamber 109, among other things, in order to protect the thermionic cathode 107 from influences of the reactive gas in the process space PR and permit a higher electron emission.

- 5 Spaced away from the recipient wall 103, 101 and setting up the intermediate space ZW together with it, the process space casing 113 enclosing the process space PR, analogous to Figure 2, is preferably mounted in an exchangeable manner. The process space PR within the casing 113 as well as the intermediate space ZW are pumped here by way of the same pump connection
- 10 115, in which case optionally different pump cross-sections lead from this connection 115, on the one hand, to the intermediate space ZW, and, on the other hand, to the process space PR.

- An anode arrangement acts within the process space PR. As illustrated in Figure
- 15 5, this anode arrangement is preferably formed by two or more anodes 117a and 117b arranged concentrically with respect to the diaphragm axis A. They can be conducted (not shown), in each case, independently of one another, to ground potential or to electric anode potentials, which, also preferably, can be adjusted independently of one another. Also preferably, the metallic recipient wall 101,
 - 20 103 is applied to a reference potential, preferably ground potential. The anodes 117a, 117b offset along the diaphragm axis A, in addition to being electrically operable independently of one another, preferably (not shown) are also heatable and coolable independently of one another. This is implemented in that

temperatures adjusting medium lines are carried in these anodes and/or helical heating filaments are installed.

In Figure 5, the plasma beam PL, which is generated by the preferably used plasma generating arrangement, is illustrated in Figure 5 in a dash-dotted manner, with a plasma density distribution indicated at V in a purely heuristic manner, coaxial to the axis A of the diaphragm. As a result of a corresponding action upon the anodes 117a and 117 by anodic potentials and a controlled temperature adjustment of these anodes, the plasma density distribution V can be adjusted in a targeted manner.

In the process space PR, a wafer holder 119 is mounted or – as will be explained in the following – can be introduced into the process space PR in a controlled manner. Although it is definitely possible to provide the substrate holder 119, for the preferred treatment of disk-shaped work pieces 120 defining a carrier surface 119a, with this carrier surface 119a parallel to the diaphragm axis A, at an oblique angle thereto or perpendicular thereto – according to Figure 5 –, but eccentrically, the wafer holder 119 is arranged by means of its carrier surface 119a very preferably concentrically to the axis A of the diaphragm 111. By means of an external drive 121, the wafer holder 119, as illustrated by means of the double arrow F, can be moved towards or back from the receiving opening 123 defined by the process space casing 113. When the wafer holder 119 is completely moved up by means of the drive 121 against the process space PR, its edge part 125 closes off the clear opening 123 of the process casing 113 at

least in such a way that charge carriers are prevented from exiting the process space PR.

A work piece or part to be treated, which, as mentioned above, is preferably disk-shaped, is placed through a slotted valve 129 on stationary receiving supports 126, while the wafer or work piece holder 119 is lowered. Subsequently, the wafer holder 119 is lifted, reaches by means of its carrier surface 119a under the work piece or the wafer 120, lifts it off the stationary support 126, and moves it upward into the process space PR, while, when the processing position is reached, closing off by means of its edge surface 125 the process space to the above-mentioned extent.

The supports 126 are mounted on a work piece temperature-adjusting device 127, which is acted upon by temperature adjusting medium with a temperature adjusting medium feeding and removal lines 128. Normally, the introduced substrate 120 is heated by way of the plate 128a. The wafer holder 119 is illustrated in Figure 5 by a broken line in its processing position.

The recipient wall 101 and its face-side end plates 103 and 131 are temperature adjusted, preferably cooled. For this purpose, the wall 101 forming the casing is constructed as a double wall, with a temperature adjusting medium system installed in-between. Likewise, temperatures adjusting medium line systems are installed into the front plates 103 and 131.

Helmholtz coils 133 as well as distributed deflection coils 135 are mounted outside the vacuum recipient. By means of the Helmholtz coils 133, a magnetic field pattern is generated in the process space PR, which is essentially parallel and symmetrical to the axis A. By means of the deflection coils 135, this

5 magnetic field pattern can be moved in planes perpendicular to the axis A, as schematically illustrated in Figure 6. As a result of this "displacement" of the magnetic field intensity distribution H_A , a "displacement" of the plasma density distribution V is obtained on a substrate applied to the substrate carrier 119. As a result, a relative movement is achieved between the plasma density distribution

10 V and the work piece surface on the substrate carrier 119, which is to be treated, as if the substrate were displaced with respect to the plasma with a time-constant plasma density distribution. As a result of this field distribution control, the same effect is obtained on the substrate as if this were mechanically moved with respect to the plasma but without any mechanical substrate movement.

15

Reactive gas is admitted by way of the reactive gas inlet 137 into the process space PR. As illustrated, the reactive gas inlet is preferably arranged coaxially to the axis A in the immediate area of the substrate 120 or the substrate carrier 119 lying in the processing position, with inlet openings essentially parallel to the

20 substrate surface to be treated.

As mentioned above, the vacuum recipient 101, 103, which is preferably made of stainless steel, is cooled intensively. It meets UHV requirements. In this case,

the intensive cooling prevents the heating-up of the steel during the process and thus a connected release of carbon-containing gases from the steel.

With respect to the material of the process space casing 113, particularly its surface that is exposed to the process, the statements made by means of Figure 1 apply. The inert material, preferably a dielectric material and, as mentioned, preferably selected from the Group G of materials, is stable at the high process temperatures and does not form gaseous compounds with the used reactive gases, such as particularly hydrogen, hydrosilicon, germane, boroethane, chlorine, NF_3 , HCl , SiH_3CH_3 , GeH_3CH_3 , N_2 , ClF_3 , PH_3 , AsH_4 . Thus, it is achieved that there will be no contaminations of the part 120. Interference coating of the interior surface of the process space casing 113 is critical only under the aspect of particle formation. A thin interference coating may even be preferred in order to ensure a still better purity of the process, which is then surrounded virtually only by process-inherent material.

In the case of Type I process modules, the vacuum chamber wall, usually made of stainless steel, is not coated because it is protected from the reactive gases and the plasma by the process space casing 113; also, because, as illustrated in Figure 5, the intensive cooling additionally considerably reduces a precipitation from the gaseous phase there. The statements made with respect to the interior surface of the process space casing 113 also apply to the surfaces of the substrate holder 119 exposed to the process.

The process space casing 113 is preferably constructed in several parts (not shown), so that it can be removed or exchanged without demounting the anode arrangement 117a, 117b. By the removal of the process space casing 113 illustrated in Figure 5, a preferred embodiment of the Type II_{ne} process module is realised, and by respectively replacing the process space casing 113 with a similarly shaped casing made of metal, a Type II_e process module according to Figure 3 is realised.

The following is a compilation of the processes carried out in each case by means of the process modules introduced by means of Figures 1 to 5.

Type I

While meeting quality requirements, as required when coating parts with an epitaxial layer, this process module is used for carrying out reactive coatings in a plasma-assisted manner, or plasma-assisted reactive etching, or plasma-assisted reactive altering processes of the material composition on the work piece up to the pre-defined penetration depths; or, particularly combined with above-mentioned process steps according to the invention, the surfaces of the work pieces or parts are subjected to a plasma-assisted reactive cleaning, particularly in hydrogen plasma. After passing through a pre-defined number of the above-mentioned treatment steps or as required, these Type I process modules are subjected to a self-cleaning process without introducing a work piece part or using a substrate dummy. This self-cleaning comprises preferably, on the one hand, a plasma-assisted reactive etching step and on the other hand,

a subsequent plasma-assisted reactive cleaning step for etching residues, preferably carried in a hydrogen plasma.

Type II

- 5 The Type II process modules are used for cleaning work pieces in a more penetrating manner, as required, for example, when they are moved from the ambient atmosphere to the above-mentioned treatment steps, which meet epitaxial quality requirements. Also in these Type II process modules, in combination with the treatment processes meeting the above-mentioned highest
10 quality demands, the parts are cleaned by means of the above-mentioned low-energy plasma, in a reactive manner, preferably first by a plasma-assisted reactive etching, then by a plasma-assisted reactive cleaning, preferably in hydrogen plasma.
- 15 With respect to preferred coating processes, specifically for the depositing of hetero- or homo-epitaxial layers by means of the Type I modules, reference is made to the complete contents of the approach according to the initially mentioned W098/58099.
- 20 Figure 7 is a schematic view of a Type I or Type II process module 140. During the passage operation, parts 142 to be treated sequentially are supplied to the process module 140 and treated parts are removed from module 140 respectively. On the time axis t illustrated in Figure 7, only as an example, coating and/or etching and/or material altering and/or cleaning steps according to

the invention on the parts 142 are illustrated in a hatched manner, in each case, followed, as required or after a pre-defined number of such treatment steps, by a non-hatched self-cleaning step of the module 140 charged in the passage operation.

5

Figure 8 schematically illustrates how, inside a vacuum atmosphere of a system 144, for example, an inline system, for example, work pieces are first subjected in a Type II process module to an initial cleaning and are then, in Type I process modules subjected to coating, etching, material altering and optionally also

10 cleaning steps. Here also, analogous to the representations in Figure 7, the provided process modules are subjected to a self-cleaning after a respective given number of processing cycles.

As mentioned initially, a preferred process of this type is the production of virtual

15 substrates. Accordingly, in the Type II process module, the base, suitable for a subsequent hetero-epitaxial layer growth, is reactively cleaned in a plasma-assisted manner, using a halogen, but preferably hydrogen, as the reactive gas. Subsequently, in one or several of the subsequent Type I process modules, the hetero-epitaxial layer is grown in such a way that the grid constant is changed

20 and, by the successive graded building-in of another material, a surface structure is achieved, which is as free of defects as possible. Then – again in another Type I module – optionally the epitaxial growth of the semiconductor layer to be used is implemented in a definably mechanically restrained manner for adjusting the band gap and the setting the desired semiconductor characteristics, as, for

example, the charge carrier mobility. Optionally, additional treatment steps according to the invention will follow until the finished virtual substrate is unloaded from the system 144 via the lock.

- 5 An expert will be familiar with the fact that, also during the production of the virtual substrate, additional layers can be built in, or that cleaning steps can be provided between the coating steps, in that case preferably as "soft cleaning steps" in a Type I process module.
- 10 Although schematically, Figure 8 illustrates an "inline" system, in which the work piece transport from one module to the next takes place in a vacuum in an essentially linear manner.

- Figure 9 is a schematic top view of the preferred arrangement of several Type I and Type II process modules as respective clusters for forming a cluster system. This comprises a circular vacuum transport chamber 150, which services the process modules essentially in a radial manner. Unprocessed substrates are loaded from a transfer chamber 152 and treated substrates are transferred therein, where the latter, for example, cool off. From the, for example, provided
15 input and output transfer chamber 152, the substrates are removed by means of a robot unit 154 situated in the standard atmosphere, or are fed to the respective transfer chamber 152 from storage magazines 156 for untreated substrates and removed from the respective transfer chamber 152 to storage magazines 158 for
20 treated finished substrates. With respect to its time sequences, the system is

controlled by a program control system, for example, a freely programmable program control system.

The described process modules, which can all be converted into one another,
5 can treat substrates, which have a diameter of at least 150 mm, preferably of at least 200 mm, preferably even of at least 300 mm. In the case of the epitaxial coating by means of the process described in the above-mentioned W098/58099, **which is enclosed as Attachment A with respect to the process disclosure of the present application**, coating rates of at least 60 nm/min. are reached on
10 the above-mentioned substrates.

[blank]

Process for the production of coated work pieces, utilization of the process and installation for it

(Appendix 'A' Start of the description PCT/CH98/00221)

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This invention concerns a process for the production of coated work pieces in accordance with the generic term of Claim 1, utilisations thereof in accordance with Claims 28 to 35, an appendix for the execution of the mentioned process in accordance with the generic term of Claim 36 and its utilisation in accordance with Claims 51 to 54.

10

In this the invention starts on the basis of problems that occur during the production of thin layers using CVD and PECVD processes. The experience gained regarding this in accordance with the invention can be transferred in particular to the production of semi-conductor layers, such as in the production of solar cells or modulation-doped FET or hetero-bipolar transistors.

15

Thin semi-conductor films are either deposited like a silicon substrate in mono-crystalline form, i.e. epitaxially, onto a substrate that is also mono-crystalline or in poly-crystalline form or amorphous form onto poly-crystalline or amorphous substrate, e.g. on glass. Even the invention in the following is described mainly with reference to the production of silicon and/or germanium coated substrates, it can, as mentioned before, be used for the production of other work pieces and work pieces coated with other materials.

20

25

Known processes for the depositing of epitaxial semi-conductor films are:

- Molecular Beam Epitaxies, MBE
- Thermo-chemical gaseous phase depositing, CVD (Chemical Vapour Deposition)
- Remote plasma-assisted CVD processes with DC or Hf discharge, RPECVD (Remote-Plasma-enhanced CVD)

30

- Microwave plasma-assisted chemical gaseous phase depositing and ECRCVD (Electron-Cyclotron-Resonance-Plasma-Assisted CVD)

The CVD process is a collective term for a large number of thermal deposition methods, which differ either in the structure of the related apparatus' or their operation. For example, a CVD process can be carried out at normal atmospheric pressure or at much lower pressure values down to the field of ultra high vacuum. With regard to this (1) as well as (2) can be referred to.

- 10 In the commercial production of epitaxial Si layers only CVD is commonly used. The used reactive gases are silicon-containing gases, e.g. chlorine hydrosilicons, SiCl_4 , Si_3H_8 and SiH_2Cl_2 as well as hydrosilicons, such as SiH_4 or Si_2H_6 . Characteristic for the standard CVD processes are the high deposition temperatures in the range of 1,000 °C and more as well as pressure values
- 15 typically 20 mbar to 1,000 mbar, that is up to normal atmospheric pressure.

Depending on the process conditions, coating rates of up to several μm per minute can be achieved, corresponding to several 100 Å/sec, for which (1) is again referred.

- 20 Low-pressure chemical gaseous phase deposition (LPCVD, Low Pressure Chemical Vapour Deposition, synonymous with LPVPE, Low Pressure Vapour Phase Epitaxy) on the other hand takes place at pressures below 1 mbar and allows for lower process temperatures, down to typically 700 °C. With regard to
- 25 this (3) and (6) are referred to in addition to (1).

With regard to LPCVD and with reference to (6) a growth rate of

$$\text{GR} = 50 \text{ Å/min}$$

- 30 is stated for a deposition temperature of 650 °C. And this for a reactive gas flow for hydrosilicon of

$$F = 14 \text{ sccm}$$

This results in a parameter that is relevant for the gas yield, that is the growth rate per reactive gas flow unit, GR_F at

$$GR_F = 3.6 \text{ \AA/ (sccm \cdot min)}$$

On 5" wafers, corresponding to a surface area

$$A_5 = 123 \text{ cm}^2,$$

converted from the actual area A_2 for 2" wafers, this results in a deposition quantity (growth amount) GA at

$$GA = 5.2 \cdot 10^{16} \text{ Si atoms / sec.}$$

Again in reference to a reactive gas flow unit, this results in the parameter 'Deposition quantity per reactive gas flow unit', hereinafter referred to as 'Gas utilisation number', GA_F at

$$GA_F = 8.4 \cdot 10^{-3},$$

corresponding to 8.4 0/00.

At 650 °C an epitaxial layer is created.

If the deposition temperature is reduced to 600 °C, then a poly-crystalline layer will be created. This with

$$GR = 3 \text{ \AA/min}$$

$$F = 28 \text{ sccm Hydrosilicon}$$

$$GR_F = 0.11 \text{ Å} / (\text{sccm} / \text{min})$$

$$GA = 3.1 \cdot 10^{15} \text{ Si atoms} / \text{sec on } A_5$$

$$GA_F = 2.5 \cdot 10^{-4}, \text{ corresponding to } 0.25 \text{ o/oo.}$$

5 On principle the following criteria are necessary for defect-free epitaxial layer growth:

- In the case of transmission electron microscopy on cross section preparations the proof of the epitaxy is provided via electron diffraction and high resolution.
- In the range of 10 – 15 μm along the border area to the substrate that typically can be radiated no defect must be visible. Typical magnification values during the defect analysis are 110'000 to 220'000.

15

Another development is the ultra-high vacuum chemical gaseous phase deposition (UHV-CVD) with working pressures in the range of 10^{-4} to 10^{-2} mbar, typically in the range of 10^{-3} , for which (4) as well as (5), (7) are referred to. It allows very low work piece temperatures. However, the growth rates and coating rates respectively are extremely low, for example approx. 3 Å / min. for pure silicon at 550 °C in accordance with (5).

20

The reason for the low growth rates is that the absorption and disintegration rate of the reactive molecules, for example of SiH_4 , decreases with increasing hydrogen coating of the work piece surface. Therefore the growth of the layer is limited by the desorption rate of H_2 , which, however, increases exponentially with the temperature. With regard to this (8) is referred to. Due to the lower binding energy of the Ge-H bond in comparison with the Si-H bond, the hydrogen absorption of a Si-Ge alloy surface is greater, so that at the same substrate temperature a higher growth rate than for pure Si is the result, e.g. for a content of 10% Ge by a factor of 25 at 550 °C (5).

30

Another possibility for achieving high deposition rates with epitaxy quality at low substrate temperatures is (9) to decompose the reactive gases using a μ -wave plasma (ECRCVD).

- 5 Through the use plasma sources, which are based on the principle of electron-cyclotron resonance, the intrusion of high-energy ions into the substrate is to be prevented.

10 As a rule such sources work with pressure values in the range of 10^{-3} to 10^{-4} mbar. However, this lead to longer free distances than in the case of capacitive excited high-frequency Hf plasmas. This in turn may lead to undesirable ion bombardment of the substrate and thus to the creation of defects, as shown in (10). However, the energy of ions hitting the substrate can be limited by an external control of the substrate potential, by which ion damage can be
15 prevented to greatest degree. With the ECRCVD method as well, the growth rates for pure silicon amount to only a few $10 \text{ \AA} / \text{min}$ at low deposition temperatures $\leq 600 \text{ }^\circ\text{C}$.

In summary the following results;

20

Layers that are deposited in a quality that is also suitable for the depositing of epitaxial layers, as of today can be deposited at deposition temperatures $\leq 600 \text{ }^\circ\text{C}$:

25

- via UHV-CVD with growth rates GR of approx. $3 \text{ \AA} / \text{min}$ or
- Via ECRCVD with a growth GR that is higher by approx. the factor 1 ($30 \text{ \AA} / \text{min}$).

30

PECVD processes, the plasma of which is generated via DC discharges, could not be used for the production of layers with epitaxy quality – that is correspondingly lower defect density (see above) – neither for the building of

epitaxial nor the building of amorphous or poly-crystalline layers, at least not with a growth rate GR, reliability and effectiveness or effect ratio that has to be ensured for industrial production.

5 On the other hand, the use of capacitive coupled high frequency fields for the generating of Hf plasmas for PECVD processes was reported very early on, with regard to which (11) is referred to. The difficulty in the procedure lies in the fact that not only reactive gases are decomposed in such Hf plasmas. At the same time the substrate surface is subjected to an intensive bombardment with high-
10 energy ions, as specifically exploited in the case of reactive disintegration or high frequency etching. On the one hand this facilitates the hydrogen desorption, but at the same time it leads to defects in the growing layers. A method derived from that, RPCVD, Remote Plasma Chemical Vapour Deposition, takes this into consideration by not exposing the substrates to be coated directly to the Hf
15 plasma, which leads to better results (12). However, the achieved growth rates are low, that is in most cases only fractions of nm per minute up to a maximum of some nm per minutes according to (13).

It is the object of this invention to present a process that can be used in industrial
20 production and which allows to grow layers with epitaxy quality, with significantly higher growth rates than have been known until now.

This is achieved by processes that were named at the beginning, which are characterised according to the wording of the characterising part of Claim 1 and
25 an appendix respectively, which is characterised by the characterising part of Claim 36. Preferred embodiments of the process are specified in the Claims 2 to 27, preferred embodiments of the appendix in the claims 37 to 50. The process in accordance with the invention is particularly suitable for the production of semi-conductor coated substrates with an epitaxial, amorphous or poly-crystalline
30 layer, and among these in particular of Si, Ge, or Si/Ge alloy layers as well as Ga or Ga compound layers.

In this especially doped semi-conductor layers can be deposited. Layers containing silicon and/or germanium, doped preferably with at least one element from the groups III or V of the periodic system or layers containing gallium with at least one element of the groups II, III, IV or VI of the periodic system, e.g. with Mg or Si.

On the basis of the coating techniques dealt with at the beginning for the generating of epitaxial layers, the following can be said in summary:

- 10 - The CVD processes, in particular the UHV-CVD processes results in excellent layer qualities, even at substrate temperatures below 500 °C. Therefore they offer themselves even to the production of epitaxial layers, where extremely high demands are made on the quality of the layer. However, the growth rate for Si for example, is extremely low for these processes; as mentioned in the range of 3 Å / min at 550 °C.
- 15
- Microwave plasma-assisted processes, ECRCVD, have the advantage that the decomposition of the reactive molecules can take place without a high level of thermal energy. The ion bombardment of the substrate leads to increased hydrogen desorption. Both effects could lead to a significant increase of the growth rate. However, at low temperatures unacceptably high defect densities are observed, induced by ion bombardment. Even though controlling it via the substrate-bias tension increases the quality of the layer, it does not change anything in the comparably small rates.
- 20
- 25

Thus there seems to exist an inherent contradiction: Ion bombardment of the substrate on the one hand leads to increased growth rates due to increased hydrogen desorption, but at the same time it leads to an increase in the defect density.

30 According to (2) the following picture emerges for thermal CVD processes operated under atmospheric pressure:

- Si growth rate GR: 2×10^{-3} nm/min
(at 600 °C, $3 \cdot 10^{-2}$ nm/min measured and converted to 550 °C)
- Gas flow, SiCl_2H_2 , F: 100 sccm

5

This results in a growth rate GR per SiCl_2H_2 flow unit,
 $\text{GR}_F \approx 2 \times 10^{-4} \text{ \AA} \text{ (sccm.min)}$.

A gas flow F of 100 sccm SiCl_2H_2 corresponds to 4.4×10^{19} molecules / sec.

10

The growth rate of 2×10^{-3} nm/min corresponds to a growth rate of 2×10^{-4} silicon mono layers per second on a 5" wafer, corresponding to a surface area A_6 of 123 cm^2 . For the total area per second this results in a deposited quantity of

15

$$\text{GA} = 1.7 \times 10^{13} \text{ silicon atoms / sec.}$$

By creating a relationship between the silicon quantity deposited per second and the reactive gas quantity admitted per second, the gas utilisation number GA_F is the result at

20

$$\text{GA}_F = 3.9 \times 10^{-7}.$$

This corresponds to an utilisation of approx. 0.0004 0/00.

We state that the following results for atmospheric CVD:

25

$$\text{GR}_F \approx 2 \times 10^{-4} \text{ \AA} / \text{ (sccm.min)}$$

$$\text{GA}_F \approx 0.0004 \text{ 0/00}$$

30

From (5) combined with (4) and (7) the estimate for UHV-CVD is as follows:

$$\text{GR}_F \approx 0.1 \text{ \AA} / \text{ (sccm.min)} \text{ and}$$

$GA_F \approx 0.0035$ corresponding to approx. 35 0/00

This much concerning the processes used in the industry until now for the production of layers in epitaxy quality.

5

From DE-OS 36 14 384 another PECVD process is known, in which the DC glow discharge is used in the form of a low voltage discharge. With this layers with particularly good mechanical characteristics are to be deposited quickly, that is with high growth rates.

10

A cathode chamber with a hot cathode communicates with a vacuum recipient via a diaphragm. Opposite the diaphragm an anode is provided. Parallel to the discharge axis formed between the diaphragm and the anode, an admission set-up is provided for a reaction gas. Arranged opposite that arrangement and the discharge axis respectively the work pieces are arranged. With regard to the anode potential, discharge voltages U_{AK} below 150 V are provided and the discharge is operated with a current strength I_{AK} of at least 30 A. for the coating the work pieces are brought to a negative potential between 48 and 610 V.

20

The test shown therein results in the following picture;

Example	GR [$\text{\AA}$ / min]	GR _F [$\text{\AA}$ / (sccm.min)]
1	10^3	2.5
2	380	1.2
3	2×10^3	2.5
4 (Si)	166	0.7
5	466	1.2
6	750	0.7
7	250	0.5
8	500	0.75
9	316	0.38

10	344	0.18
11	62	0.18
12	58	0.14

This invention is now starting from the knowledge, the work piece coatings can be carried out with a layer quality, that meets the demands made for epitaxy layers, by using for this purpose, in contrast to the expectations up to now, a non-
5 microwave plasma PECVD process – that is a PECVD process with DC discharge – and in particular a PECVD process as, in its principle, it is known from DE-OS 36 14 348. As will be shown, it is possible to achieve in epitaxy quality

- 10 a) growth rates GR of at least $150 \text{ \AA} / \text{min}$, even of at least $600 \text{ \AA} / \text{min}$
- b) GR_F of at least $7.5 \text{ \AA} / (\text{sccm.min})$ or even $40 \text{ \AA} / (\text{sccm.min})$, preferably even $75 \text{ \AA} / (\text{sccm.min})$ and furthermore
- 15 c) to achieve gas utilisation figures GA_F at least in the range of 5%.

It is recognised that the plasma discharge in the DC-PECVD process used in accordance with the invention leads to lowest-energy ions, also to lowest-energy electrons, that, however, the charge carrier density, in particular the electron
20 density at the utilised discharge is very large.

Hereafter the invention will be explained by way of examples using illustrations:

Fig. 1 shows in a diagram a first preferred embodiment of an installation in
25 accordance with the invention for the execution of the processes in accordance with the invention.

Fig. 2 in a diagram shows a second preferred embodiment of an installation in accordance with Fig. 1 with several operation variations.

Fig. 3 shows the dependence of the growth rate on the wafer temperature during the operation of an installation in accordance with Fig. 2 for a silicon coating process.

5

Fig. 4 in a function of the discharge current shows the increase of the growth rate relative to the reactive gas flow GR_F .

10

Fig. 5 in a function of the reactive gas flow shows the growth rate for different plasma densities in the area of the work pieces.

Fig. 6 in a function of the germanium concentration shows the growth rate at the deposited layer and

15

Fig. 7 in the field growth rate / gas utilisation figure shows the result in accordance with the state of technology and in accordance with the invention.

20

Apropos, an installation in accordance with, for example, DE-OS 36 14 384 can certainly be used for the execution of the processes in accordance with the invention, if it is operated in such a way that the conditions in accordance with the invention are met.

25

In accordance with Fig. 1 a first installation preferred today for the carrying out of the process in accordance with the invention has a vacuum recipient 1, to which a cathode chamber 5 to which a diaphragm 3 is attached via a flange. In the well-known way the cathode chamber 5 can be connected to the electrical potential of the recipient 1 or the cathode chamber 5 can be insulated with regard to the recipient 1 and connected to a different potential (not shown).

30

Provided in the cathode chamber 5 is a hot cathode 7, a filament, preferably heated directly via a heat current generator 9.

Provided in the diaphragm axis A, opposite the diaphragm 3 in the recipient 1, is a work piece carrier 13 mounted in an insulated manner. A work piece heater 17 may be provided in the area of the work piece carrier 13. The recipient 1 is evacuated with a vacuum pump 27, preferably a turbo vacuum pump and in particular a turbo molecular pump. Sensors, such as for example a plasma monitor etc., can be provided for observation and, if required, for control purposes, using the connection 31.

Concentric to the axis A of the discharge with the discharge current I_{AK} , a gas injection ring 23 is provided as reactive gas injection installation, connected to a gas tank arrangement 25 for reactive gas, which is admitted into the recipient with controllable flow F (sccm).

A connection 6 reaches into the cathode chamber 5 to a working gas tank, for example with Ar. Using an electro and/or permanent magnet arrangement 29, a magnetic field B is generated in general concentric to the axis A in the recipient, which is particularly effective in the area of the diaphragm 3. Preferably the field can be moved away from the concentricity.

The installation with its design in accordance with Fig. 1 is operated as follows:

- The recipient wall in accordance with 1 is used as anode of the discharge and for that purpose is connected to a reference potential, as shown preferably to earth. Correspondingly the cathode 7 is connected to a (negative) potential via a preferably adjustable DC generator 11. Above the generator 11 lies the discharge voltage U_{AK} , the discharge current I_{AK} flows between cathode 7 and recipient 1.
- In a second operation variation of the installation illustrated in Fig. 1, the work piece carrier 13 is connected to the voltage U_s using a DC bias generator 15.

Fig. 2 shows another preferred installation in accordance with the invention for the execution of the process in accordance with the invention. For the same parts the same reference signs are used as in Fig. 1. The installation in accordance with Fig. 2 differs of the one illustrated and described in Fig. 1 as follows:

5

A ring-type ancillary anode 19 is provided, which is arranged concentrically to the discharge axis A.

Here the following operation modes are possible:

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- As shown in the diagram with the variation switch S, the recipient wall of the recipient 1 is, as already in Fig. 1, connected to the reference and preferably to the earth potential or tied or even operated as floating potential via an impedance element 14, preferably a resistance element, to a potential, preferably a reference potential. In that case the ancillary anode 19, if the recipient 1 is connected to the reference potential, connected either to the potential of the recipient or connected to voltage using the preferably adjustable DC generator 21.

15

20 - If the recipient 1 is tied to a reference potential via the impedance element 14, then the ancillary anode is operated using the DC generator 21 and it appears the discharge voltage U_{AK} as shown by the intermittent line between cathode 7 and ancillary anode 19. This is also the case if the recipient wall 1 is operated as floating potential.

25

Nowadays the operation of an installation in accordance with Fig. 2 is preferred with the recipient wall connected to earth and ancillary anode 19 as well as work piece carrier 13 operated potential-controlled. In all installation variations the following settings are important:

30

- Total pressure P_T in the recipient:

$$10^{-4} \text{ mbar} \leq P_T \leq 10^{-1} \text{ mbar}$$

5 preferably $10^{-3} \text{ mbar} \leq P_T \leq 10^{-2} \text{ mbar}$

typically in the range of $5 \cdot 10^{-3}$ mbar. This pressure is mainly ensured by the partial pressure of the working gas, preferably Argon. The vacuum pump 27, as mentioned before, is therefore preferably designed as turbo vacuum pump, in particular turbo molecular pump.

- Working gas pressure P_A :

This is selected as follows:

$$10^{-4} \text{ mbar} \leq P_A \leq 10^{-1} \text{ mbar}$$

preferably $10^{-3} \text{ mbar} \leq P_A \leq 10^{-2} \text{ mbar}$

- 20 • Reactive gas partial pressure PR:

This is preferably selected as follows:

$$10^{-5} \text{ mbar} \leq P_R \leq 10^{-1} \text{ mbar}$$

25 preferably at $10^{-4} \text{ mbar} \leq P_R \leq 10^{-2} \text{ mbar}$

30 In particular for gases containing silicon and/or germanium partial pressure values between 10^{-4} mbar and $25 \cdot 10^{-3}$ mbar are recommended. In order to support the planarity (surface roughness), in particular in the case of multiple layer depositions and layers with doping it is furthermore recommended, to provide also a hydrogen partial pressure in the range of 10^{-4} to 10^{-2} , preferably of approx. 10^{-3} mbar.

- Gas streams

Argon: to the greatest extent dependent on the volume of the recipient and cathode chamber, for the setting of the necessary partial pressure P_A and P_T respectively.

Reactive gas flow: 1 to 100 sccm, in particular for gases containing silicon and/or germanium:

H_2 : 1 to 100 sccm.

- Discharge voltage U_{AK} :

The discharge voltage, be it between cathode 7 and recipient 1 in accordance with Fig. 1 or between cathode 7, recipient 1 and ancillary anode 19 and between cathode 7 and ancillary anode 19 respectively, is adjusted as follows:

$$10 \text{ V} \leq U_{AK} \leq 80 \text{ V, preferably}$$

$$20 \text{ V} \leq U_{AK} \leq 35 \text{ V,}$$

- Discharge currents, I_{AK} :

These are selected as follows:

$$5 \text{ A} \leq I_{AK} \leq 400 \text{ A, preferably}$$

$$20 \text{ A} \leq I_{AK} \leq 100 \text{ A}$$

- Work piece voltage U_S :

In any case this voltage is selected to be lower than the sputter threshold of the discharge. In all cases it is set as follows:

$$- 25 \text{ V} \leq U_s \leq +25 \text{ V}$$

5

preferably for Ga compounds, preferably for Si, Ge and their compounds

$$- 20 \text{ V} \leq U_s \leq +20 \text{ V}$$

10

preferably negative and in that preferably at

$$- 15 \text{ V} \leq U_s \leq -3 \text{ V}$$

- Current density at the place of the work piece surface to be coated:

15

This is measured in advanced using a probe at the place, where later on the surface to be coated will be positioned. It is set with reference to the surface of the probe at a minimum of 0.05 A/cm^2 , preferably at a minimum of 0.1 A/cm^2 up to the maximum discharge current / substrate surface.

20

This current density is measured and adjusted as follows:

25

One or several probes are positioned at the place of the surface that later on is to be coated and with regard to earth and anode potential respectively are connected to a variable positive voltage. This is increased until the measured current no longer increases. The value of the current, in relationship to the probe surface, results in the total current density. By adjusting the discharge it is now set to the required value. The adjustment of the mentioned current density values is possible without problems between 5 and 400 A respectively and preferably between 20 and 100 A.

30

The high flow of low-energy ions and electrons, that impact the work piece, is a characteristic feature of the process in accordance with the invention, which therefore is abbreviated LE-PECVD for 'Low Energy Plasma Enhanced CVD'.

During the coating process silicon and/or germanium layers can be doped by the addition of a doping gas with an element of the group III or V of the periodical system, such as phosphine, boroethane, arsine etc., into n- or p-conducting layers. Thus p/n semi-conductor transitions can be generated in situ, e.g.

5 particularly economical for the solar cell production.

If gallium layers or gallium compound layers are deposited, they can be doped with an element from the groups II or III or IV or VI of the periodic system, e.g. with Mg or Si, by using a doping gas.

10

Using the anode 19 and/or the magnetic field B, the low-voltage discharge can be compressed and/or deflected from the work piece carrier 13. Thus the plasma density at the work piece carrier can be increased (rate) and/or varied (setting of the distribution) or wobbled or deflected in a controlled manner across a wide range. Using the heater 17, the work pieces and substrates respectively can be heated up to approx. 800 °C, independently of the ions and/or electrons arising. The arrangement of magnets 29 generates the field B using permanent and/or electro-magnets, preferably with a flow density of some 10 to some 100 Gauss in the discharge space.

20

Due to the unusually low discharge voltages, as mentioned preferably in the range of 20 to 35 V, the result is a plasma potential of the discharge according to (15) near the anode potential. With regard to the potential, the work piece and substrate potential respectively can easily adjusted, so that the ion energies lie below 15 eV, by which means ion damage during the growth phase of the layer on the work piece can be completely prevented.

25

As has been mentioned, the highest possible plasma density at the work piece should be aimed for. In this case the plasma density is given by the current density at the surface of the work piece. As stated above it is measured and adjusted in a calibration process using probes.

30

The installations, as illustrated in the diagrams of Fig. 1 and Fig.2, are likely today's preferred embodiments, while the processes in accordance with the invention can easily also be realised on other installations, as for example illustrated in DE-OS 36 14 384, if they are equipped and operated accordingly.

5 Until today the significant parts seems to be the potential-controlled operation of the work piece.

Using an installation as illustrated in a diagram in Fig. 2, 3" silicon mono-crystalline substrates were coated epitaxially with silicon and a silicon /
10 germanium alloy respectively. The volume of the recipient 1 was 60 l.

The installation was operated as follows:

Ancillary anode 19 to the potential of the recipient 1; work piece carrier 13 to
15 controlled bias potential. Recipient as anode to earth.

The following working point settings were made:

20 • Work piece temperatures T_s

Plasma-induced the result are work piece temperatures of only a few 100 °C, for example of approx. 150 °C.

25 This is extremely advantageous for the coating of thermally critical substrates, such as for example organic substrates.

Higher, desired temperatures are achieved by separate heating. For the production of Si and/or Ge layers and layers with Si-Ge compounds work
30 piece temperatures T_s of

$$300\text{ °C} \leq T_s \leq 600\text{ °C}$$

are recommended, for Ga layers or Ga compound layers:

$$300\text{ }^{\circ}\text{C} \leq T_s \leq 800\text{ }^{\circ}\text{C}$$

- 5 Because the process is 'cold', there is great flexibility in the selection of the temperatures, depending on layer material and substrate material.

	Flow [sccm]	Partial Pressure [mbar]
Ar	50	6.8×10^{-3}
H ₂	5	7×10^{-4}
SiH ₄	10	10^{-3}

Discharge current I_{AK} : 70 A.

10

Discharge voltages U_{AK} : 25 V

Substrate temperature: 550 °C (heated with heater)

- 15 In a first test the substrate temperature was varied using the heater 17. At the same time the other working parameters were left constant. Fig. 3 shows the result. This figure shows that the growth rate GR depends only to a very small degree on the work piece and substrate temperature T_{13} respectively. The reason of the great scattering of the measured values is the fact that operating
- 20 parameters had to be manually re-adjusted at the test installation prior to every deposition.

- Starting from the mentioned working point values, the discharge current I_{AK} was then varied by setting the discharge voltage U_{AK} and, if necessary, the variation
- 25 of the cathode heating current. Again all other parameters were kept constant. Even if the discharge current I_{AK} at the surface to be coated does not directly correspond to the charge carrier density and plasma density respectively, the plasma density, with otherwise constant parameters, is still mainly proportional to

the discharge current, corresponding to the current density at the work piece surface to be coated. Therefore the result shown in Fig. 4 definitely shows the proportionality and the proportionality factor between the growth rate GR and the plasma density. This proportionality should continue as long as the gas utilisation
 5 does not exceed approx. 60 % and saturation problems occur. As mentioned before, the plasma density can also be influenced by, for example, the adjustment of the discharge current as well as the focussing and defocusing of the low voltage discharge or its deflection. Here, too, the relatively great dispersion is explained by the procedure during the setting of the discharge
 10 conditions.

Highly revealing is lastly Fig. 5. It shows the result of tests, in which the reactive gas flow F was varied, while the other parameters were kept constant, starting from the working point 10 sccm. The straight line (a) was the result of the low
 15 voltage discharge, which was locally slightly offset with regard to axis A of Fig. 1 due to the magnetic field setting, which in turn led to a plasma density reduction or a lower rate at the substrate, for a discharge current I_{AK} of 20 A.

Graph (b) shows the rate for the non-deflected discharge and at $I_{AK} = 20$ A. (c)
 20 finally shows the increased rate for a non-deflected discharge with $I_{AK} = 70$ A.

For a reactive gas flow of 10 sccm at a temperature of the substrate of 550 °C and 70 A discharge current I_{AK} the result is a GR of approx. 15 Å / sec as confirmed by Fig. 3.

25 For a discharge current of 70 A at a reactive gas flow of 10 sccm this result is also confirmed by Fig. 4. The GR declines to approx. 6 Å / sec for a discharge current of 20 A.

30 Now the results in accordance with the invention will be compared with the results of previously known technologies.

a) Comparison with APCVD (2)

For example, Fig. 5 shows for the point P1:

5 $GR \approx 1,200 \text{ Å/min}$, compared with

$GR \approx 2 \times 10^{-2} \text{ Å/min}$ for APCVD.

For the point P1 Fig.5 shows a value of

10

$GR_F 80 \text{ Å/min (sccm.min)}$

The corresponding value for APCVD is

15

$GR_F \approx 2 \times 10^{-4} \text{ Å / (sccm.min)}$

If the gas utilisation figure for a 3" substrate is calculated for LEPECVD in accordance with the invention, this will result in

20

$GA_F \approx 6.8 \times 10^{-2}$, corresponding to approx. 6.8 %.

In this it has to be taken into consideration that these numbers will, of course, improve significantly for larger substrate areas, e.g. 5".

25

Fig. 7 shows the following results:

- In field I: for APCVD, LPCVD, RPECVD;
- In field II: for UHVCVD
- In field III: for ECRCVD
- In field IV: in accordance with this invention

30

35

These are valid for temperatures $\leq 600 \text{ °C}$.

In the connection it has to be emphasised once more, that the procedure in accordance with the invention allows the coating of relatively large areas, due to which fact the gas utilisation figure GA_F increases additionally.

- 5 If, analogous, the largest growth rate GR, growth rate per reactive gas flow unit GR_F and the gas utilisation figure GA_F are compared with the corresponding figures for CVD under atmospheric pressure conditions, then the result are drastic improvements in every aspect in accordance with the invention. If, finally, the result in accordance with this invention are compared to those that result,
- 10 when a PECVD process is operated with low voltage discharge in accordance with DE-OS 36 14 384, it becomes apparent that surprisingly the growth rate of 1,200 Å/min achieved in accordance with the invention is significantly greater than the highest growth rate achieved with the previously known processes and that in addition the growth rate per reactive gas flow unit GR_F achieved in
- 15 accordance with the invention is higher by almost two powers of 10.

- It is therefore very surprising that through very particular operating conditions of the installation, in principle as they were previously known from DE-OS 36 14 384, such improvements can be achieved, taking into consideration that the
- 20 layers deposited in accordance with the invention, follow epitaxy conditions with regard to defect density.

- This was extremely easily checked by the fact that during the described operation of the installation in accordance with Fig. 2 on the basis of the stated
- 25 working point parameters, a high-quality epitaxy coating was achieved, when a mono-crystalline substrate was inserted and an amorphous coating when an amorphous substrate was inserted, while the working point parameters were maintained.

- 30 Fig. 5 furthermore shows under P2 the measuring point, if a SiGe epitaxy layer is deposited, which contains 4 % Ge, instead of a pure Si layer.

As this already shows, in contrast to the previously explained knowledge the situation does not change for the procedure in accordance with the invention if a Ge/Si alloy is deposited. This is confirmed by Fig. 6, where the growth rate GR is shown as a function of the Ge content in % for the given working points. This
5 shows that over a very large range of the Ge to Si ratio the growth rate basically does not change.

The process in accordance with the invention was primarily substantiated on the basis of tests, in which Si, Ge or Si/Ge alloy layers and Ga and Ga compound
10 layers respectively, all of them doped and not doped, deposited.

The process in accordance with the invention achieves, in combination, the highest layer quality with very high deposition rates and simultaneously very high degree of efficiency with regard to deposited layer material per admitted reactive
15 gas quantity and that at low temperatures of ≤ 600 °C. Thus the proposed procedure is extremely suitable for industrial production of the highest quality, be it epitaxial or other layers.

(Anhang "A" PCT/CH98/00221)

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Patent Claims:

1. Process for the manufacture of coated work pieces with a quality level sufficient for epitaxy, characterised by the fact that the work piece is coated
5 using PECVD with the application of a DC discharge.
2. Process in accordance with Claim 1, characterised by the fact that the coating is carried out with a growth rate of
10 $GR \geq 150 \text{ \AA} / \text{min}$

and with a gas utilisation figure of

 $1 \% \leq GA_F \leq 90 \%$.
15
3. Process in accordance with Claim 2, characterised by the fact that the growth rate is

 $GR \geq 300 \text{ \AA} / \text{min}$, preferably
20 $GR \geq 600 \text{ \AA} / \text{min}$, especially preferably

 $GR \geq 1,000 \text{ \AA} / \text{min}$.
- 25 4. Process in accordance with Claim 3, characterised by the fact that the gas utilisation figure is

 $GA_F = 5 \%$.
- 30 5. Process in accordance with one of the Claims 1 to 4, characterised by the fact that that the discharge is adjusted in such way that during the probe measurements on the location, where later on the work piece surface that is

to be coated will be positioned, and on the same potential a current density of at least 0.05 a/cm^2 probe surface is set, preferably of at least 0.1 a/cm^2 probe surface up to a density of the maximum discharge current / substrate surface.

- 5 6. Process in accordance with Claim 5, characterised by the fact that the measured current density is created mainly by the impact of electrons.

7. Process in accordance with one of the Claims 1 to 6, characterised by the fact that a discharge current I_{AK} of

10

$$5 \text{ A} \leq I_{AK} \leq 400 \text{ A}$$

is selected, preferably

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$$20 \text{ A} \leq I_{AK} \leq 100 \text{ A}.$$

8. Process in accordance with one of the Claims 1 to 7, characterised by the fact that a discharge voltage U_{AK} of

20

$$10 \text{ V} \leq U_{AK} \leq 80 \text{ V}$$

is selected, preferably

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$$20 \text{ V} \leq U_{AK} \leq 35 \text{ V}.$$

9. Process in accordance with one of the Claims 1 to 8, characterised by the fact that in the process space a reactive gas partial pressure P_R of

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$$10^{-5} \text{ mbar} \leq P_R \leq 10^{-1} \text{ mbar}$$

is selected, preferably

$$10^{-4} \text{ mbar} \leq P_R \leq 10^{-2} \text{ mbar}.$$

10. Process in accordance with one of the Claims 1 to 9, characterised by the fact that the discharge is mainly used as source of electrons for the reactive gas dissociation.

11. Process in accordance with one of the Claims 1 to 10, characterised by the fact that a low voltage discharge is used as DC discharge, preferably a hot cathode low voltage discharge.

12. Process in accordance with one of the Claims 1 to 11, characterised by the fact that in the process space an overall pressure P_T is set as follows:

$$10^{-4} \text{ mbar} \leq P_T \leq 10^{-1} \text{ mbar}$$

preferably

$$10^{-3} \text{ mbar} \leq P_T \leq 10^{-2} \text{ mbar}.$$

13. Process in accordance with one of the Claims 1 to 12, characterised by the fact that a working gas partial pressure P_A in the recipient is set as follows:

$$10^{-4} \text{ mbar} \leq P_A \leq 10^{-1} \text{ mbar, preferably}$$

$$10^{-3} \text{ mbar} \leq P_A \leq 10^{-2} \text{ mbar}.$$

14. Process in accordance with one of the Claims 1 to 13, characterised by the fact that the discharge voltage is connected between discharge cathode and a vacuum recipient wall that is connected to a reference potential, preferably earth potential.

15. Process in accordance with Claim 14, characterised by the fact that the work piece in the process space

5

- is operated on a floating potential or
- connected to a switched on bias potential.

16. Process in accordance with Claim 15, characterised by the fact that the work piece is operated at a voltage U_s with reference to the discharge anode, which is negative, preferably is $U_s \geq -25$ V, preferably between -15 and -3 V.

10

17. Process in accordance with one of the Claims 14 to 16, characterised by the fact that an ancillary anode is provided along the discharge path, preferably in the form of a ring anode encompassing the discharge and is operated preferably adjustable voltage with reference to the discharge cathode, which preferably is not larger than the discharge voltage.

15

18. Process in accordance with one of the Claims 1 to 13, characterised by the fact that an anode is provided for the discharge, mounted in the vacuum recipient and insulated with regard to it, preferably in the form of a ring anode.

20

19. Process in accordance with Claim 18, characterised by the fact that the work piece in the process space

25

- is operated on a floating potential or
- connected to a switched on bias potential.

20. Process in accordance with Claim 19, characterised by the fact that the work piece with regard to the discharge cathode is operated at no more than the discharge voltage.

30

21. Process in accordance with one of the Claims 18 to 20, characterised by the fact that the vacuum recipient wall is operated

5

- at a floating potential or
- tethered to a reference potential via an impedance element.

10

22. Process in accordance with one of the Claims 1 to 13, characterised by the fact that the work piece with regard to the anode of the discharge is operated at a voltage between -25 V and $+25\text{ V}$, preferably for Ga compounds, preferably for Si, Ge or their compounds, preferably at

15

$$-20\text{ V} \leq U_s \leq +20\text{ V}$$

and preferably at a negative one.

20

23. Process in accordance with one of the Claims 1 to 22, characterised by the fact that the work piece temperature is maintained at a maximum of $600\text{ }^{\circ}\text{C}$, preferably between $300\text{ }^{\circ}\text{C}$ and $600\text{ }^{\circ}\text{C}$, preferably for Si, Ge and their compounds and preferably for Ga compound between $300\text{ }^{\circ}\text{C}$ and $800\text{ }^{\circ}\text{C}$.

25

24. Process in accordance with one of the Claims 1 to 23, characterised by the fact that the coating is carried out with a coating rate per reactive gas unit GR_F , which is at least $7.5\text{ \AA} / (\text{sccm}.\text{min})$, preferably at least $40\text{ \AA} / (\text{sccm}.\text{min})$, especially preferred at least $75\text{ \AA} / (\text{sccm}.\text{min})$.

30

25. Process in accordance with one of the Claims 1 to 12, characterised by the fact that desired coating rate changes are effected by adjusting the reactive gas flow in the vacuum recipient, with the adjustment being proportional to this.

26. Process in accordance with one of the Claims 1 to 25, characterised by the fact that desired coating rate changes are effected by adjusting the discharge current density, with the adjustment being proportional to this, preferably through adjustment of the discharge current and / or the discharge voltage and / or through deflection and / or through bundling variations of the discharge with regard to the work piece, the latter preferably electro-statically and / or magnetically.
27. Process in accordance with one of the Claims 1 to 26, characterised by the fact that the work piece is heated independently of the discharge.
28. Utilisation of a PECVD process with DC discharge for the production of epitaxy coatings
29. Utilisation of a process in accordance with one of the Claims 1 to 17 and utilisation in accordance with Claim 28 for the production of substrates with a semi-conductor layer.
30. Utilisation in accordance with Claim 29 for the production of substrates with a semi-conductor epitaxy layer or a poly-crystalline or an amorphous semi-conductor layer, preferably controlled by the uncoated substrate, in particular its surface characteristics.
31. Utilisation in accordance with one of the Claims 28 to 30 for the production of substrates with a silicon and / or germanium layer or a Si/Ge alloy layer, preferably doped with a least one element from the group III and / or V of the periodic system.
32. Utilisation in accordance with one of the Claims 28 to 30 for the production of substrates with a Ga layer or a Ga compound layer, preferably doped with a least one element from the group II, III, IV or VI of the periodic system, e.g. with Mg or Si.

33. Utilisation in accordance with one of the Claim 28 to 32, characterised by the fact that at least one gas containing Si and / or Ge is used as reactive gas and that preferably hydrogen gas is additionally introduced into the reaction space.
- 5
34. Utilisation in accordance with one of the Claims 28 to 33 for the work piece coating with coating rates per reactive gas flow unit, GR_F , of at least $7.5 \text{ \AA} / (\text{sccm.min})$, preferably at least $40 \text{ \AA} / (\text{sccm.min})$, especially preferred at least $75 \text{ \AA} / (\text{sccm.min})$.
- 10
35. Utilisation in accordance with Claim 34 for the coating of substrates at substrate temperatures below $600 \text{ }^\circ\text{C}$, preferably between $300 \text{ }^\circ\text{C}$ and $600 \text{ }^\circ\text{C}$ for Si, Ge and their compounds, preferably between $300 \text{ }^\circ\text{C}$ and $800 \text{ }^\circ\text{C}$ for preferably Ga compounds.
- 15
36. Installation for the carrying out of the process in accordance with one of the Claims 1 to 26 with a vacuum recipient, coupled to it via a diaphragm a cathode chamber with at least one hot cathode and work piece carrier arranged in the recipient as well as an anode arrangement, whereby the work piece carrier is mounted in the recipient in an electrically insulated manner.
- 20
37. Installation in accordance with Claim 36, characterised by the fact that the work piece carrier with regard to the anode can be connected to an adjustable voltage or is floating with regard to the potential, whereby the recipient casing is connected to the anode potential and the cathode with regard to the anode potential can be connected to the cathode potential, preferably between 10 and 80 V , in this especially preferable between 20 and 35 V , whereby the work piece carrier with regard to the anode potential can be adjusted by a maximum of $\pm 25 \text{ V}$.
- 25
- 30

38. Installation in accordance with Claim 36 or 37, characterised by the fact that the anode arrangement for the discharge includes the vacuum recipient wall or that the anode arrangement in the recipient is mounted in an insulated manner.

5

39. Installation in accordance with Claim 38, characterised by the fact that the work piece carrier is potential-floating and arranged in such a way that its voltage with regard to the anode voltage does not adjust itself to lower than -25 V , preferably -3 to -15 V .

10

40. Installation in accordance with Claim 38, characterised by the fact that the work piece carrier with regard to the anode arrangement can be connected to a voltage of -25 V to $+25\text{ V}$, preferably to a negative one, preferably to -15 V to -3 V , using a preferably adjustable bias source.

15

41. Installation in accordance with one the Claims 36 to 40, characterised by the fact that an ancillary anode is provided, preferably in the form of a ring anode arranged concentrically to the axis of the diaphragm, which with regard to the recipient wall can be or respectively is connected to an equal or unequal potential.

20

42. Installation in accordance with one of the Claims 36 to 41, characterised by the fact that the recipient wall is potential-floating or tethered to a reference potential via an impedance element, preferably a resistance element.

25

43. Installation in accordance with one of the Claims 36 to 42, characterised by the fact that a voltage U_{AK} of

$$10\text{ V} \leq U_{AK} \leq 80\text{ V}, \text{ preferably}$$

30

$$20\text{ V} \leq U_{AK} \leq 35\text{ V}$$

is set between hot cathode and at least one part of the anode arrangement.

44. Installation in accordance with one of the Claims 36 to 43, characterised by the fact that a voltage of

5

$$- 25 \text{ V} \leq U_s \leq +25 \text{ V}$$

is set between the work piece carrier and the highest potential at the anode arrangement, preferably a negative one, preferably of

10

$$- 15 \text{ V} \leq U_s \leq -3 \text{ V}.$$

45. Installation in accordance with one of the Claims 36 to 44, characterised by the fact that a gas feeder line connected to a working gas tank, preferably an argon gas tank, ends in the cathode chamber.

15

46. Installation in accordance with one of the Claims 36 to 45, characterised by the fact that a magnet arrangement is provided mainly concentrically to the diaphragm axis for the generating of a magnetic field in the recipient that is coaxial to the diaphragm axis or offset towards it, whereby the magnet arrangement includes permanent magnets and / or at least one coil arrangement.

20

47. Installation in accordance with one of the Claims 36 to 46, characterised by the fact that the recipient is connected to a turbo vacuum pump, preferably a turbo molecular pump

25

48. Installation in accordance with one of the Claims 36 to 47, characterised by the fact that the hot cathode supplies an electron stream of 5 to 400 A, preferably between 20 and 100 A.

30

49. Installation in accordance with one of the Claims 36 to 48, characterised by the fact that the work piece carrier is arranged in the recipient at the place with the highest electron density of the discharge, preferably mainly concentric to the diaphragm axis.
- 5
50. Installation in accordance with one of the Claims 36 to 49, characterised by the fact that the recipient is connected to a gas tank arrangement, which contains a gas containing Si and / or Ge or a gas containing Ga, preferably in addition also H₂.
- 10
51. Utilisation of the installation in accordance with one of the Claims 36 to 50 in accordance with the Claims 28 to 35.
52. Utilisation of a PECVD coating process with DC discharge for the growing of epitaxy layers.
- 15
53. Process for the operation of a PECVD installation in accordance with one of the Claims 36 to 50, in such a way that through the setting of the characteristics of the work piece surfaces, such as crystal structure, it is controlled, whether a poly-crystalline, amorphous or epitaxial layer is generated.
- 20
54. Utilisation of the process in accordance with one of the Claims 1 to 27 or an installation in accordance with one of the Claims 36 to 50 for the production of solar cells.
- 25

Summary**(End of the Appendix 'A' of the description PCT/CH98/00221)**

5

It is proposed to deposit coatings on work piece in a quality sufficient for epitaxy and in doing so to significantly increase the rate of deposit by using a PECVD process, using a DC plasma discharge, instead of, for example, UHV-CVD or ECR-CVD process.

10

(no Figures)

(Anhang "A")

appendix

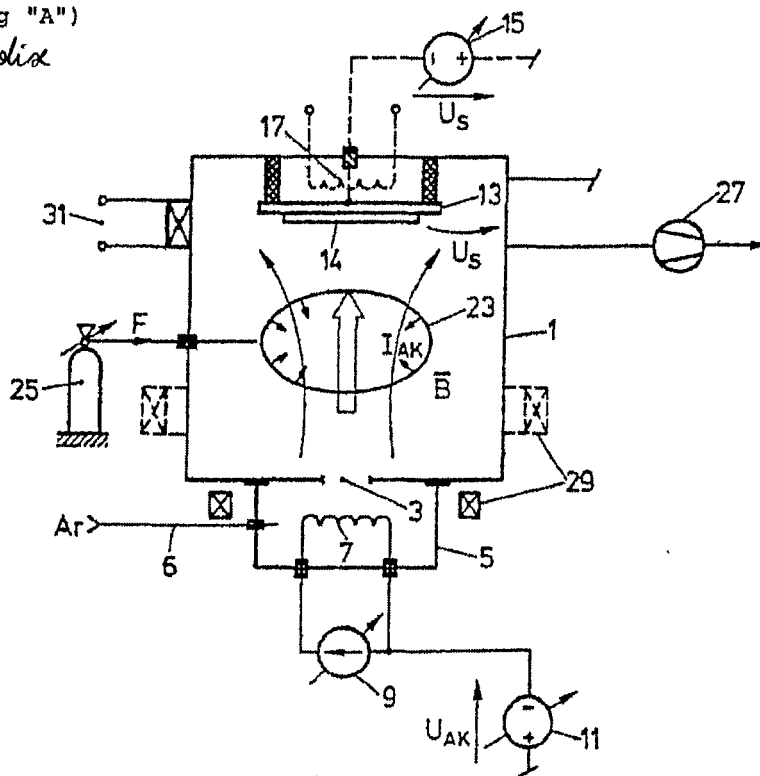


FIG.1

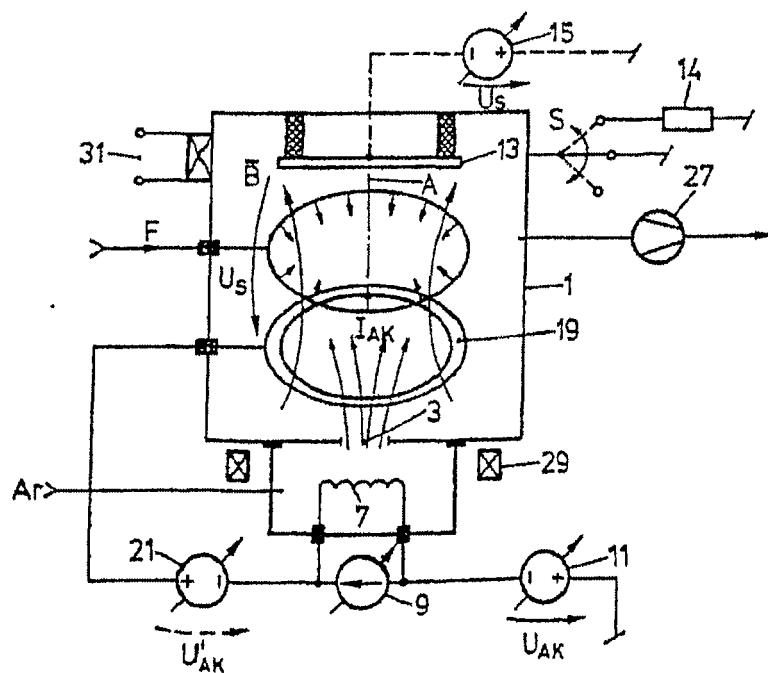


FIG. 2

Anhang "A"

Appendix

J. Gieddke

(Anhang "A")

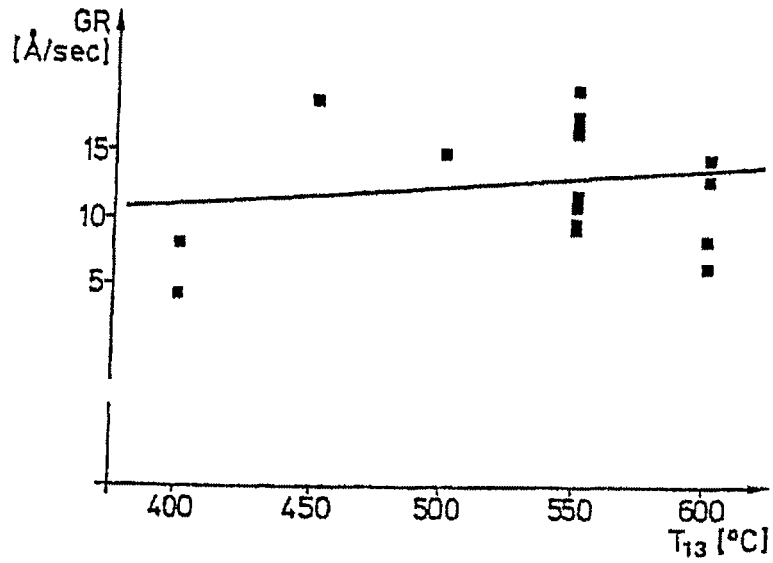
Appendix

FIG. 3

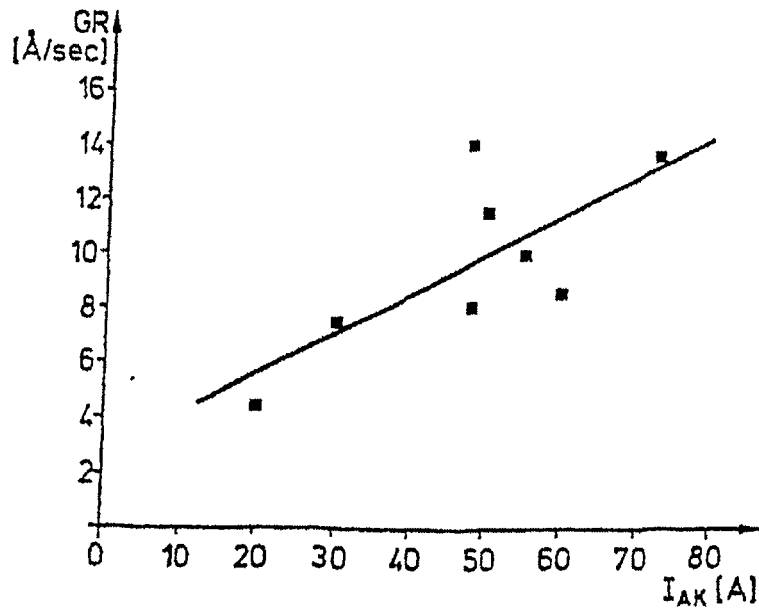


FIG. 4

Anhang "A"

*Appendix**Y. Gaudin*

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Appendix
(Anhang "A")

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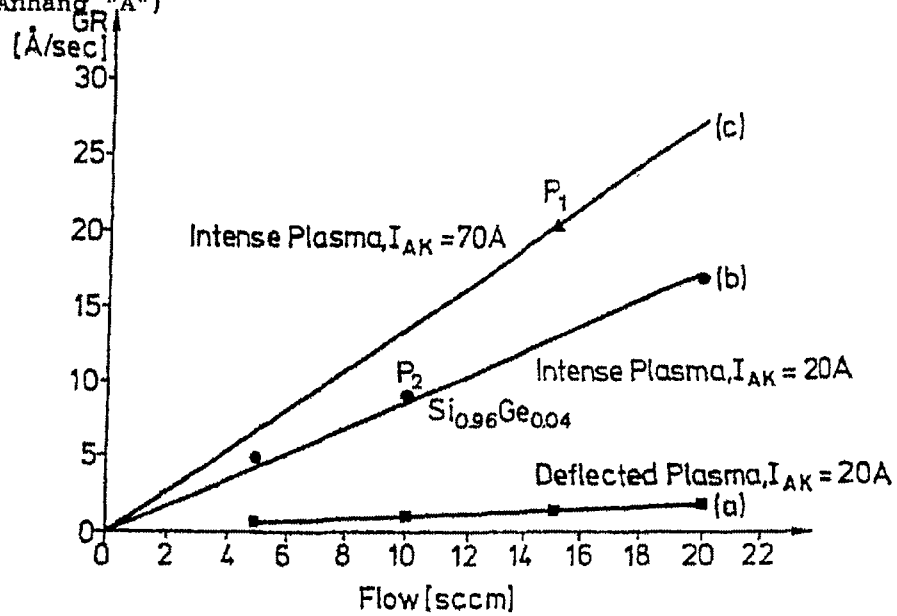


FIG. 5

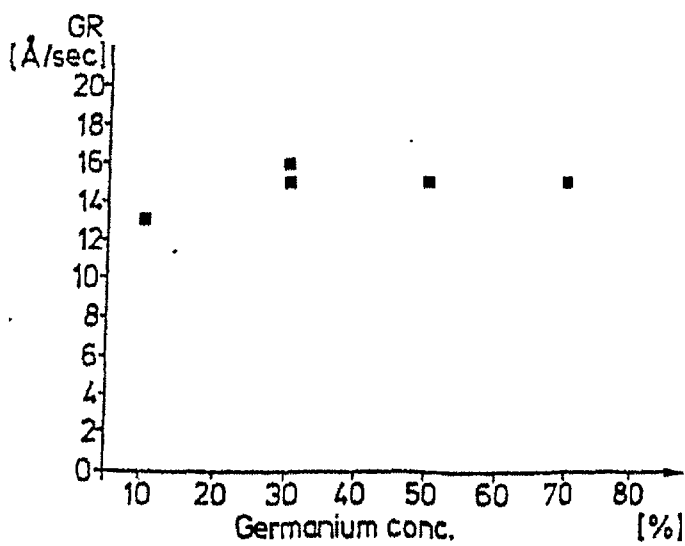


FIG. 6

Anhang "A"

Appendix

J. Gerdike

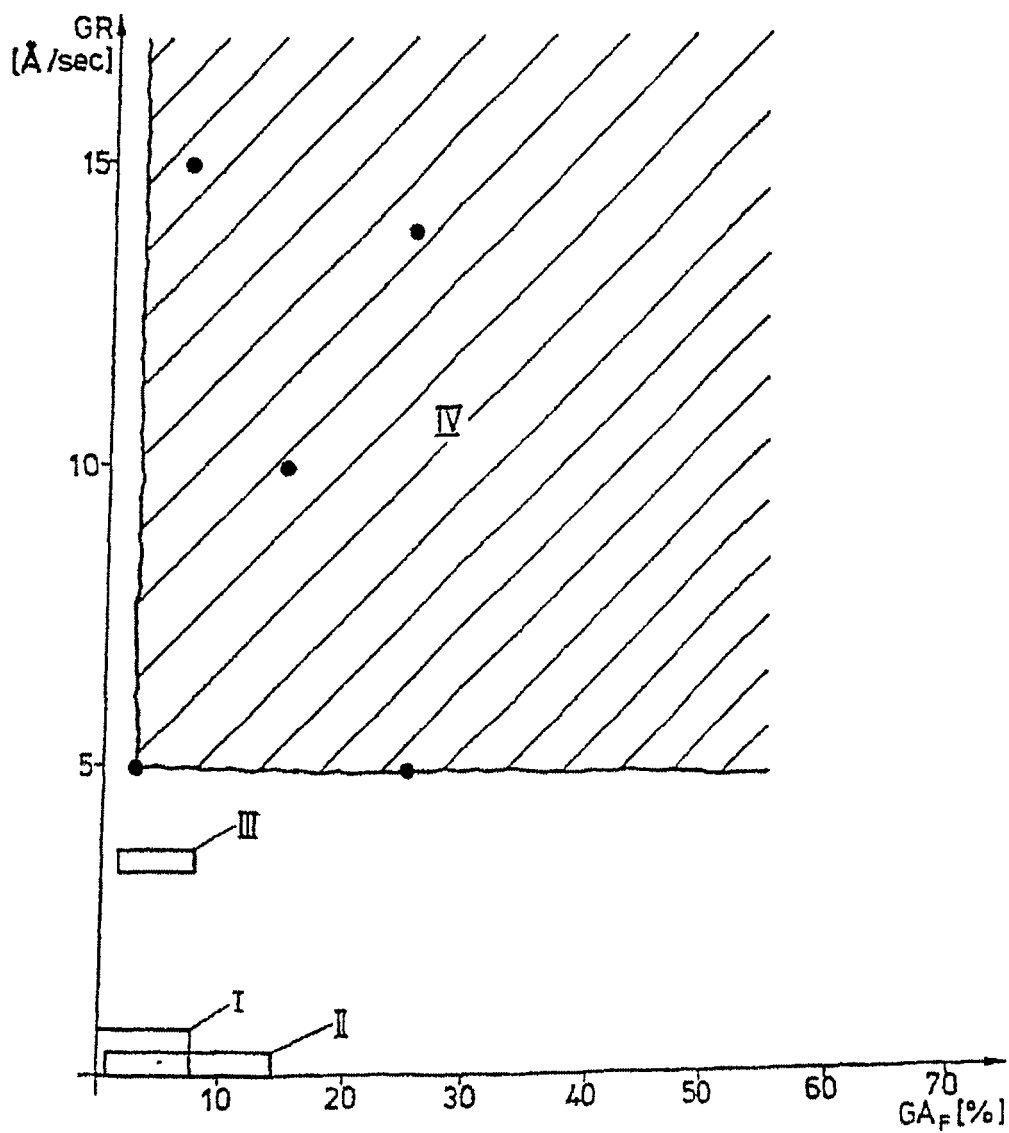
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Appendix
(Anhang "A")

25



Anhang "A"
Appendix

FIG.7

J. Gaudelich

Patent Claims:

1. Process for the production of parts as electronic, opto-electronic, optical or micro-mechanical components or as intermediate products therefore,
 5 through the use of at least one-plasma-assisted treatment step, during which an reactive gas or gas mixture that is admitted into the process space (PR) is activated using a low-energy plasma discharge (PL) with an ion energy E
 10
$$0 \text{ eV} < E \leq 15 \text{ eV}$$

 at the surface of the part lying in the plasma discharge, characterised by the fact that the process atmosphere (PR) during the treatment step is separated (15; 15a; 14; 15b) from the internal wall of a vacuum recipient
 15 (1) connected to the environment.
2. Process in accordance with Claim 1, characterised by the fact that the at least one plasma-assisted treatment step is one of the following:
 20 (a) Coating of the part or
 (b) Changing of the material composition of the part up to a set penetration depth
 25 (c) Etching of the surface of the part.
3. Process in accordance with Claim 1 or 2, characterised by the fact that before and / or after the a least one plasma-assisted treatment step a plasma-assisted cleaning step is carried out as an additional plasma-assisted treatment step of the type stated, preferably in a plasma
 30 containing hydrogen, inert gas or a mixture thereof.

4. Process in accordance with one of the Claims 1 to 3, characterised by the fact that, at a location that is different from the execution of the aforementioned at least one plasma-assisted treatment step, the part is cleaned through the use of a plasma-assisted partial cleaning step, during which a reactive gas or gas mixture admitted to a process space (PR) – preferably containing hydrogen – is activated using a low-energy plasma discharge (PL) with an ion energy (E) of

$$0 \text{ eV} < E \leq 15 \text{ eV}$$

10

at the surface of the part, while during the partial cleaning step the process atmosphere is separated through a metallic encapsulation (15b) from the internal walls of a vacuum recipient that is exposed to the environment or – and this is preferred – while the cleaning process atmosphere is limited directly by the internal walls of the vacuum recipient (1) that is connected to the environment.

15

5. Process in accordance with one of the Claims 3 or 4 for generating a virtual substrate, characterised by the fact that

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- i) a substrate is subjected to a cleaning process in accordance with Claim 3 or 4, preferably while also using hydrogen as reactive gas;
- ii) a hetero-epitaxial layer is grown as a plasma-assisted treatment step;
- iii) a semi-conductor layer to be used is grown, if necessary, as a further plasma-assisted treatment step.

25

6. Process in accordance with one of the Claims 1 to 5, characterised by the fact that parts that arrive in a process space (PR) in series in a timed sequence are each subjected to at least one plasma-assisted treatment step and that after the execution of a pre-set number of those plasma-

30

assisted treatment steps a further plasma-assisted treatment step is carried out in the aforementioned process space (PR), which step consists of a plasma-assisted process space cleaning step without inserted part or with a substrate dummy, which preferably includes first an etching step, afterwards a cleaning step, preferably in a plasma containing hydrogen, inert gas or a mixture thereof.

7. Process in accordance with one of the Claims 1 to 6, characterised by the fact that the part, locally separated, is subjected to at least two of the plasma-mechanical treatment steps and that the transport of the part in between is carried out in a vacuum.

8. Process in accordance with Claim 7, characterised by the fact that the transport in the vacuum is at least in part linear or, and preferably so, along a circular path with linear feeder movements to the processes, preferably with a movement component that is radial to the circular path.

9. Process in accordance with one of the Claims 1 to 8, characterised by the fact that the separation through the restriction of the process space is effected through a surface, which in its new state is chemically inert against the plasma-activated reactive gas or gas mixture, preferably through a dielectric or graphite surface.

10. Process in accordance with Claim 9, characterised by the fact that the inert surface is the surface of a separation wall, which in most parts is maintained at a distance from the internal wall of the vacuum recipient (ZW).

11. Process in accordance with Claim 10, characterised by the fact that the process space (PR) and the intermediate space (ZW) between separation wall and internal walls of the vacuum recipient are pumped equally or differently (13a, 13b, 115).

12. Process in accordance with one of the Claims 9 to 11, characterised by the fact that the surface in its new state is realised from at least one of the following materials:
- 5 Quartz, graphite, silicon carbide, silicon nitride, aluminum oxide, titanium oxide, tantalum oxide, niobium oxide, zirconium oxide or a layered combination of these materials, diamond-like carbon or diamonds.
- 10 13. Process in accordance with one of the Claims 1 to 12, characterised by the fact that a feeder opening (123) is provided for the part (120) in a separation wall and that this opening is closed during the treatment, with the part and / or with a carrier (119) for the part (120).
- 15 14. Process in accordance with one of the Claims 1 to 13, characterised by the fact that the plasma discharge is realised with an electron source (105) with an electron energy ≤ 100 eV, preferably ≤ 50 eV, in particularly preferred using a DC discharge.
- 20 15. Process in accordance with Claim 14, characterised by the fact that, that the plasma discharge is realised using a thermionic cathode (107), preferably with a directly heated thermionic cathode.
- 25 16. Process in accordance with one of the Claims 1 to 15, characterised by the fact that in the process space at least two locally offset and preferably heatable anodes (117a, 117b) are provided for the plasma discharge, preferably each electrically operable separately and that the plasma density distribution (V) in the process space is dynamically or statically adjusted or controlled by controlling the respectively connected electrical
- 30 potentials and / or their temperature.

17. Process in accordance with one of the Claims 1 to 16, characterised by the fact that a magnetic field (H) is generated in the process space (PR) (133, 135) and that by using this magnetic field the plasma density distribution (V) at the surface of the part is set or controlled, preferably at least in places wobbling it.
18. Process in accordance with one of the Claims 1 to 17, characterised by the fact that the reactive gas is admitted into the process atmosphere in a distributed manner (137), preferably with a flow direction mainly parallel to the surface of the part (120) and, further preferred, with injection jets that are equidistant from the surface of the part.
19. Process in accordance with one of the Claims 1 to 18, characterised by the fact that the partial pressure of gases in the process atmosphere (PR), apart from one inert working gas and the reactive gas and its gaseous reaction products respectively is kept to a maximum of 10^{-8} mbar, preferably to a maximum of 10^{-9} mbar (UHV) for the at least one plasma-assisted treatment step.
20. Process in accordance with one of the Claims 1 to 19, characterised by the fact that the at least one plasma-assisted treatment step is the depositing of a homo or hetero epitaxial layer.
21. Process in accordance with Claim 20, characterised by the fact that a silicon / germanium layer is deposited as homo or hetero epitaxial layer.
22. Process in accordance with one of the Claims 1 to 21, characterised by the fact that the part is in general a part in the form of a disk (120).
23. Process in accordance with one of the Claims 1 to 22, characterised by the fact that the part subjected to the treatment is a silicon wafer or a

wafer made of a compound semi-conductor, preferably made of gallium arsenide or indium phosphide or silicon carbide or glass.

24. Process in accordance with one of the Claims 1 to 23, characterised by the fact that one layer with at least one of the following materials is deposited:
 Silicon, silicon-germanium compound, silicon-germanium-carbon compound, diamond, diamond-like compound, silicon carbide, silicon nitride, aluminium oxide, silicon oxide, gallium nitride, gallium arsenide, aluminium, copper, indium phosphide, cubical boron nitride.
25. Process in accordance with one of the Claims 1 to 24 for the production of virtual substrates, that contain preferably silicon-germanium.
26. Process in accordance with one of the Claims 1 to 25 for the production of parts with a diameter of the simultaneously to be treated surfaces of at least 150 mm, preferably at least 200 mm, preferably even of at least 300 mm.
27. Process in accordance with one of the Claims 1 to 26, characterised by the fact that the plasma-assisted treatment is the coating of the part with a coating rate of at least 60 nm/min.
28. Process for the production of a virtual substrate or a component building on it, preferably on a silicon-germanium basis, comprising at least one cleaning step, characterised by the fact that this cleaning step is carried out as plasma-assisted cleaning step, in which the substrate to be cleaned is exposed to reactive gas or gas mixture that is admitted into a process space, activated using a low-energy plasma discharge with an ion energy E at the surface of the part of

$$0 \text{ eV} < E \leq 15 \text{ eV}.$$

29. Vacuum treatment system, in particular for the execution of a process in accordance with one of the Claim 1 to 28 with

5

- at least one vacuum chamber (1), in it

- at least one work piece carrier (5),

10

- one plasma generating arrangement for the generating of a plasma within the chamber (1),

- one gas admission arrangement (7) in the chamber (1) connected to one gas tank arrangement with at least one reactive gas or gas mixture,

15

characterised by the fact that within the vacuum chamber (1) a process chamber (PR) is provided, in which the work piece carrier (5) lies free in the processing position, in which the plasma (PL) is generated and to which the gas admission arrangement is connected in an effect connection, whereby furthermore the surface of the internal wall of the process chamber, in its new state, consists of one material (15, 15a, 113) that is inert against the plasma-activated reactive gas or gas mixture, preferably a dielectric material or a graphite material.

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25

30. Vacuum treatment system in accordance with the generic term of Claim 29, characterised by the fact that a process chamber (PR) is provided in the vacuum chamber, in which the work piece carrier (15) lies free in the processing position, in which the plasma (PL) is generated and to which the gas admission arrangement (7) is connected in an effect connection, in which furthermore the process chamber (PR) is formed by an casing

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(14, 15b), which in predominant surface sections is distanced inwardly from the vacuum chamber wall.

- 5 31. Vacuum treatment system with the combined characteristics of Claims 29 and 30.
- 10 32. Vacuum treatment system in accordance with one of the Claims 29 to 31, characterised by the fact that in its new state the internal surface (15, 15a, 113) of the process chamber at least on a great majority of sections consists of at least one of the following materials:

Quartz, graphite, silicon carbide, silicon nitride, aluminum oxide, titanium oxide, tantalum oxide, niobium oxide, zirconium oxide, or a layered combination of these materials, diamond-like carbon or diamonds.
- 15 33. System in accordance with one of the Claims 29 to 32, characterised by the fact that the wall of the process chamber (14, 15b, 113) is mounted in an exchangeable manner with regard to the vacuum wall (1).
- 20 34. System in accordance with one of the Claims 29 to 33, characterised by the fact that the plasma generating arrangement is an arrangement for the generating of a low-energy plasma discharge with an ion energy E in the area of the work piece carrier (5) of $0 \text{ eV} < E \leq 15 \text{ eV}$.
- 25 35. System in accordance with Claim 34, characterised by the fact that the plasma generating arrangement includes an electron source (105) with an electron energy $\leq 100 \text{ eV}$, preferably $\leq 50 \text{ eV}$, preferably a DC low voltage plasma generating arrangement, in particular preferred with a thermionic cathode (107), in particular with a directly heated thermionic
30 cathode.

36. System in accordance with one of the Claims 29 to 35, characterised by the fact that, communicating with the vacuum chamber (1) via a diaphragm (111) a cathode chamber (109) is mounted on the vacuum chamber (1) and preferably electrically isolated with regard to this.
- 5
37. System in accordance with Claim 36, characterised by the fact that the axis (A) of the diaphragm (111) crosses the work piece receiving surface (119a) of the work piece carrier (119), preferably intersecting it mainly vertically, preferably mainly in the centre.
- 10
38. System in accordance with Claim 30 or one of the Claims 32 to 37, insofar as dependent on Claim 30, characterised by the fact that the material of the walls of the process chamber (15b) consists of one metal, preferably Tantalum or Inconel.
- 15
39. System in accordance with one of the Claims 35 to 38, characterised by the fact that within the process chamber (PR) at least two locally offset anodes (117a, b) are provided, which can be connected to different electrical potentials and each of which can preferably be heated.
- 20
40. System in accordance with Claim 36 or 37, characterised by the fact that along the diaphragm axis (A), offset with regard to its longitudinal direction, at least two anodes (117a, b), preferably coaxial to the axis, are provided in the process chamber, which, further preferred, can be connected to different electrical potentials and, further preferred, each
- 25
41. System in accordance with one of the Claims 29 to 40, characterised by the fact that the vacuum wall (101) in most parts of the surface is designed as double-walled structure and that the intermediate space is connected to a temperature equalisation connection, preferably with a connection for a temperature equalisation liquid.
- 30

42. System in accordance with one of the Claims 29 to 41, characterised by the fact that a magnetic field generating arrangement (133, 135), preferably one that can be adjusted, is provided, which generates a magnetic field in the process chamber (PR) and which includes Hemholtz coils (133) preferably provided outside of the vacuum chamber.
43. System in accordance with one of the Claims 29 to 42, characterised by the fact that the process chamber (PR) along most parts of the surface is distanced from the vacuum wall (1) and that the inside of the process chamber (PR) and the intermediate space created in that way are connected with regard to effect via equal or different pump cross sections with a joint pump connection or that at least one pump connection each is provided for the process chamber and the intermediate space.
44. System in accordance with one of the Claims 29 to 43, characterised by the fact that the work piece carrier (119), with regard to an opening (123) in the process chamber (PR), is movable by a drive, preferably linear and in the direction of the normal line of the opening surface, and that it preferably closes off the internal space of the process chamber in the position, where it is driven up against the process chamber (PR).
45. System in accordance with one of the Claims 29 to 44, characterised by the fact that the work piece carrier (119) is connected to a temperature equalisation device (127) with regard to their effects.
46. System in accordance with one of the Claims 29 to 45, characterised by the fact that the vacuum chamber (1) has at least one work piece feeder opening (129), which is sealed when it is closed.
47. Vacuum treatment system in accordance with one of the Claims 29 to 46, characterised by the fact that the vacuum chamber (1) has work piece

feeder (129) opening, the closing of which can be controlled, and that at least two of the vacuum chambers are provided, the feeder openings of which are connected via a vacuum work piece transport arrangement.

5 48. System in accordance with Claims 47, characterised by the fact that the vacuum transport arrangement is a linear transport arrangement or a rotary (150) transport arrangement, preferably the latter.

10 49. System in accordance with one of the Claims 47 to 48, characterised by the fact that the process chamber (PR) in one of the provided vacuum chambers (1) is limited by the metallic internal surface of the vacuum chamber (1) itself and that it has the plasma generating arrangement for the generating of the plasma as well as gas admission arrangement connected to a tank arrangement with at least one reactive gas.

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