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(71) Applicant: **PICOSUN OY** [FI/FI]; Tietotie 3, FI-02150 Espoo (FI).

(72) Inventors: **SAMMELSELG, Väino**; Aardia Str. 144-33, Tartu, Estonia (EE). **KOSTAMO, Juhana**; Norppatie 4 C 11, FI-02260 Espoo (FI). **BAYERL, Willi**; Kirchstrstr. 18a, 82054 Sauerlach (DE). **AARIK, Jaan**; Mõisavahe 60-41, 50707 Tartu (EE). **AARIK, Lauri**; Anne Str. 51-10, Tartu (EE). **LINDFORS, Sven**; Nuottamiehentie 8, FI-02230 Espoo (FI). **ADAM, Peter**; Plinganserstr. 42 c, 81369 München (DE). **POUTIAINEN, Juho**; Mestarintie 4 B 3, FI-00640 Helsinki (FI).

(74) Agent: **ESPATENT OY**; Kaivokatu 10 D, FI-00100 Helsinki (FI).

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(54) Title: PROTECTING AN INTERIOR OF A GAS CONTAINER WITH AN ALD COATING

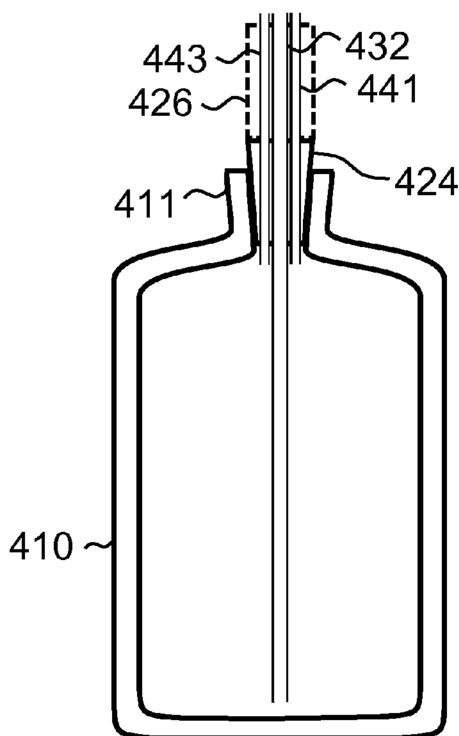

Fig. 4A

(57) Abstract: An apparatus and method for protecting a gas container interior (410), where an inlet and exhaust manifold comprising a port assembly attachable to a port (411) of the gas container is provided, the gas container interior is exposed to sequential self-saturating surface reactions by sequential inlet of reactive gases via said port assembly and said port into the gas container interior, and reaction residue is pumped via said port and said port assembly out from the gas container. Technical effects are: a conformal protective coating, coating only the inside of the gas container and a reduced cleaning need of a surrounding chamber.

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Protecting an interior of a gas container with an ALD coating

FIELD OF THE INVENTION

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The present invention generally relates to atomic layer deposition (ALD). More particularly, the invention relates to providing protective coating by means of ALD.

BACKGROUND OF THE INVENTION

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This section illustrates useful background information without admission of any technique described herein representative of the state of the art.

Atomic Layer Epitaxy (ALE) method was invented by Dr. Tuomo Suntola in the
15 early 1970's. Another generic name for the method is Atomic Layer Deposition (ALD) and it is nowadays used instead of ALE. ALD is a special chemical deposition method based on the sequential introduction of at least two reactive precursor species to at least one substrate.

20 Thin films grown by ALD are dense, pinhole free and have uniform thickness. For example, in an experiment aluminum oxide has been grown by thermal ALD from trimethylaluminum $(CH_3)_3Al$, also referred to as TMA, and water resulting in only about 1% non-uniformity over a substrate wafer.

25 One interesting application of ALD technique is providing protective coatings on surfaces.

SUMMARY

30 According to a first example aspect of the invention there is provided a method of protecting a gas container interior, the method comprising:
providing an inlet and exhaust manifold comprising a port assembly attachable to a port of the gas container;

exposing the gas container interior to sequential self-saturating surface reactions by sequential inlet of reactive gases via said port assembly and said port into the gas container interior; and
pumping reaction residue via said port and said port assembly out from the gas
5 container.

The gas container may be, for example, a gas bottle or a gas cylinder. The sequential self-saturating surface reactions (according to ALD) produce the desired protective coating within the gas container interior. Accordingly, the gas
10 container interior may be coated by using ALD so that all surfaces within the gas container which see the reactive gases end up coated.

In certain example embodiments, the method comprises attaching said port assembly to said port of the gas container. Said port of the gas container may be a
15 gas container mouth. The gas container mouth may be threaded.

In certain example embodiments, the method comprises pumping reaction residue and purge gas from the gas container interior by a vacuum pump attached to an exhaust side of the inlet and exhaust manifold. The vacuum pump may provide
20 one or more of the following effects: It may be used to pump the gas container interior into vacuum. It may be configured to pump reaction residue from the gas container via the port assembly.

The gas container may be used as the reaction chamber for ALD reactions.
25 Accordingly, in certain example embodiments, the gas container is used as a reaction vessel sealed by the port assembly. The sequential self-saturating surface reactions are thereby limited to occur within the gas container interior.

In certain example embodiments, the gas container whose inner walls are coated
30 forms a hot wall reaction chamber heated by an external heater.

In certain example embodiments, both gas inlet and gas exhaust occurs via a same port or opening of the gas container. In certain example embodiments, the

inlet and exhaust manifold hermetically connected to the gas container opens directly into the gas container and allows alternate supply of the precursors needed for performing an ALD process, purging the inner volume of the gas container with an inert gas and evacuation of the precursors, gaseous reaction 5 products and purge gas from the gas container.

In certain example embodiments, the gas container is closable (or closed) by the inlet and exhaust manifold.

10 In certain example embodiments, said port assembly comprises a sealing part. In certain example embodiments, the sealing part is detachably attachable to the gas container mouth in the place of a gas container stop valve. The sealing part, in certain example embodiments, comprises a tapered thread. In certain example embodiments, the tapered thread is configured to fit to a counter thread in the gas 15 container mouth. The sealing part may be twisted into the gas container mouth to seal the gas container mouth. In certain example embodiments, there is a sealing tape, such as Teflon tape between the tapered thread and the threaded gas container mouth to improve sealing. In certain example embodiments, at least one in-feed line and an exhaust line pass through the sealing part. In certain example 20 embodiments, said port assembly comprises a fitting part detachably attachable to the sealing part. The fitting part may form a (cylindrical) continuation of the sealing part. In certain example embodiments, when the fitting part is detached from the sealing part, the sealing part is twistable to tighten against the gas container mouth. Depending on the implementation, the fitting part may allow the sealing 25 part to twist also when attached to the fitting part. In certain example embodiments, at least one in-feed line and an exhaust line pass both through the sealing part and the fitting part. In certain example embodiments, an interface between the sealing part and the fitting part is airtight when the fitting part has been attached to the sealing part. In certain example embodiments, there is an 30 airtight feedthrough at an opposite end of the fitting part for at least one of an in-feed and an exhaust line to pass through.

In embodiments, in which the gas container is placed into a chamber of a reactor

for deposition, such as a reaction or vacuum chamber, the sealing by the port assembly prevents a coating from being deposited onto the chamber walls. This reduces the need to clean the chamber walls.

5 In certain example embodiments, the gas container is used as a reaction vessel sealed by a sealing part comprised by the port assembly.

In certain example embodiments, said sealing part comprises a tapered thread detachably attachable to said port of the gas container in the place of a stop valve.

10

In certain example embodiments, said port assembly comprises a fitting part attachable to the sealing part allowing the sealing part to twist to tighten against said port of the gas container.

15 In certain example embodiments, the method comprises:
guiding inactive purge gas into an intermediate space between the gas container and a surrounding chamber wall, and
pumping said inactive purge gas out from the intermediate space.

20 An over pressure generated by guiding the inactive purge gas into the intermediate space further improves the sealing effect of the port assembly. The intermediate space in an embodiment is kept in a vacuum pressure by a vacuum pump which is in fluid communication with the intermediate space. By arranging a material flow from the intermediate space through an exhaust conduit to a pump,
25 such as the vacuum pump, any precursor material ended up into the intermediate space can be removed.

The inlet and exhaust manifold provides at least one in-feed line and an exhaust line. Precursor vapor is discharged from said at least one in-feed line at a
30 discharge point within the gas container. The exhaust line begins at an exhaust point within the gas container. In certain example embodiments, the discharge point (i.e., a gas discharge point) within the gas container is arranged at a different level than the exhaust point (i.e., a gas exhaust point). The discharge point in

certain example embodiments resides at the bottom (or bottom section) of the gas container the exhaust point being in the top (or top section). In other example embodiments, the discharge point resides in the top (or top section) of the gas container interior the exhaust point being at the bottom (or bottom section)

In certain example embodiments, the inlet and exhaust manifold comprises one or more in-feed lines with their controlling elements controlled by a computer-implemented control system.

In certain example embodiments, the inlet and exhaust manifold comprises ALD reactor in-feed equipment. In certain example embodiments, the in-feed equipment comprises in-feed line(s) and at least the desired precursor and inactive gas flow controlling elements, such as valve(s), mass flow controller(s) or similar, and their control system.

The control system may be implemented for example by software in a laptop computer or similar. Accordingly, in certain example embodiments, the inlet and exhaust manifold comprises one or more in-feed lines with their controlling elements controlled by a computer-implemented control system. Suitable replaceable precursor and inactive gas sources may be attached to the in-feed equipment.

According to a second example aspect of the invention there is provided an apparatus for protecting a gas container interior, comprising:
an inlet and exhaust manifold comprising a port assembly attachable to a port of the gas container, the apparatus being configured to expose the gas container interior to sequential self-saturating surface reactions by sequential inlet of reactive gases via said port assembly and said port into the gas container interior; and
a pump configured to pump reaction residue via said port and said port assembly out from the gas container.

In certain example embodiments, a gas discharge point provided by the inlet and

exhaust manifold is arranged at a different level than a gas exhaust point provided by the inlet and exhaust manifold. The different levels here typically mean different heights.

5 In certain example embodiments, the inlet and exhaust manifold comprises precursor vapor and purge gas in-feed lines and their controlling elements. The pump may attached to the exhaust side of the inlet and exhaust manifold. The pump may be a vacuum pump.

10 In certain example embodiments, the inlet and exhaust manifold comprises a gas container-specific port assembly configured to attach the inlet and exhaust manifold into said port of the gas container thereby forming a fluid communication path between the inlet and exhaust manifold and the gas container interior. Similarly, a fluid communication path between the gas container interior and the 15 pump is formed.

In certain example embodiments, the port assembly comprises a sealing part attachable to the port of the gas container.

20 In certain example embodiments, the sealing part comprises a tapered thread.

In certain example embodiments, the apparatus comprises:
a chamber surrounding the gas container and an inactive gas in-feed line configured to guide inactive purge gas into an intermediate space between the gas 25 container and a surrounding chamber wall.

The apparatus comprising the inlet and exhaust manifold may be mobile so that it can be moved to meet the user’s needs. In certain example embodiments, the inlet and exhaust manifold comprises a separate inlet manifold and a separate exhaust 30 manifold both being able to simultaneously couple to the gas container port and designed to work together in a gas container interior protecting method.

Different non-binding example aspects and embodiments of the present invention

have been illustrated in the foregoing. The above embodiments are used merely to explain selected aspects or steps that may be utilized in implementations of the present invention. Some embodiments may be presented only with reference to certain example aspects of the invention. It should be appreciated that corresponding embodiments may apply to other example aspects as well. Any appropriate combinations of the embodiments may be formed.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1	shows a schematic view of an apparatus and its use for protecting a gas container interior in accordance with an example embodiment;
Figs. 2A-2B	show alternative in-feed arrangements in accordance with certain example embodiments;
Fig. 3	shows another example embodiment;
Figs. 4A-4B	show a sealing arrangement in accordance with certain example embodiments; and
Fig. 5	shows a method in accordance with an example embodiment.

DETAILED DESCRIPTION

In the following description, Atomic Layer Deposition (ALD) technology is used as an example. The basics of an ALD growth mechanism are known to a skilled person. As mentioned in the introductory portion of this patent application, ALD is a special chemical deposition method based on the sequential introduction of at least two reactive precursor species to at least one substrate. The at least one substrate is exposed to temporally separated precursor pulses in a reaction vessel to deposit material on the substrate surfaces by sequential self-saturating surface reactions. In the context of this application, the at least one substrate comprises the interior (inner surface) of a gas container, for example a gas bottle. Further, in

the context of this application, the term ALD comprises all applicable ALD based techniques and any equivalent or closely related technologies, such as, for example MLD (Molecular Layer Deposition) technique.

5 A basic ALD deposition cycle consists of four sequential steps: pulse A, purge A, pulse B and purge B. Pulse A consists of a first precursor vapor and pulse B of another precursor vapor. Inactive gas and a vacuum pump are typically used for purging gaseous reaction by-products and the residual reactant molecules from the reaction space during purge A and purge B. A deposition sequence comprises 10 at least one deposition cycle. Deposition cycles are repeated until the deposition sequence has produced a thin film or coating of desired thickness. Deposition cycles can also be more complex. For example, the cycles can include three or more reactant vapor pulses separated by purging steps. All these deposition cycles form a timed deposition sequence that is controlled by a logic unit or a 15 microprocessor.

In certain example embodiments as described in the following, there is provided a method and apparatus for protecting a gas container (such as a gas cylinder, or gas bottle) interior with a protective coating. The gas container here is a pressure 20 vessel. The gas container itself forms a reaction chamber (or a reaction space), and there is typically no separate substrate, but the surfaces of the gas container interior form a substrate (substrate here meaning the material on which a process is conducted). All these surfaces can be coated by an ALD process in which precursor vapors are sequentially inlet via an inlet and exhaust manifold into the 25 gas container interior. The reaction residue is pumped out from the gas container interior via an exhaust side of the inlet and exhaust manifold. The gas container can be optionally heated before and/or during ALD processing by a heater placed around the gas container.

30 Fig. 1 shows the method and related apparatus in certain example embodiments. The apparatus used to protect the interior of a gas container 10 comprises an inlet and exhaust manifold 20. The apparatus may be a mobile apparatus. A mobile apparatus may be conveniently moved into the proximity of gas containers to be

protected, if needed.

The inlet and exhaust manifold 20 is configured to be detachably attached to a gas container port 11. Fig. 1 shows the inlet and exhaust manifold 20 attached by a port assembly 24 to the gas container port 11. The port assembly 24 may be a gas container-specific part. The port assembly comprises a sealing arrangement (not shown) to seal the interface between the gas container port 11 and the port assembly 24. In an example implementation, the port assembly comprises a seal (not shown) which tightens against its counter surface in the gas container port 11.

The inlet and exhaust manifold 20 comprises ALD reactor in-feed equipment 70. The in-feed equipment 70 comprises the required in-feed lines and their controlling elements. Attached to the port assembly 24 in Fig. 1 is a first precursor vapor in-feed line 41, a second precursor in-feed line 42 and a purge gas in-feed line 43. The first precursor in-feed line 41 originates from a first precursor source 21, the second precursor in-feed line 42 from a second precursor source 22, and the purge gas in-feed line 43 from a purge/inactive gas source 23. The in-feed lines 41-43 extend, travelling through the port assembly 24 and gas container port 11, from the sources 21-23 to the interior of the gas container 10. The in-feed lines 41-43 end at respective discharge points. An exhaust line 32 begins at an exhaust point within the gas container interior. The discharge points should reside in a different level than the exhaust point to effectively obtain uniform deposition. In the embodiment shown in Fig. 1 the discharge points of the in-feed lines 41-43 are at the bottom section of the gas container 10 the exhaust point being in the top section.

The in-feed line controlling elements comprise flow and timing controlling elements. A first precursor in-feed valve 61 and mass (or volume) flow controller 51 in the first precursor in-feed line 41 control the timing and flow of first precursor pulses. Correspondingly, a second precursor in-feed valve 62 and mass (or volume) flow controller 52 in the second precursor in-feed line 42 control the timing and flow of second precursor pulses. Finally, a purge gas in-feed valve 63 and mass (or volume) flow controller 53 control the timing and flow of purge gas.

In the embodiment shown in Fig. 1, the operation of the in-feed equipment 70 is controlled by a control system. Fig. 1 shows a control connection 72 between the in-feed equipment 70 and a control system 71. The control system 71 may be implemented for example by software in a laptop computer or similar.

In certain example embodiments, the ALD process within the gas container interior is performed in a vacuum pressure. The inlet and exhaust manifold 20 comprises a vacuum pump 33. In certain example embodiments, the vacuum pump 33 is located in the end of the exhaust line 32 provided by the inlet and exhaust manifold 20. The vacuum pump 33 can be optionally controlled by the control system 71 via an optional electrical connection 73 (which is between the control system 71 and the vacuum pump 33). In certain example embodiments, the gas container is heated by an external heater (not shown).

In operation, the vacuum pump 33 pumps the interior of the gas container 10 into vacuum. Precursor vapor of the first precursor and second precursor are sequentially discharged into the gas container interior from the discharge points of the first and second precursor in-feed lines 41 and 42, respectively. In the purge steps, inactive purging gas is discharged into the gas container interior from the discharge point of the purge gas in-feed line 43. The arrows 15 depict the flow direction of precursor vapor and purge gas within the gas container from the respective discharge points towards the exhaust point (via which they are pumped into the exhaust line 32). The desired thickness of protective coating onto the gas container inner surface is obtained by repeating deposition cycles as needed.

Further referring to Fig. 1, it should be noted that in other embodiments, the inlet and exhaust manifold 20 may be arranged differently. Instead of separate in-feed lines at least part of the in-feed lines may be in common. The valve types may vary. The flow controlling element locations may vary, etc. For example, three-way valves may be used instead of two-way valves, immediately reflecting changes in in-feed line routing. Concerning the precursor sources and purge gas, their selection depends on the implementation and desired coating. The gas container

10 can be heated by an optional heater 16 from the outside of the gas container 10. The heater may be a helical coil heater arranged around the gas container 10. The operation of the heater can be optionally controlled be the control system 71 over a connection.

5

Applicable coatings depending on the application are, for example, metal oxides, such as aluminum oxide, titanium oxide, tantalum oxide, and tungsten carbide, and their combinations, but the coatings are not limited to these materials.

10 Figs. 2A and 2B show two alternative embodiments for the placement of in-feed and exhaust lines within the gas container 10. The gas container 10 has an inner wall shape allowing free movement of low-pressure gases.

Fig. 2A corresponds to the arrangement shown in Fig. 1. Accordingly, the in-feed 15 lines 41-43 and exhaust line 32 travel through the gas container port 11. The in-feed lines 41-43 end at respective discharge points. The exhaust line 32 begins at an exhaust point. The discharge points of the in-feed lines 41-43 are at the bottom section of the gas container 10 the exhaust point being in the top section. The direction of gas flow is shown by the arrows 15.

20

In the preferred embodiment shown in Fig. 2B, the exhaust line to the contrary begins at the bottom section of the gas container 10 whereas the discharge points of the in-feed lines 41-43 are in the top section. The in-feed lines 41-43 and exhaust line 32 travel through the gas container port 11. The in-feed lines 41-43 25 end at respective discharge points. The exhaust line 32 begins at an exhaust point. The direction of gas flow is shown by the arrows 15.

Fig. 3 shows a method and apparatus for protecting a gas container interior in accordance with another example embodiment. This embodiment basically 30 corresponds to the embodiment shown in Fig. 1, however, disclosing certain further features.

Fig. 3 shows pressure vessel, such as a chamber 30 surrounding the gas

container 10. The chamber 30 may be, for example, a vacuum chamber or ALD reaction chamber generally used in the field of ALD. The gas container 10 is loaded into the chamber 30 via a loading hatch 31, or similar, and is attached by its port 11 to the port assembly 24. The in-feed lines 41-43 are passed into the chamber 30 through a feedthrough 36 arranged into the chamber 30 wall. The exhaust line 32 is passed out from the chamber 30 through a feedthrough 46 arranged into the chamber 30 wall. The location of the feedthroughs 36 and 46 depend on the implementation. The feedthroughs 36 and 46 may even be implemented by a single feedthrough. The feedthroughs 36 and 46 are sealed.

The basic operation concerning the deposition of a protective coating within the gas container 10 is similar to that described in connection with Fig. 1.

The embodiment shown in Fig. 3 optionally comprises a purge gas in-feed conduit 44 through which inactive purge gas is guided (discharged) into an intermediate space 40 between the gas container 10 and a surrounding chamber 30 wall. The purge gas flows to the conduit 44, for example, along a branch 43a divided from the purge gas in-feed line 43.

The intermediate space 40 is pumped by the vacuum pump 33 via an exhaust conduit 45 arranged on the opposite side of the intermediate space 40. The exhaust pump 33 is in fluid communication with the intermediate space 40 through an exhaust line 47 extending from the exhaust conduit 45 to the exhaust pump 33. The exhaust lines 32 and 47 may join at some point on the way to the exhaust pump 33.

The pumping causes a flow within the intermediate space 40 that conducts any precursor material ended up into the intermediate space 40 into the exhaust line 47. An over pressure generated by guiding the inactive purge gas into the intermediate space 40 further improves the sealing effect of the port assembly 24. The arrows 35 depict the flow direction within the intermediate space 40.

Fig. 4A shows a sealing arrangement in accordance with an example embodiment.

The gas container 410 comprises a gas container port 411 which is here a mouth of the gas container. An inlet and exhaust manifold comprises a port assembly comprising a sealing part 424. The sealing part is detachably attachable, by for example twisting, to the gas container mouth 411 in the place of a gas container
5 stop valve. For this purpose, the sealing part 424 is a tapered thread part. The tapered thread of the sealing part is configured to fit to a counter thread (not shown) in the gas container mouth 411 to tighten and seal the gas container mouth 411. As mentioned, the sealing part 424 can be, for example, twisted into the gas container mouth to seal the gas container mouth.

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In certain example embodiments, there is sealing tape 425, such as Teflon tape around the tapered thread between the tapered thread and the threaded gas container mouth 411 to improve sealing as illustrated in Fig. 4B which is an enlargement of certain parts of Fig. 4A.

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Figs. 4A and 4B show two in-feed lines 441 and 443 as well as an exhaust line 432 arranged similarly as in the preferred Fig. 2B. Accordingly, the gas discharge point is in the very proximity of the gas container mouth and the exhaust point at the opposite end of the gas container (i.e., at the bottom). The in-feed lines and
20 exhaust line pass through the sealing part 424 extending through the sealing part into an interior of the gas container 410. In certain example embodiments, the port assembly further comprises a fitting part 426 detachably attachable to the sealing part. The fitting part 426 forms a (cylindrical) continuation of the sealing part 424. In certain example embodiments, when the fitting part 426 is detached from the
25 sealing part 424, the sealing part 424 is twistable to tighten against the gas container mouth 411. Depending on the implementation, the fitting part 426 may allow the sealing part 424 to twist also when attached to the fitting part 426. The in-feed lines 441 and 443 as well as the exhaust line 432 pass both through the sealing part 424 and the fitting part 426. The interface between the sealing part
30 424 and the fitting part 426 is airtight when the fitting part 426 has been attached to the sealing part 424. In certain example embodiments, there is an airtight feedthrough at an end opposite to the sealing part end of the fitting part 426 (as depicted in the upper section of Fig. 4A) for at least one of an in-feed line 441,443

and an exhaust line 432 to pass through. An airtight feedthrough here means basically a feedthrough at which gas can flow between the inside of a part and the outside of a part 426 only through a pipeline. An airtight interface, similarly, means an interface at which gas can flow from the part (for example, fitting part 426) on a
5 first side of the interface to the part (for example, sealing part 424) on the other side only through the interface.

In embodiments, in which the fitting part is omitted, the feedthrough(s) are preferably arranged in the (upper) end of the sealing part 424.

10

As to the general operation of the embodiments shown in Figs. 4A and 4B, a reference is made also to the embodiments shown in Figs. 1 to 3.

Fig. 5 shows a method in accordance with an example embodiment. In step 81, an
15 inlet and exhaust manifold is attached to a gas container. ALD processing is performed in step 82. The ALD processing comprises exposing the gas container interior to sequential self-saturating surface reactions and pumping reaction residue out from the gas container. Finally, in step 83, the inlet and exhaust manifold is detached from the gas container.

20

Without limiting the scope and interpretation of the patent claims, certain technical effects of one or more of the example embodiments disclosed herein are listed in the following: A technical effect is protecting gas container interior by a conformal protective coating. Another technical effect is coating only the inside of the gas
25 container the outside being not coated. Another technical effect is reduced cleaning need of a surrounding chamber.

It should be noted the some of the functions or method steps discussed in the preceding may be performed in a different order and/or concurrently with each
30 other. Furthermore, one or more of the above-described functions or method steps may be optional or may be combined.

The foregoing description has provided by way of non-limiting examples of

particular implementations and embodiments of the invention a full and informative description of the best mode presently contemplated by the inventors for carrying out the invention. It is however clear to a person skilled in the art that the invention is not restricted to details of the embodiments presented above, but that it can be
5 implemented in other embodiments using equivalent means without deviating from the characteristics of the invention.

Furthermore, some of the features of the above-disclosed embodiments of this invention may be used to advantage without the corresponding use of other
10 features. As such, the foregoing description should be considered as merely illustrative of the principles of the present invention, and not in limitation thereof. Hence, the scope of the invention is only restricted by the appended patent claims.

Claims

1. A method of protecting a gas container interior, the method comprising:
providing an inlet and exhaust manifold comprising a port assembly
5 attachable to a port of the gas container;
exposing the gas container interior to sequential self-saturating surface reactions by sequential inlet of reactive gases via said port assembly and said port into the gas container interior; and
pumping reaction residue via said port and said port assembly out from the
10 gas container.

2. The method of claim 1, comprising attaching said port assembly to said port of the gas container.

15 3. The method of claim 1 or 2, comprising pumping reaction residue and purge gas from the gas container interior by a vacuum pump attached to an exhaust side of the inlet and exhaust manifold.

4. The method of any preceding claim, wherein a gas discharge point within the
20 gas container is arranged at a different level than a gas exhaust point.

5. The method of any preceding claim, wherein the gas container is used as a reaction vessel sealed by a sealing part comprised by the port assembly.

25 6. The method of claim 5, wherein said sealing part comprises a tapered thread detachably attachable to said port of the gas container in the place of a stop valve.

7. The method of claim 5 or 6, wherein said port assembly comprises a fitting
30 part attachable to the sealing part allowing the sealing part to twist to tighten against said port of the gas container.

8. The method of any preceding claim, comprising:

guiding inactive purge gas into an intermediate space between the gas container and a surrounding chamber wall, and

pumping said inactive purge gas out from the intermediate space.

5 9. The method of any preceding claim, wherein the inlet and exhaust manifold comprises one or more in-feed lines with their controlling elements controlled by a computer-implemented control system.

10. An apparatus for protecting a gas container interior, comprising:

10 an inlet and exhaust manifold comprising a port assembly attachable to a port of the gas container, the apparatus being configured to expose the gas container interior to sequential self-saturating surface reactions by sequential inlet of reactive gases via said port assembly and said port into the gas container interior; and

15 a pump configured to pump reaction residue via said port and said port assembly out from the gas container.

11. The apparatus of claim 10, wherein a gas discharge point provided by the inlet and exhaust manifold is arranged at a different level than a gas exhaust point

20 provided by the inlet and exhaust manifold.

12. The apparatus of claim 10 or 11, wherein the inlet and exhaust manifold comprises precursor vapor and purge gas in-feed lines and their controlling elements.

25

13. The apparatus of any of claims 10-12, wherein the inlet and exhaust manifold comprises a gas container-specific port assembly configured to attach the inlet and exhaust manifold into said port of the gas container thereby forming a fluid communication path between the inlet and exhaust manifold and the gas

30 container interior.

14. The apparatus of any of claims 10-13, comprising:

a chamber surrounding the gas container and an inactive gas in-feed line

configured to guide inactive purge gas into an intermediate space between the gas container and a surrounding chamber wall.

15. The apparatus of any of claims 10-14, wherein the port assembly comprises a
5 sealing part attachable to the port of the gas container.

16. The apparatus of claim 15, wherein the sealing part comprises a tapered thread.

10 17. The apparatus of claims 10-16, wherein the apparatus is mobile.

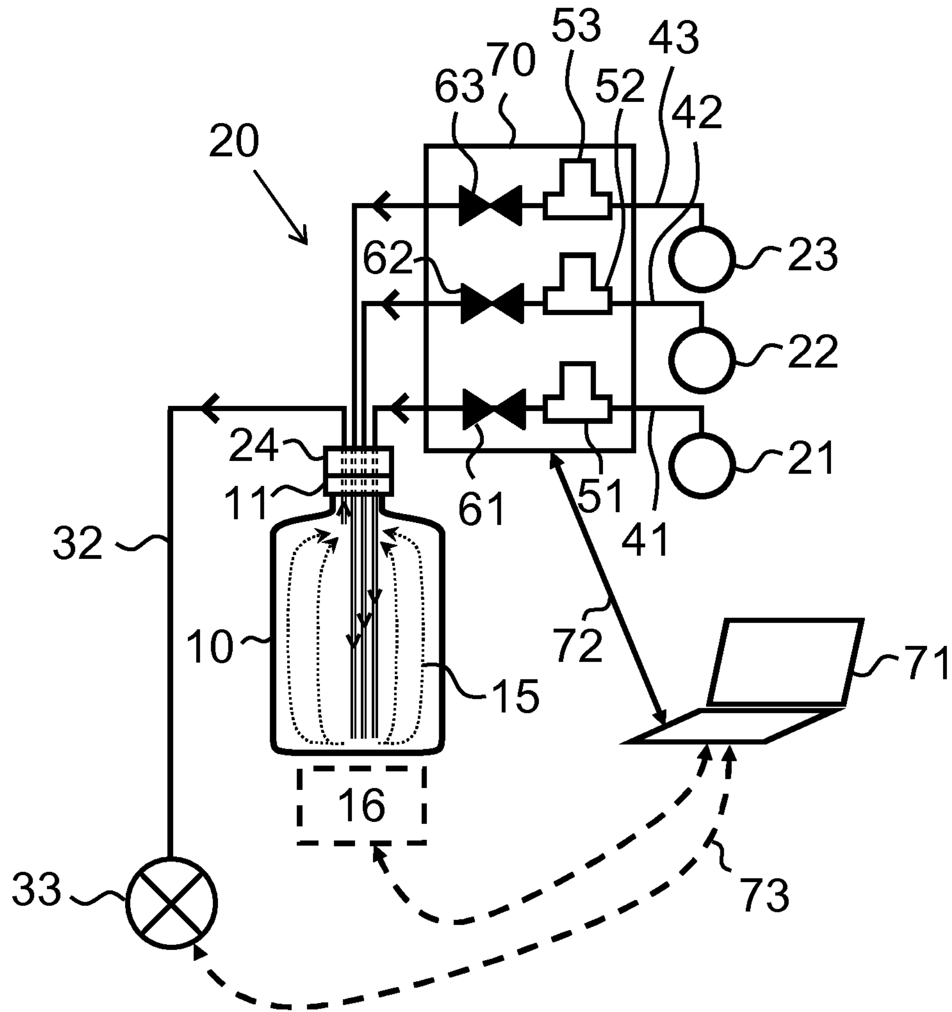

Fig. 1

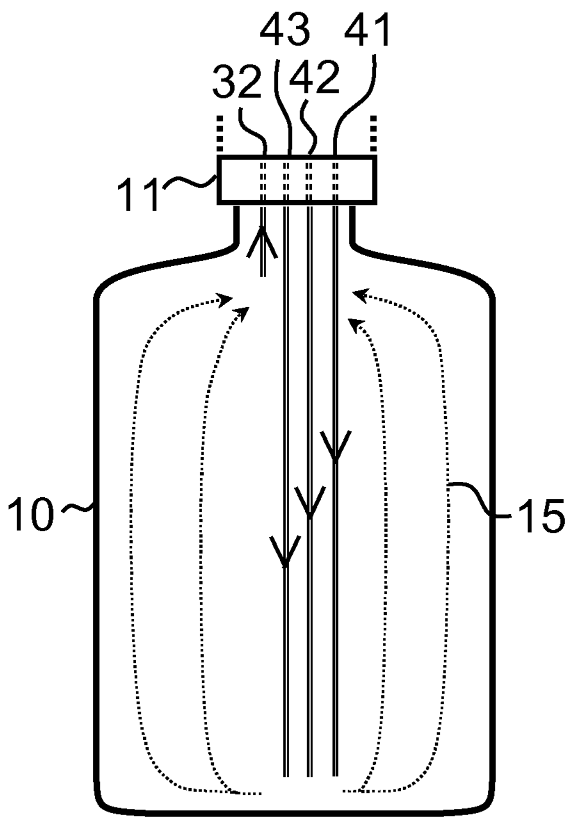

Fig. 2A

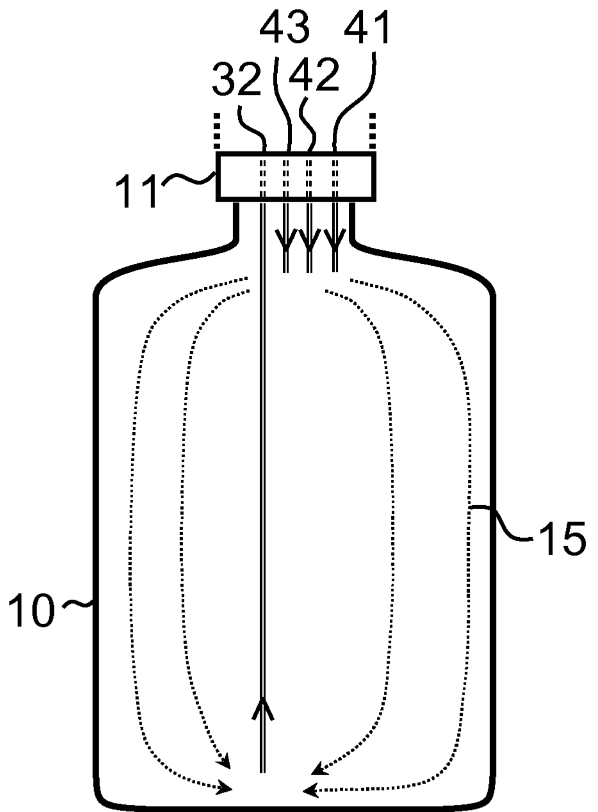

Fig. 2B

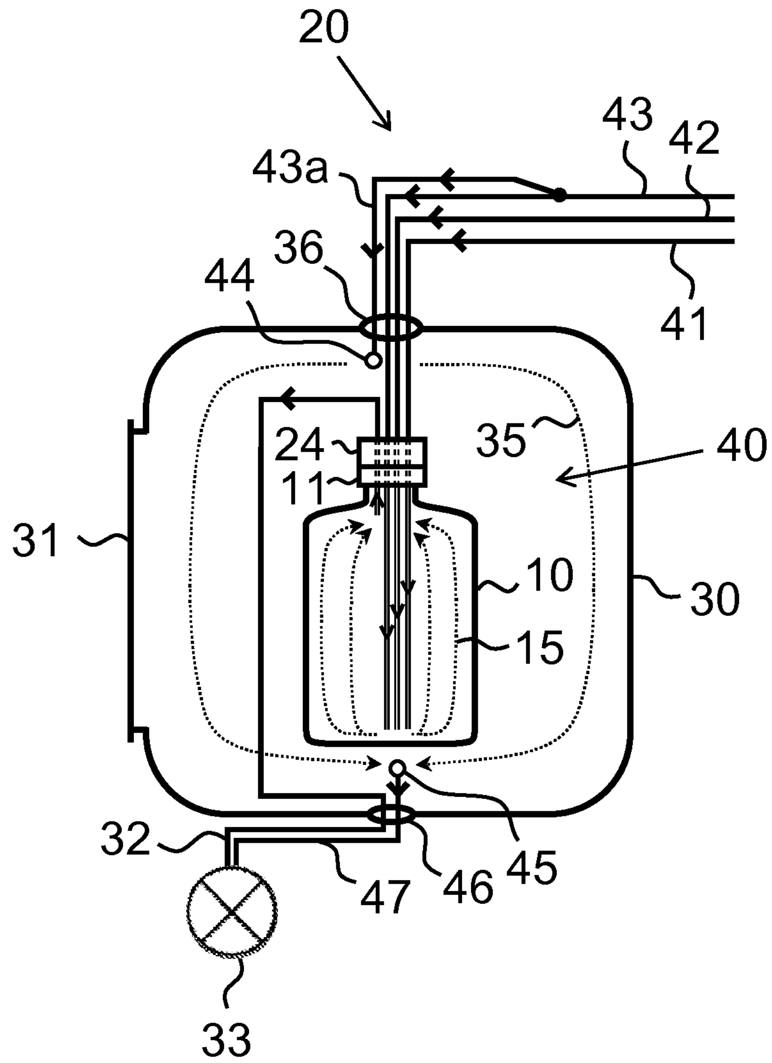

Fig. 3

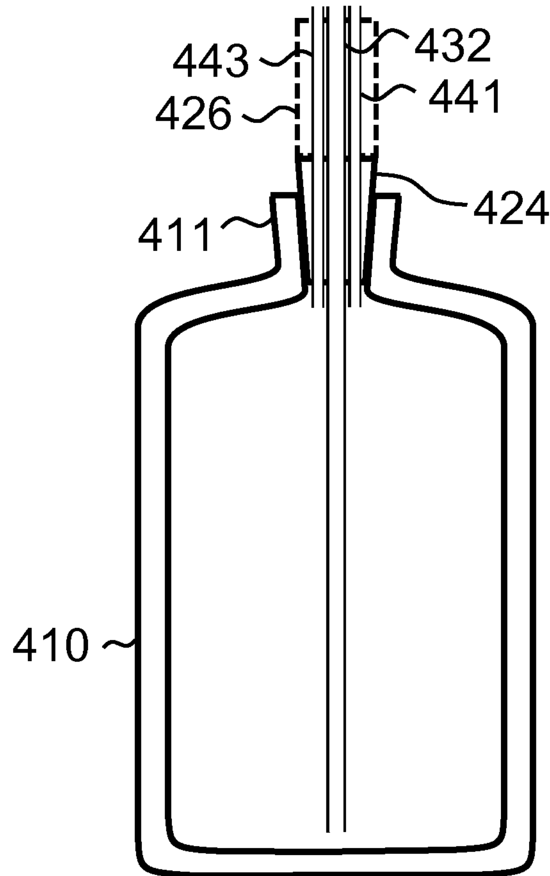

Fig. 4A

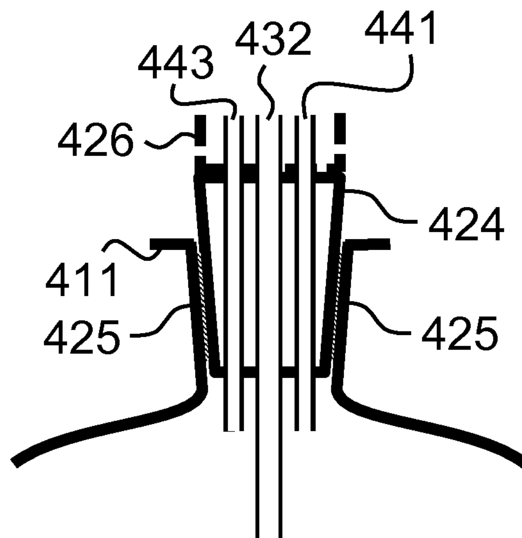

Fig. 4B

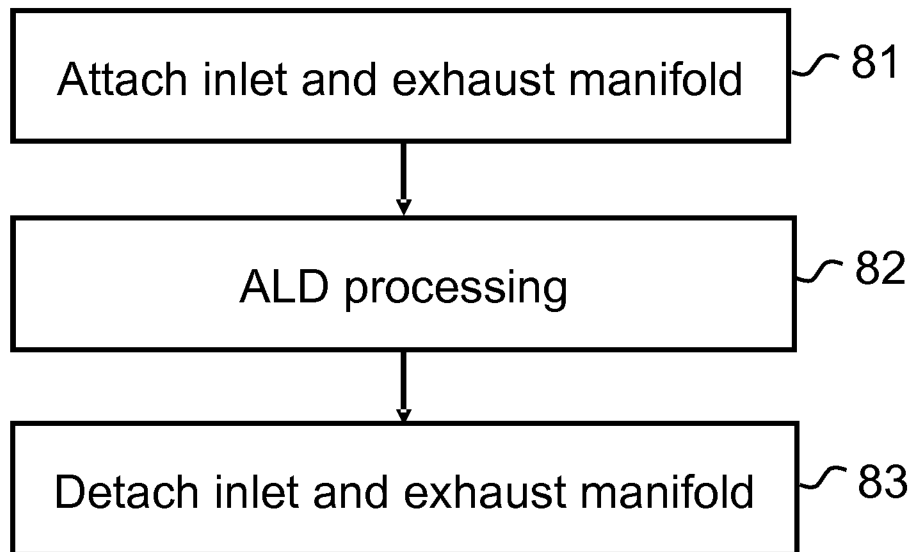

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2014/050152

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4859489 A1 (PINKHASOV EDUARD), 22 August 1989 (1989-08-22); abstract; column 1, line 51 - column 2, line 40; column 3, line 3 - column 4, line 49; figure 1; claims 1, 5 --	1-17
A	US 6416577 B1 (SUNTOLA TUOMO ET AL), 9 July 2002 (2002-07-09); abstract; column 1, line 61 - column 3, line 53; column 4, line 38 - column 5, line 59; figures 1-2 --	1-17
A	CN 102452797 A (YINGZUO NANO TECHNOLOGY BEIJING CO LTD), 16 May 2012 (2012-05-16); abstract; figure 2; Original document; whole document; abstract: Retrieved from: EDODOC database and WPI database, week 201241, AN 2012-G27643; see also the English machine translation --	1-17

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28-10-2014	28-10-2014

Name and mailing address of the ISA/SE
Patent- och registreringsverket
Box 5055
S-102 42 STOCKHOLM
Facsimile No. + 46 8 666 02 86

Authorized officer
Ingrid Grundfelt
Telephone No. + 46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2006321528 A (KIRIN BREWERY), 30 November 2006 (2006-11-30); figures 1,3-4; Original document; whole document; abstract: Retrieved from: EDODOC database and WPI database, week 200707, AN 2007-063014; see also the English machine translation, especially paragraphs 0038-0049 --	6-7, 16
A	JP 2008261060 A (MITSUBISHI HEAVY IND FOOD & PA), 30 October 2008 (2008-10-30); figures 2,6,9; Original document; whole document; abstract: Retrieved from: EDODOC database and WPI database, week 200880, AN 2008-N74982; see also the English machine translation, especially paragraphs 0023-0024, 0056-0059 and claims 1,4 --	6-7, 16
A	JP 2006160269 A (KIRIN BREWERY ET AL), 22 June 2006 (2006-06-22); figures 1-2; Original document; whole document; abstract: Retrieved from: EDODOC database and WPI database, week 200646, AN 2006-449148 -- --------	1-17

Continuation of: second sheet

International Patent Classification (IPC)

C23C 16/455 (2006.01)

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