

AN APPARATUS AND METHOD FOR COLLECTING ANESTHETIC GASES AND A METHOD FOR PRODUCING A REVERSIBLE ADSORBENT

Technical field

5 Aspects of the present invention relate to an apparatus for collecting one or more
anesthetic gases in a gas stream derived from exhalation air from a patient, a method
for collecting one or more anesthetic gases in a gas stream derived from exhalation air
from a patient, and a method for producing a reversible adsorbent, which, for example,
may be used in an apparatus and method of the above-mentioned sorts.

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Background

Anesthetic gases are used in the medical field for pain relief and are administered to
the patient via a mask fitted over the nose and/or mouth of the patient. Nitrous oxide is
an example of an anesthetic gas used in the medical field for pain relief. Nitrous oxide
15 is also known as laughing gas. In general, mixtures of nitrous oxide (N₂O) and oxygen
(O₂) are used. For example, nitrous oxide may be used in the fields of surgery, dental
care and maternity care during delivery because of the anaesthetic and analgesic
effects of nitrous oxide on a patient. In general, nitrous oxide is administered to the
patient via a mask fitted over the nose and/or mouth of the patient.

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In general, the composition of the air exhaled by a patient receiving nitrous oxide is
substantially the same as the composition of the inhaled air except that there is an
increase in moisture content (water) and carbon dioxide. In general, exhalation air from
a patient inhaling an anesthetic gas, such as nitrous oxide, is collected and not
25 released directly to the ambient so as to avoid exposure to members of the healthcare
staff. For example, nitrous oxide is an air pollutant which is considered at least 300
times more effective than carbon dioxide as a "greenhouse gas". Apparatuses for
collecting and adsorbing anesthetic gas may be used.

Summary

30 The inventor of the present invention has found drawbacks in conventional solutions
for the collection of anesthetic gas in a gas stream derived from exhalation air from a

patient. For example, some conventional solutions are not sufficiently efficient. For example, some conventional solutions are too complex.

5 An object of the invention is to provide a solution which mitigates or solves drawbacks and problems of conventional solutions.

The above and further objects are solved by the subject matter of the independent claims. Further advantageous embodiments of the invention can be found in the dependent claims.

10 According to a first aspect of the invention, the above mentioned and other objects are achieved with an apparatus for collecting one or more anesthetic gases in a gas stream derived from exhalation air from a patient and captured by a mask arrangement, wherein the apparatus comprises

15 a chamber comprising an inlet connectable to a mask arrangement for capturing a gas stream derived from exhalation air from a patient,

wherein the chamber is configured to receive the gas stream via the inlet,

wherein the chamber houses one or more adsorption units comprising one or more reversible adsorbents for adsorption of one or more anesthetic gases, and

20 wherein the reversible adsorbent comprises one or more molecular sieves impregnated with a metal-containing compound.

An advantage of the apparatus according to the first aspect is that the collection of anesthetic gases, such as nitrous oxide, in a gas stream derived from exhalation air from a patient is improved. An advantage of the apparatus according to the first aspect is that an improved reversible adsorbent for anesthetic gases is provided. An advantage of the apparatus according to the first aspect is that the adsorption of anesthetic gases, such as nitrous oxide, in a gas stream derived from exhalation air from a patient is improved. The apparatus may be mobile, immobile, or stationary. An advantage of the apparatus according to the first aspect is that the design of the apparatus can be made less complex in relation to conventional solutions. An advantage of the apparatus according to the first aspect is an improved desorption of one or more anesthetic gases. For example, the desorption of anesthetic gas may be

performed in room temperature without any additional heating or cooling, which would result increased electric power consumption. Thus, a less complex and more efficient collection of anesthetic gas is attained, i.e., both a more efficient adsorption and desorption of anesthetic gas is attained. Thus, a less complex structure of the apparatus for the collection of anesthetic gas can be provided.

Anesthetic gases may comprise nitrous oxide, halothane, isoflurane, desflurane, sevoflurane. In general, anesthetic gases are also known as inhaled anesthetics. In general, anesthetic gases may be administered as primary therapy for preoperative sedation and adjunctive anesthesia maintenance to intravenous (IV) anesthetic agents (i.e., midazolam, propofol) in the perioperative setting. Anesthetic gases, such as nitrous oxide, may be used in the fields of surgery, dental care and maternity care during delivery for pain relief.

According to an advantageous embodiment of the apparatus according to the first aspect, the molecular sieve is impregnated with one or more of the group of:

- an iron-containing compound;
- a zinc-containing compound; and
- an iron- and zinc-containing compound.

An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of anesthetic gases. An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to a further advantageous embodiment of the apparatus according to the first aspect, the one or more molecular sieves comprises/comprise molecular sieve beads having one or more coating layers comprising or consisting of a metal-containing compound. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of anesthetic gases. An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to another advantageous embodiment of the apparatus according to the first aspect, the one or more molecular sieves comprises/comprise molecular sieve beads having one or more coating layers comprising or consisting of one or more of the group of:

- 5 • an iron-containing compound;
- a zinc-containing compound; and
- an iron- and zinc-containing compound.

An advantage of this embodiment is a further improved collection of anesthetic gases.

An advantage of this embodiment is a further improved adsorption of anesthetic gases.

10 An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to yet another advantageous embodiment of the apparatus according to the first aspect, the coating layer comprises or consists of one or more of the group of:

- a crystallized iron-containing metal oxide;
- 15 • a crystallized zinc-containing metal oxide; and
- a crystallized iron- and zinc-containing metal oxide.

An advantage of this embodiment is a further improved collection of anesthetic gases.

An advantage of this embodiment is a further improved adsorption of anesthetic gases.

An advantage of this embodiment is a further improved desorption of anesthetic gases.

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According to still another advantageous embodiment of the apparatus according to the first aspect, one or spaces are formed between the molecular sieve beads. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of anesthetic gases.

25 An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to an advantageous embodiment of the apparatus according to the first aspect, the molecular sieve is porous, wherein the molecular sieve has a porosity in the range of 4 to 6 Å. An advantage of this embodiment is a further improved collection

30 of anesthetic gases. An advantage of this embodiment is a further improved adsorption of anesthetic gases. An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to a further advantageous embodiment of the apparatus according to the first aspect, the adsorption unit comprises one or more beds comprising the one or more molecular sieves. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of anesthetic gases. An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to another advantageous embodiment of the apparatus according to the first aspect, the chamber comprises an outlet for guiding gas processed in the chamber away from the chamber. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of anesthetic gases.

According to yet another advantageous embodiment of the apparatus according to the first aspect, the chamber comprises an outlet for guiding desorbing gas from the reversible adsorbent away from the chamber. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to still another advantageous embodiment of the apparatus according to the first aspect, the apparatus is in the form of a mobile unit to be used close to one or more patients receiving pain relief. An advantage of this embodiment is a further improved collection of anesthetic gases.

According to an advantageous embodiment of the apparatus according to the first aspect, the apparatus comprises the mask arrangement. An advantage of this embodiment is a further improved collection of anesthetic gases.

According to a further advantageous embodiment of the apparatus according to the first aspect, the mask arrangement comprises a mask configured to fit over the nose and/or mouth of the patient.

According to another advantageous embodiment of the apparatus according to the first aspect, the apparatus is configured for the collection of nitrous oxide and/or a mixture of nitrous oxide and one or more other anaesthetic gases in a gas stream derived from exhalation air from a patient and captured by the mask arrangement, wherein the one or more reversible adsorbents is/are configured to adsorb nitrous oxide.

The above-mentioned features and embodiments of the apparatus may be combined in various possible ways providing further advantageous embodiments.

According to a second aspect of the invention, the above mentioned and other objects are achieved with a method for collecting one or more anesthetic gases in a gas stream derived from exhalation air from a patient and captured by a mask arrangement, wherein the method comprises:

receiving the gas stream in an adsorbent-containing chamber comprising an inlet connected to the mask arrangement so as to adsorb one or more anesthetic gases by way of the adsorbent contained in the adsorbent-containing chamber, wherein the adsorbent is reversible and comprises one or more molecular sieves impregnated with a metal-containing compound.

Advantages of the method according to the second aspect and its embodiments may correspond to advantages of the apparatus according to the first aspect and its embodiments mentioned above or below.

According to an advantageous embodiment of the method according to the second aspect, the method comprises:

guiding gas processed in the adsorbent-containing chamber away from the adsorbent-containing chamber.

According to a further advantageous embodiment of the method according to the second aspect, the method comprises:

guiding desorbing gas from the adsorbent away from the adsorbent-containing chamber.

According to another advantageous embodiment of the method according to the second aspect, the method comprises:

receiving the gas stream in an adsorbent-containing chamber comprising an inlet connected to the mask arrangement so as to adsorb nitrous oxide by way of the adsorbent contained in the adsorbent-containing chamber.

According to yet another advantageous embodiment of the method according to the second aspect, the method comprises:

controlling the temperature of the adsorbent to a temperature in the range of 30°C to 80°C so as to desorb desorbing gas from the adsorbent.

An advantage of this embodiment is a further improved collection of anesthetic gases.

An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to still another advantageous embodiment of the method according to the second aspect, the method comprises:

controlling the temperature of the adsorbent to a temperature in the range of 30°C to 40°C so as to desorb nitrous oxide from the adsorbent.

An advantage of this embodiment is a further improved collection of anesthetic gases.

An advantage of this embodiment is a further improved desorption of anesthetic gases.

According to an advantageous embodiment of the method according to the second aspect, the method comprises:

controlling the temperature of the adsorbent to a temperature in the range of 70°C to 80°C so as to desorb sevoflurane from the adsorbent.

An advantage of this embodiment is a further improved collection of anesthetic gases.

An advantage of this embodiment is a further improved desorption of anesthetic gases.

The above-mentioned features and embodiments of the method according to the second aspect may be combined in various possible ways providing further advantageous embodiments.

According to a third aspect of the invention, the above mentioned and other objects are achieved with a method for producing a reversible adsorbent, wherein the method comprises:

- 5 mixing heat-treated molecular sieve with a solution comprising or consisting of isopropanol and one or more metal acetylacetonates so as to produce a composition; and
- drying the produced composition so as to produce the reversible adsorbent.

10 An advantage of the method according to the third aspect is that an improved reversible adsorbent is provided. An advantage of the method according to the third aspect is an improved collection of anesthetic gases, such as nitrous oxide, in a gas stream derived from exhalation air from a patient by way of the improved reversible adsorbent. An advantage of the method according to the third aspect is an improved adsorption of anesthetic gases, such as nitrous oxide, by way of the improved reversible adsorbent.

15 An advantage of the method according to the third aspect is an improved desorption of one or more anesthetic gases by way of the improved reversible adsorbent. For example, the desorption of anesthetic gases may be performed in room temperature without any additional heating or cooling. Thus, a less complex and more efficient collection of anesthetic gas is attained, i.e., both a more efficient adsorption and

20 desorption of anesthetic gas is attained.

According to an advantageous embodiment of the method according to the third aspect, the method comprises:

- 25 before mixing the heat-treated molecular sieve with said solution, heat-treating molecular sieve at a temperature of at least 300°C so as to produce the heat-treated molecular sieve.

An advantage of this embodiment is a further improved reversible adsorbent. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of one or more anesthetic gases. An advantage of this embodiment is a further improved desorption of one or more anesthetic gases.

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According to a further advantageous embodiment of the method according to the third aspect, the method comprises:

before mixing the heat-treated molecular sieve with said solution, preparing said solution by mixing isopropanol and one or more metal acetylacetonates at a temperature of at least 70°C.

An advantage of this embodiment is a further improved reversible adsorbent. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of one or more anesthetic gases. An advantage of this embodiment is a further improved desorption of one or more anesthetic gases.

According to another advantageous embodiment of the method according to the third aspect, the method comprises:

when or after drying the produced composition, heat-treating the produced composition at a temperature of at least 300°C in order to crystallize one or more metal oxides of the produced composition onto the heat-treated molecular sieve so as to produce the reversible adsorbent.

An advantage of this embodiment is a further improved reversible adsorbent. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of one or more anesthetic gases. An advantage of this embodiment is a further improved desorption of one or more anesthetic gases.

According to yet another advantageous embodiment of the method according to the third aspect, the method comprises:

before drying the produced composition, mixing heat-treated molecular sieve with a solution comprising or consisting of isopropanol and one or more of iron acetylacetonate and zinc acetylacetonate so as to produce the composition.

An advantage of this embodiment is a further improved reversible adsorbent. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of one or more anesthetic gases. An advantage of this embodiment is a further improved desorption of one or more anesthetic gases.

According to still another advantageous embodiment of the method according to the third aspect, the method comprises:

5 before mixing the heat-treated molecular sieve with said solution, preparing said solution by mixing isopropanol and one or more of iron acetylacetonate and zinc acetylacetonate at a temperature of at least 70°C.

10 An advantage of this embodiment is a further improved reversible adsorbent. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of one or more anesthetic gases. An advantage of this embodiment is a further improved desorption of one or more anesthetic gases.

According to an advantageous embodiment of the method according to the third aspect, the method comprises:

15 when or after drying the produced composition, heat-treating the produced composition at a temperature of at least 300°C in order to crystallize one or more of an iron-containing metal oxide and a zinc-containing metal oxide of the produced composition onto the heat-treated molecular sieve so as to produce the reversible adsorbent.

20 An advantage of this embodiment is a further improved reversible adsorbent. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of one or more anesthetic gases. An advantage of this embodiment is a further improved desorption of one or more anesthetic gases.

25 According to a further advantageous embodiment of the method according to the third aspect, wherein the molecular sieve is porous, wherein the molecular sieve has a porosity in the range of 4 to 6 Å. An advantage of this embodiment is a further improved reversible adsorbent. An advantage of this embodiment is a further improved collection of anesthetic gases. An advantage of this embodiment is a further improved adsorption of one or more anesthetic gases. An advantage of this embodiment is a further improved desorption of one or more anesthetic gases.

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The above-mentioned features and embodiments of the method according to the third aspect may be combined in various possible ways providing further advantageous embodiments.

- 5 Further advantageous embodiments of the apparatus according to the first aspect, of the method according to the second aspect and of the method according to the third aspect and further advantages with the embodiments of the present invention emerge from the detailed description of embodiments.

10 ***Brief Description of the Drawings***

Embodiments of the invention will now be illustrated, for exemplary purposes, in more detail by way of embodiments and with reference to the enclosed drawings, where similar references are used for similar parts, in which:

- 15 Figure 1 is a schematic sectional side view of an embodiment of the apparatus according to the first aspect of the invention;
- Figure 2 is a schematic enlargement of an adsorption unit of the apparatus of figure 1;
- Figure 3 is a schematic view of a molecular sieve bead of the adsorption unit of figure 2;
- 20 Figure 4 is a schematic flow chart illustrating aspects of embodiments of the method according to the second aspect of the invention;
- Figure 5 is a schematic flow chart illustrating further aspects of embodiments of the method according to the second aspect of the invention;
- 25 Figure 6 is a schematic flow chart illustrating aspects of embodiments of the method according to the third aspect of the invention; and
- Figure 7 is a schematic flow chart illustrating further aspects of embodiments of the method according to the third aspect of the invention.

30 ***Detailed Description***

With reference to figures 1 to 3, an embodiment of the apparatus 100 and aspects of embodiments of the apparatus 100 for collecting one or more anesthetic gases in a gas stream 102 derived from exhalation air from a patient and captured by a mask

arrangement 104 according to the first aspect of the invention are schematically illustrated.

5 With reference to figure 1, the apparatus 100 includes a chamber 106 including an inlet 108, such as a gas inlet, connectable, such as fluidly and/or mechanically connectable, to a mask arrangement 104 for capturing a gas stream 102 derived from exhalation air from a patient. For some embodiments, the apparatus 100 may optionally include a casing 110 housing the chamber 106. The chamber 106 is configured to receive the gas stream 102 via the inlet 108. The chamber 106 houses one or more adsorption
10 units 112a-c comprising one or more reversible adsorbents 114 for adsorption of one or more anesthetic gases. The reversible adsorbent 114 comprises one or more molecular sieves 116 impregnated with a metal-containing compound.

15 Anesthetic gases may comprise nitrous oxide (N_2O), halothane, isoflurane, desflurane, sevoflurane. In general, anesthetic gases are also known as inhaled anesthetics. In general, anesthetic gases may be administered as primary therapy for preoperative sedation and adjunctive anesthesia maintenance to intravenous (IV) anesthetic agents (i.e., midazolam, propofol) in the perioperative setting. Anesthetic gases, such as nitrous oxide, may be used in the fields of surgery, dental care and maternity care
20 during delivery for pain relief. In general, mixtures of nitrous oxide (N_2O) and oxygen (O_2) are used for pain relief.

For some embodiments, the molecular sieve 116 is impregnated with one or more of the group of: an iron-containing compound; a zinc-containing compound; and an iron-
25 and zinc-containing compound.

With reference to figures 2 and 3, for some embodiments, the one or more molecular sieves 116 may comprise molecular sieve beads 118 (or bodies, or solids) having one or more coating layers 120 (or surface regions, or outer layers) comprising or
30 consisting of a metal-containing compound. The bead 118 may have different shapes. For example, the bead 18 may be shaped as a ball, a sphere, or a cylinder, for example, so as to provide spaces 122 between the beads 118. However, other shapes of the beads 118 are possible.

With reference to figure 3, for some embodiments, the one or more molecular sieves 116 may comprise molecular sieve beads 118 having one or more coating layers 120 comprising or consisting of one or more of the group of: an iron-containing compound;
5 a zinc-containing compound; and an iron- and zinc-containing compound.

With reference to figure 3, for some embodiments, the coating layer 120 may comprise or consist of one or more of the group of: a crystallized iron-containing metal oxide; a crystallized zinc-containing metal oxide; and a crystallized iron- and zinc-containing
10 metal oxide.

With reference to figure 3, for some embodiments, the molecular sieve 116 may be defined, or described, as being porous, wherein the molecular sieve 116 may have a porosity in the range of 4 to 6 Å, such as approximately 5 Å. For example, 5 Å is
15 advantageous for applications involving nitrous oxide (N₂O). It is to be understood that 1 Å, or 1 angstrom, or 1 ångström, is equal to 0.1 nm. For some embodiments, it may be defined that the molecular sieve 116 forms pores, wherein the molecular sieve 116 has a pore diameter in the range of 4 to 6 Å, such as approximately 5 Å. For some
20 embodiments, the determination of the porosity, the pore diameter and/or the associated ranges or values in Å may in general be characterized by conventional gas adsorption using a physical adsorption instrument.

With reference to figure 2, for some embodiments, one or spaces 122 may be formed between the molecular sieve beads 118. For some embodiments, the adsorption unit
25 112a-c may include one or more beds 124 comprising the one or more molecular sieves 116. For some embodiments, it may be defined that the bed 124 comprises one or more reversible adsorbents 114.

With reference to figure 1, for some embodiments, the chamber 106 may include an
30 outlet 126 for guiding gas processed in the chamber 106 away from the chamber 106, such as unabsorbed gases or gas mixtures. For some embodiments, the chamber 106 may include an outlet 126 for guiding desorbing gas from the reversible adsorbent 114 away from the chamber 106, i.e., gas that has been desorbed from the adsorbent 114.

In the embodiment illustrated in figure 1, the same outlet 126 is used for guiding gas processed in the chamber 106 and for guiding desorbing gas from the reversible adsorbent 114 away from the chamber 106. However, for other embodiments, the outlet 126 for guiding gas processed in the chamber 106 away from the chamber 106 may be a separate outlet 126 in relation to the outlet 126 for guiding desorbing gas from the reversible adsorbent 114 away from the chamber 106. For some embodiments, it may be defined that the outlet 126, or gas outlet, of the chamber 106 is configured to discharge one or more gas streams.

With reference to figure 1, for some embodiments, the apparatus 100 may be in the form of a mobile unit to be used close to one or more patients receiving pain relief. Thus, the apparatus 100 may be mobile and easily movable. The apparatus 100 may be movable by a user or operator. However, for other embodiments, the apparatus 100 may be stationary, and may, for example, be integrated into the infrastructure of a hospital, or other healthcare or treatment facility. The apparatus 100 may be directly, or indirectly, connectable to at least one patient and/or to a mask 128 for administering anesthetic gas to a patient and for capturing exhalation air from the patient. The apparatus 100 may be configured to be used or applied in the proximity of a patient receiving pain relief by inhaling anesthetic gas, such as oxygen containing nitrous oxide, also known as laughing gas. For some embodiments, the apparatus 100 may be remote in relation to the patient.

With reference to figure 1, for some embodiments, the apparatus 100 comprises the mask arrangement 104. For some embodiments, it may be defined that the mask arrangement 104 includes a mask 128 configured to fit over the nose and/or mouth of the patient. The mask 128 may be directly, or indirectly, fluidly connected to the inlet 108 of the chamber 106 and may be mechanically connected to the inlet 108 of the chamber 106, for example via one or more tubes or lines 130. Thus, for some embodiments, the apparatus 100 and/or the inlet 108 of the chamber 106 may be connectable to the mask 128 for capturing exhalation air from the patient and optionally for administering anesthetic gas to a patient.

With reference to figure 1, for some embodiments, the apparatus 100 may be configured for the collection of nitrous oxide and/or a mixture of nitrous oxide and one or more other anaesthetic gases in a gas stream 102 derived from exhalation air from a patient and captured by the mask arrangement 104, wherein the one or more reversible adsorbents 114 may be configured to adsorb nitrous oxide.

For some embodiments, the adsorption unit 112a-c may include one or more gas permeable walls 132. The gas-permeable wall 132 may include one or more of the group of: a grid; a net; and a mesh. It is to be understood that the gas-permeable wall 132 may include other gas-permeable members, elements or surfaces, such as a solid wall forming several through-holes, for example a perforated plate. For some embodiments, the adsorption unit 112a-c may include two or more gas-permeable walls 132 spaced apart from one another, for example spaced apart by one or more solid or non-gas-permeable walls, or spacers. For some embodiments, it may be defined, described, that the adsorption unit 112a-c holds the one or more reversible adsorbents 114 in a space defined or limited by said one or more gas permeable walls 132. For some embodiments, the adsorption unit 112a-c may be defined, or described, to allow, or be configured to allow, a flow of gas therethrough, or a through-flow of gas. However, said one or more gas permeable walls 132 may be excluded, and the adsorption unit 112a-c may be arranged in other manners.

With reference to figure 1, for some embodiments, the apparatus 100 may include a heater 134 for heating the reversible adsorbent 114. For some embodiments, the apparatus 100 may include one or more temperature sensors 136 for measuring the temperature of reversible adsorbent 114. However, the heater 134 and/or the temperature sensor 136 may be excluded. For example, the desorption of anesthetic gas, such as nitrous oxide (N_2O), may be performed in room temperature without any additional heating or cooling, and thus avoiding an increased or additional electric power consumption. For some embodiments, if two or more anesthetic gases, such as two or more different kinds of anesthetic gas, are adsorbed, then the desorption process is advantageously performed with the heating of reversible adsorbent 114 and/or the molecular sieve 116 to different temperatures, so as to desorb selectively one or more of anesthetic gases.

When an item is disclosed to be connected to another item in this disclosure, it may imply that the two items are fluidly connected to one another. When an item is disclosed to be connected to another item in this disclosure, it may imply that the two items are mechanically connected to one another. When an item is disclosed to be connected to another item in this disclosure, it may imply that the two items are both fluidly and mechanically connected to one another.

With reference to figures 4 and 5, aspects of embodiments of the method 200 for collecting one or more anesthetic gases in a gas stream 102 derived from exhalation air from a patient and captured by a mask arrangement 104 according to the second aspect of the invention are schematically illustrated in flow charts.

With reference to figure 4, embodiments of the method 200 include the step of:

- receiving 201 the gas stream 102 in an adsorbent-containing chamber 106 comprising an inlet 108 connected to the mask arrangement 104 so as to adsorb one or more anesthetic gases by way of the adsorbent 114 contained in the adsorbent-containing chamber 106, wherein the adsorbent 114 is reversible and comprises one or more molecular sieves 116 impregnated with a metal-containing compound.

With reference to figure 5, some embodiments of the method 200 may include one or more of the steps of:

- receiving 201 the gas stream 102 in the adsorbent-containing chamber 106;
- guiding 202 gas processed in the adsorbent-containing chamber 106 away from the adsorbent-containing chamber 106;
- controlling 203 the temperature of the adsorbent 114 to a temperature in the range of 30°C to 80°C so as to desorb desorbing gas from the adsorbent 114; and
- guiding 204 desorbing gas from the adsorbent 114 away from the adsorbent-containing chamber 106, i.e., gas that has been desorbed from the adsorbent 114.

For some embodiments of the method 200, the method 200 may comprise the step of:

- controlling 203a the temperature of the adsorbent to a temperature in the range of 30°C to 40°C (degrees Celsius) so as to desorb nitrous oxide from the adsorbent. The range of 30°C to 40°C may correspond to room temperature. However, room temperature may also be below 30°C.

For some embodiments of the method 200, the method 200 may comprise the step of:

- controlling 203b the temperature of the adsorbent to a temperature in the range of 70°C to 80°C so as to desorb sevoflurane from the adsorbent.

For some embodiments of the method 200, the method 200 may comprise the step of:

- receiving 201 the gas stream 102 in an adsorbent-containing chamber 106 comprising an inlet 108 connected to the mask arrangement 104 so as to adsorb nitrous oxide by way of the adsorbent 114 contained in the adsorbent-containing chamber 106.

For some embodiments of the method 200, the step of desorption of the adsorbent 114 may include blowing air or any other gas or gas mixture through the adsorbent 114, such as until substantially all adsorbed anesthetic gas is removed from the adsorbent 114.

With reference to figures 6 and 7, aspects of embodiments of the method 300 for producing a reversible adsorbent 114 according to the third aspect of the invention are schematically illustrated in flow charts.

With reference to figure 6, embodiments of the method 300 include the step of:

- mixing 303 heat-treated molecular sieve with a solution comprising or consisting of isopropanol (also referred to as isopropyl alcohol) and one or more metal acetylacetonates (or, one or more metal acetylacetonate compounds) so as to produce a composition; and
- drying 304 the produced composition so as to produce the reversible adsorbent.

For some embodiments, the step of drying 302 the produced composition may be defined or described to involve the step of having the solution absorbed by the heat-treated molecular sieve so as to produce the reversible adsorbent. The steps 303 and 304 disclosed above may be described as steps of an impregnation process or method. Acetylacetonate is an organic compound with a chemical formula $\text{CH}_3\text{COCH}_2\text{COCH}_3$. Acetylacetonate may be classified as a 1,3-diketone.

With reference to figure 7, some embodiments of the method 300 may include one or more of the steps of:

- before mixing the heat-treated molecular sieve with said solution, heat-treating 301 molecular sieve at a temperature of at least 300°C so as to produce the heat-treated molecular sieve;
- before mixing the heat-treated molecular sieve with said solution, preparing 302 said solution by mixing isopropanol and one or more metal acetylacetonates at a temperature of at least 70°C ;
- before mixing the heat-treated molecular sieve with said solution, preparing 302a said solution by mixing isopropanol and one or more of iron acetylacetonate and zinc acetylacetonate at a temperature of at least 70°C . For some embodiments, iron acetylacetonate and zinc acetylacetonate may be mixed in different molar ratios 0-1 (for example, 0.1 to 0.9, etc.), by way of a solid state reaction so as to produce a complex metal oxide based on above mentioned metals;
- before drying the produced composition, mixing 303a heat-treated molecular sieve with a solution comprising or consisting of isopropanol and one or more of iron acetylacetonate and zinc acetylacetonate so as to produce the composition;
- when or after drying the produced composition, heat-treating 305 the produced composition at a temperature of at least 300°C in order to crystallize one or more metal oxides of the produced composition onto the heat-treated molecular sieve so as to produce the reversible adsorbent; and

- when or after drying the produced composition, heat-treating 305a the produced composition at a temperature of at least 300°C in order to crystallize one or more of an iron-containing metal oxide and a zinc-containing metal oxide of the produced composition onto the heat-treated molecular sieve so as to produce the reversible adsorbent.

Iron acetylacetonate may be referred to as: 2,4-pentanedione iron(III), $\text{Fe}(\text{acac})_3$, ferric acetylacetonate, or iron(III) 2,4-pentanedionate. Zinc acetylacetonate may be referred to as: Bis(2,4-pentanedionato)zinc, or $\text{Zn}(\text{acac})_2$.

With reference to figures 6 and 7, for some embodiments of the method 300, the molecular sieve 116 may be defined, or described, as being porous, wherein the molecular sieve 116 may have a porosity in the range of 4 to 6 Å, such as approximately 5 Å. For example, 5 Å is advantageous when the produced reversible adsorbent is to be used for the adsorption and/or desorption of nitrous oxide (N_2O). The reversible adsorbent 114 produced according to the embodiments of the method illustrated in figures 6 and 7 may be applied to the embodiments of figures 1 to 5 or used in other applications.

For some embodiments, the step of heat-treating the molecular sieve and/or the produced composition may be performed in, or by way of, a furnace, or any other heating chamber or equipment. For some embodiments, the one or more solutions may be heated on a heating or hot plate, or by way of any other heating equipment. For some embodiments, the step of drying the produced composition may be formed by means of a vacuum dryer, a vacuum evaporator, a rotary evaporator, or any other dryer or drying equipment, or through passive drying. For some embodiments, one or more of the steps of mixing may be performed by a stirrer, such as a magnetic stirrer, a magnetic mixer, or any other mixer or mixing equipment.

Unless disclosed otherwise, it should be noted that the method steps illustrated in figures 4 to 7 and described herein do not necessarily have to be executed in the order illustrated in figures 4 to 7. The steps may essentially be executed in any suitable order. Further, one or more steps may be added without departing from the scope of the

appended claims. One or more steps may be excluded without departing from the scope of the appended claims.

5 Embodiments of the reversible adsorbent disclosed above are not sensitive to humidity, or less sensitive to humidity in relation to conventional adsorbents. A desorption capacity of approx. 100 % for embodiments of the reversible adsorbent disclosed above was observed when testing for several cycles.

10 The present invention is not limited to the above-described embodiments. Instead, the present invention relates to, and encompasses all different embodiments being included within the scope of the appended independent claims.

Claims

1. An apparatus (100) for collecting one or more anesthetic gases in a gas stream (102) derived from exhalation air from a patient and captured by a mask arrangement (104), wherein the apparatus (100) comprises
- 5 a chamber (106) comprising an inlet (108) connectable to a mask arrangement (104) for capturing a gas stream (102) derived from exhalation air from a patient,
- wherein the chamber (106) is configured to receive the gas stream (102) via
- 10 the inlet (108),
- wherein the chamber (106) houses one or more adsorption units (112a-c) comprising one or more reversible adsorbents (114) for adsorption of one or more anesthetic gases, and
- wherein the reversible adsorbent (114) comprises one or more molecular
- 15 sieves (116) impregnated with a metal-containing compound.
2. An apparatus (100) according to claim 1, wherein the molecular sieve (116) is impregnated with one or more of the group of:
- an iron-containing compound;
 - 20 • a zinc-containing compound; and
 - an iron- and zinc-containing compound.
3. An apparatus (100) according to claim 1 or 2, wherein the one or more molecular sieves (116) comprises/comprise molecular sieve beads (118) having one
- 25 or more coating layers (120) comprising or consisting of a metal-containing compound.
4. An apparatus (100) according to any one of the claims 1 to 3, wherein the one or more molecular sieves (116) comprises/comprise molecular sieve beads (118) having one or more coating layers (120) comprising or consisting of one or more of the
- 30 group of:
- an iron-containing compound;
 - a zinc-containing compound; and
 - an iron- and zinc-containing compound.

5. An apparatus (100) according to claim 3 or 4, wherein the coating layer (120) comprises or consists of one or more of the group of:

- a crystallized iron-containing metal oxide;
- 5 • a crystallized zinc-containing metal oxide; and
- a crystallized iron- and zinc-containing metal oxide.

6. An apparatus (100) according to any one of the claims 3 to 5, wherein one or spaces (122) are formed between the molecular sieve beads (118).

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7. An apparatus (100) according to any one of the claims 1 to 6, wherein the molecular sieve (116) is porous, and
wherein the molecular sieve (116) has a porosity in the range of 4 to 6 Å.

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8. An apparatus (100) according to any one of the claims 1 to 7, wherein the adsorption unit (112a) comprises one or more beds (124) comprising the one or more molecular sieves (116).

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9. An apparatus (100) according to any one of the claims 1 to 8, wherein the chamber (106) comprises an outlet (126) for guiding gas processed in the chamber (106) away from the chamber (106).

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10. An apparatus (100) according to any one of the claims 1 to 9, wherein the chamber (106) comprises an outlet (126) for guiding desorbing gas from the reversible adsorbent (114) away from the chamber (106).

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11. An apparatus (100) according to any one of the claims 1 to 10, wherein the apparatus (100) is in the form of a mobile unit to be used close to one or more patients receiving pain relief.

12. An apparatus (100) according to any one of the claims 1 to 11, wherein the apparatus (100) comprises the mask arrangement (104).

13. An apparatus (100) according to claim 12, wherein the mask arrangement (104) comprises a mask (128) configured to fit over the nose and/or mouth of the patient.

5

14. An apparatus (100) according to any one of the claims 1 to 13, wherein the apparatus (100) is configured for the collection of nitrous oxide and/or a mixture of nitrous oxide and one or more other anaesthetic gases in a gas stream (102) derived from exhalation air from a patient and captured by the mask arrangement (104), and
10 wherein the one or more reversible adsorbents (114) is/are configured to adsorb nitrous oxide.

15. A method (200) for collecting one or more anesthetic gases in a gas stream (102) derived from exhalation air from a patient and captured by a mask arrangement (104), wherein the method (200) comprises:

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receiving (201) the gas stream (102) in an adsorbent-containing chamber (106) comprising an inlet (108) connected to the mask arrangement (104) so as to adsorb one or more anesthetic gases by way of the adsorbent (114) contained in the adsorbent-containing chamber (106), wherein the adsorbent (114) is reversible and
20 comprises one or more molecular sieves (116) impregnated with a metal-containing compound.

16. A method (200) according to claim 15, wherein the method (200) comprises:
guiding (202) gas processed in the adsorbent-containing chamber (106) away
25 from the adsorbent-containing chamber (106).

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17. A method (200) according to claim 15 or 16, wherein the method (200) comprises:

guiding (204) desorbing gas from the adsorbent (114) away from the
30 adsorbent-containing chamber (106).

30

18. A method (200) according to any one of the claims 15 to 17, wherein the method (200) comprises:

receiving (201) the gas stream (102) in an adsorbent-containing chamber (106) comprising an inlet (108) connected to the mask arrangement (104) so as to adsorb nitrous oxide by way of the adsorbent (114) contained in the adsorbent-containing chamber (106).

5

19. A method (200) according to any one of the claims 15 to 18, wherein the method (200) comprises:

controlling (203) the temperature of the adsorbent (114) to a temperature in the range of 30°C to 80°C so as to desorb desorbing gas from the adsorbent (114).

10

20. A method (200) according to any one of the claims 15 to 19, wherein the method (200) comprises:

controlling (203a) the temperature of the adsorbent (114) to a temperature in the range of 30°C to 40°C so as to desorb nitrous oxide from the adsorbent (114).

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21. A method (200) according to any one of the claims 15 to 20, wherein the method (200) comprises:

controlling (203b) the temperature of the adsorbent (114) to a temperature in the range of 70°C to 80°C so as to desorb sevoflurane from the adsorbent (114).

20

22. A method (300) for producing a reversible adsorbent (114), wherein the method (300) comprises:

mixing (303) heat-treated molecular sieve with a solution comprising or consisting of isopropanol and one or more metal acetylacetonates so as to produce a composition; and

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drying (304) the produced composition so as to produce the reversible adsorbent.

23. A method (300) according to claim 22, wherein the method (300) comprises:

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before mixing the heat-treated molecular sieve with said solution, heat-treating (301) molecular sieve at a temperature of at least 300°C so as to produce the heat-treated molecular sieve.

24. A method (300) according to claim 22 or 23, wherein the method (300) comprises:

before mixing the heat-treated molecular sieve with said solution, preparing (302) said solution by mixing isopropanol and one or more metal acetylacetonates at a temperature of at least 70°C.

25. A method (300) according to any one of the claims 22 to 24, wherein the method (300) comprises:

when or after drying the produced composition, heat-treating (305) the produced composition at a temperature of at least 300°C in order to crystallize one or more metal oxides of the produced composition onto the heat-treated molecular sieve so as to produce the reversible adsorbent.

26. A method (300) according to any one of the claims 22 to 25, wherein the method (300) comprises:

before drying the produced composition, mixing (303a) heat-treated molecular sieve with a solution comprising or consisting of isopropanol and one or more of iron acetylacetonate and zinc acetylacetonate so as to produce the composition.

27. A method (300) according to claim 26, wherein the method (300) comprises: before mixing the heat-treated molecular sieve with said solution, preparing (302a) said solution by mixing isopropanol and one or more of iron acetylacetonate and zinc acetylacetonate at a temperature of at least 70°C.

28. A method (300) according to claim 26 or 27, wherein the method (300) comprises:

when or after drying the produced composition, heat-treating (305a) the produced composition at a temperature of at least 300°C in order to crystallize one or more of an iron-containing metal oxide and a zinc-containing metal oxide of the produced composition onto the heat-treated molecular sieve so as to produce the reversible adsorbent.

29. A method (300) according to any one of the claims 22 to 28, wherein the molecular sieve is porous, and
wherein the molecular sieve has a porosity in the range of 4 to 6 Å.