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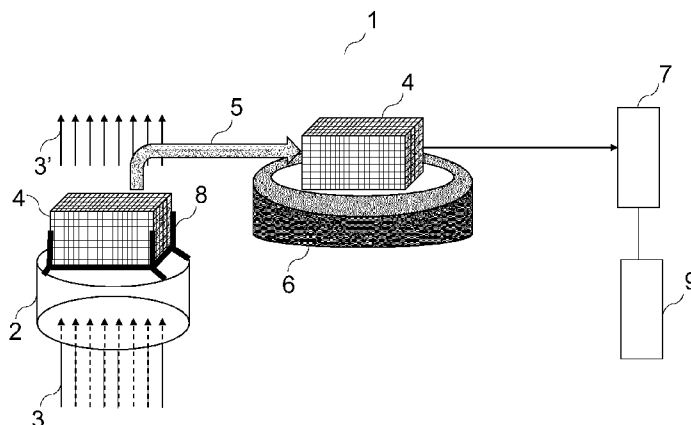
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(54) **Title:** SYSTEM AND METHOD FOR CAPTURING CARBON DIOXIDE FROM AIR

**Fig. 1**

(57) **Abstract:** The present invention relates to a system (1) for capturing carbon dioxide from ambient air (3), the system comprising: a CO₂ trapping structure (4) for placement in ambient air (3), said ambient air (3) comprising carbon dioxide, said CO₂ trapping structure (4) comprising a porous member having pores which are interconnected between opposite faces of the member; and an air conducting structure (2) comprising a means for forcing the ambient air (3) through the CO₂ trapping structure (4), wherein the CO₂ trapping structure (4) is removable positioned with respect to the air conducting structure (2) such that the air passing through the air conducting structure (2) passes through the pores of the CO₂ trapping structure (4), said pores having walls comprising an amine which binds the carbon dioxide from the ambient air (3); and a means (5) for moving the CO₂ trapping structure (4) to an environment (6) being at a temperature comprised between 60°C to 100°C, preferably between 65°C to 95°C, more preferably between 65°C to 80°C, and being at a reduced pressure so as to release the carbon dioxide from the CO₂ trapping structure (4). The use of the system and a related method are provided as well.

SYSTEM AND METHOD FOR CAPTURING CARBON DIOXIDE FROM AIR

[0001] The present invention relates to a system, the use thereof, and related method for capturing carbon dioxide from ambient air.

[0002] It is generally known that the concentration of carbon dioxide (CO₂) in the atmosphere can cause risk for the planet, thereby even influencing the global climate. Removing CO₂ from the atmosphere is seen as a way to tackle this issue. Therefore, in the art, efforts have already been made to develop systems and techniques for capturing ambient CO₂.

[0003] WO 2008/144708 for example describes a system for removing carbon dioxide from an atmosphere to reduce global warming including an air extraction system that collects carbon dioxide from the atmosphere through a medium and removes carbon dioxide from the medium; a sequestration system that isolates the removed carbon dioxide to a location for at least one of sequestration and storage and which can increase availability of renewable energy or non-fuel products such as fertilizers and construction materials; and one or more energy sources that supply process heat to the air extraction system to remove the carbon dioxide from the medium and which can regenerate it for continued use. The medium can be a porous solid comprising an amine.

[0004] WO 2010/107942 discloses a sorbent structure in structures and techniques to bind carbon dioxide in a carbon dioxide laden air stream, wherein process heat is used to separate carbon dioxide from the sorbent structure and the sorbent structure is regenerated. A preferred sorbent material used is an amine.

[0005] WO 2013/166432 describes a system and method of reducing the net carbon dioxide footprint of an industrial process that generates power from the combustion of hydrocarbon fuels in which ambient air is admixed with up to 50% by volume of an effluent gas from the power generator of the industrial process, in order to substantially increase the CO₂ concentration in the air prior to treatment. The treatment itself comprises adsorbing CO₂ from the admixed ambient air utilizing a cooled, porous substrate-supported amine adsorbent, wherein the porous substrate contacts the mixed ambient air containing condensed water in its pores. In addition, prior to regenerating the supported adsorbent, air pressure is substantially reduced in a sealed regeneration chamber and a low pressure chamber is placed in fluid connection with a higher pressure

regeneration chamber containing steam and carbon dioxide, to preheat the sorbent to be regenerated and to quickly cool the regenerated sorbent prior to use for further CO₂ adsorption.

[0006] These known systems and methods have the drawback of removing the adsorbed carbon dioxide from the sorbent (medium) comprising amine by exposing it to process heat (for example provided by steam) at a relatively high temperature, i.e. at a temperature of up to about 120°C.

[0007] Moreover, in order to regenerate the used sorbent after removal of the CO₂, it is needed to first reduce the sorbents' temperature again (through a separate cooling step) to a level enabling the efficient capturing of carbon dioxide from the air before actually re-using the sorbent.

[0008] A major drawback is thus that the known systems and methods in the art demand a relatively high energy consumption to release bonded CO₂ (and to further re-use the sorbent).

[0009] Aspects of the present invention envisage providing an improved system and related method for capturing carbon dioxide from ambient air, which overcome the disadvantages of prior art systems and methods.

[0010] More particularly, it is envisaged to provide a system and related method for capturing carbon dioxide from ambient air with a lower energy consumption compared to prior art systems and methods.

[0011] According to aspects of the invention, there is therefore provided a system for capturing carbon dioxide from ambient air, as set out in the appended claims.

[0012] According to other aspects of the invention, there is therefore provided a method for capturing carbon dioxide from ambient air, as set out in the appended claims.

[0013] According to other aspects of the invention, there is provided the use of the system of the invention, as set out in the appended claims.

[0014] Advantageous aspects of the present invention are set out in the dependent claims.

[0015] Aspects of the invention will be described in more detail with reference to the appended drawing, wherein same reference numerals illustrate same features and wherein:

[0016] **Figure 1** schematically represents an embodiment of a system (1) according to an aspect of the present invention, for capturing carbon dioxide from ambient air;

[0017] **Figure 2** schematically represents an alternative embodiment of a system (1) according to an aspect of the present invention, for capturing carbon dioxide from ambient air.

[0018] According to an aspect of the invention, there is provided a system for capturing carbon dioxide from (or present in, comprised in) ambient air.

[0019] As illustrated schematically in **figure 1**, a system (1) according to the present invention comprises (or consists of):

- a CO₂ trapping structure (4) for placement in ambient air (3), said ambient air (3) comprising carbon dioxide, said CO₂ trapping structure (4) comprising (or consisting of) a porous member having pores which are interconnected between opposite faces of the member; and
- an air conducting structure (2) comprising (or consisting of) a means for forcing the ambient air (3) through the CO₂ trapping structure (4), wherein the CO₂ trapping structure (4) is removably positioned with respect to the air conducting structure (2) such that the air passing through the air conducting structure (2) passes through the pores of the CO₂ trapping structure (4), said pores having walls comprising an amine which binds the carbon dioxide from the ambient air (3); and
- (the system (1) comprising) a means (5) for moving the CO₂ trapping structure (4) to an environment (6) being at a temperature comprised between (about) 60°C to (about) 100°C, preferably between (about) 65°C to (about) 95°C, more preferably between (about) 65°C to (about) 80°C, and (the environment (6)) being at a reduced pressure so as to release the (bonded) carbon dioxide from the CO₂ trapping structure (4).

[0020] A system (1) according to the present invention comprises the environment (6), the environment (6) being configured for receiving the CO₂ trapping structure (4).

[0021] In a system of the invention, the environment (6) is configured for being heated to a temperature comprised between (about) 60°C to (about) 100°C, preferably between (about) 65°C to (about) 95°C, more preferably between (about) 65°C to (about) 80°C and for being at a reduced pressure so as to release the (bonded) carbon dioxide from the CO₂ trapping structure (4).

[0022] In the context of the present invention, 'a CO₂ trapping structure' refers to a structure able to trap (or remove, capture, bind) CO₂ from ambient air.

[0023] In the context of the present invention, ambient air (3) refers to air comprising carbon dioxide (from the ambient, open air), said ambient air (3) being at ambient conditions of temperature and pressure.

[0024] Advantageously, the ambient air (3) passing (or flowing) through the CO₂ trapping structure (4) is at atmospheric pressure at a temperature comprised between (about) 0°C and (about) 60°C, advantageously between (about) 0°C and (about) 40°C.

[0025] Advantageously, said CO₂ trapping structure (4) comprises (or consists of) a porous member having pores which are interconnected between opposite faces of

the member.

[0026] More advantageously, said CO₂ trapping structure (4) consists of a porous member having pores which are interconnected between opposite faces of the member.

[0027] Advantageously, said air conducting structure (2) comprises (or consists of) a means for forcing the ambient air (3) through the CO₂ trapping structure (4).

[0028] Advantageously, said air conducting structure (2) comprises (or consists of) a natural draft (or draught) cooling tower, a fan assisted natural draft (or draught) cooling tower, or a ventilator (or fan).

[0029] More advantageously, said air conducting structure (2) comprises (or consists of) a ventilator (or a fan).

[0030] Advantageously, said means for forcing the ambient air (3) through the CO₂ trapping structure (4) comprises (or consists of) a ventilator (or a fan).

[0031] More advantageously, said means for forcing the ambient air (3) through the CO₂ trapping structure (4) consists of a ventilator (or a fan).

[0032] In the context of the present invention, 'the CO₂ trapping structure (4) being removable positioned with respect to the air conducting structure (2)' refers to the CO₂ trapping structure (4) being positioned (or arranged) with respect to the air conducting structure (2) and able to be subsequently removed from the air conducting structure (2).

[0033] Advantageously, said CO₂ trapping structure (4) is removable positioned (or removable arranged) with respect to the top of the air conducting structure (2).

[0034] Alternatively, in an embodiment as shown in figure 1, the CO₂ trapping structure (4) is removable attached to the air conducting structure (2) through (or via, using) a mechanical means, advantageously through a coupling (8).

[0035] More particularly, said CO₂ trapping structure (4) is removable attached (or removable placed) on top of the air conducting structure (2) (through a coupling (8)).

[0036] Alternatively, in another embodiment of the invention, the CO₂ trapping structure (4) is attached (or fixed) to the air conducting structure (2) through (or via, using) a mechanical means, advantageously through a coupling (8). In this alternative embodiment, the porous member comprised in said CO₂ trapping structure (4) is able to be subsequently moved from (or out of) the (fixed) air conducting structure (2) to (or into) the heated environment (6) through a suitable means for moving the porous member (for instance through (via) a rotation in the horizontal plane).

[0037] Alternatively, in yet another embodiment of the invention, said air conducting structure (2) is part of (is comprised in) a duct (10). Said duct (10) can be comprised in a cooling system. Said CO₂ trapping structure (4) can be removable arranged in, or advantageously removable positioned with respect to the top of, the duct

(10) such that the air passing through the duct (10) passes through the pores of the CO₂ trapping structure (4) (or porous member). **Figure 2** schematically illustrates such an alternative embodiment of a system (1) of the invention for capturing (removing) carbon dioxide from ambient air (3). The air conducting structure (2) and coupling (8) are not shown in figure 2.

[0038] More advantageously, in the system (1) of the present invention, said air conducting structure (2) is part of (is comprised in) a cooling system.

[0039] Even more advantageously, said air conducting structure (2) is a ventilator and is part of (is comprised in) a cooling system.

[0040] A suitable cooling system for use in the system (1) of the present invention will be apparent for those skilled in the art. For instance, the cooling system can be an evaporative condenser.

[0041] More advantageously, the cooling system is an evaporative condenser.

[0042] Gwk hermeticool cooling systems, provided by gwk Gesellschaft Wärme Kältetechnik mbH to produce cold water for production facilities, are exemplary cooling systems for use in the system (1) of the invention.

[0043] Advantageously, said air conducting structure (2), or said ventilator, is part of (is comprised in) a cooling system (or advantageously, an evaporative condenser) placed on top of a building or a production facility.

[0044] In the context of the present invention, a building refers to any type of building, for instance, a house, an apartment building (or apartment complex), an office building (or office block), an industrial building (such as a factory or a manufacturing plant) etc.

[0045] Advantageously, the CO₂ trapping structure (4) (or the porous member) is removable positioned with respect to the top of an air conducting structure (2), or ventilator, of an existing cooling system positioned on top of buildings or production facilities, such that the air passing through the air conducting structure (2), or ventilator, passes through the pores of the CO₂ trapping structure (4) (or porous member), said pores having walls comprising an amine which binds the carbon dioxide from the ambient air.

[0046] In a preferred embodiment of the invention, system (1) comprises (or consists of):

- a CO₂ trapping structure (4) for placement in ambient air (3), said ambient air (3) comprising carbon dioxide, said CO₂ trapping structure (4) consisting of a porous member having pores which are interconnected between opposite faces of the member; and
- an air conducting structure (2) consisting of a means for forcing the ambient air (3)

through the CO₂ trapping structure (4), preferably consisting of a ventilator, wherein the CO₂ trapping structure (4) is removable positioned with respect to the top of the air conducting structure (2) such that the air passing through the air conducting structure (2) passes through the pores of the CO₂ trapping structure (4), said pores having walls comprising an amine which binds the carbon dioxide from the ambient air (3); and

- (the system (1) comprising) a means (5) for moving the porous member to an environment (6) being at (or being heated to) a temperature comprised between (about) 60°C to (about) 100°C, preferably between (about) 65°C to (about) 95°C, more preferably between (about) 65°C to (about) 80°C, and being at a reduced pressure so as to release the (bonded) carbon dioxide from the porous member.

[0047] Using the system (1) of the present invention, CO₂ can be captured directly, and practically anywhere, from the open air.

[0048] The porous member has pores having walls comprising an amine. Amines are well known in the art to be able to capture CO₂.

[0049] Advantageously, the porous member is a three-dimensional structure having a high contact surface.

[0050] Advantageously, the porous member is a monolithic or honeycomb structure; a foam; or woven or non-woven plastic or cellulosic fibers.

[0051] Advantageously, the porous member is a monolithic or honeycomb structure made of ceramic, metal, or plastic; a polyurethane foam, a polypropylene foam, a polyester foam, a metal foam, or a ceramic foam; or woven or non-woven plastic or cellulosic fibers, wherein the support is alumina, silica, silica-alumina, titania, zirconia, carbon, zeolite, metal-organic framework (MOF), or combinations thereof.

[0052] More advantageously, the porous member is a monolithic or a honeycomb structure.

[0053] Even more advantageously, the porous member is a honeycomb structure.

[0054] Substrates produced by Corning, such as Celcor® substrates, are exemplary porous members for use in the system (1) of the invention.

[0055] Using the system (1) of the invention, (influent) ambient air (3) passing through the air conducting structure (2) and through the pores of the CO₂ trapping structure (4) (or porous member), comes into contact with the amines comprised in the walls of the pores of the CO₂ trapping structure (4) (or porous member), and the carbon dioxide from the ambient air (3) is bonded onto the amine functional groups comprised in the CO₂ trapping structure (4) (or porous member). After having passed through the air conducting structure (2) and through the pores of the CO₂ trapping structure (4) (or porous member), (effluent) ambient air (3') (released from CO₂) flows back to nature.

[0056] The CO₂ trapping structure (4) (or porous member) comprising the CO₂ attached to the amine functional groups is then moved to (or into) a heated environment (6) being at (or heated to) a temperature higher than the temperature of the (influent) ambient air (3) and being at a reduced pressure so as to release the carbon dioxide from the CO₂ trapping structure (4) (or porous member).

[0057] A suitable means (5) for moving the CO₂ trapping structure (4) (or porous member) to the environment (6) in the system (1) of the invention will be apparent for those skilled in the art.

[0058] For instance, such a means (5) can be a mechanical system for moving the CO₂ trapping structure (4) (or porous member) to the environment (6) through (via) a rotation in the horizontal plane.

[0059] The temperature of the (heated) environment (6) is comprised between (about) 60°C to (about) 100°C, advantageously between (about) 65°C to (about) 95°C, advantageously between (about) 65°C to (about) 80°C.

[0060] The present invention provides a system (1) for capturing carbon dioxide from ambient air (3) which consumes less energy to release the bonded CO₂ (i.e. bonded onto the amine functional groups comprised in the CO₂ trapping structure (4) or porous member), compared with systems available in the art operating at higher temperatures.

[0061] Advantageously, the environment (6) comprises an exhaust pump for reducing the atmospheric pressure.

[0062] Advantageously, the environment (6) is at a reduced pressure of (about) the vapor pressure of CO₂ at the given temperature of the environment (6) so as to release the carbon dioxide from the CO₂ trapping structure (4) or porous member.

[0063] Advantageously, the interior of the environment (6) comprises air.

[0064] Advantageously, the environment (6) is a heated environment (6).

[0065] Advantageously, the environment (6) is a vessel (or container). More advantageously, the environment (6) is a resealable vessel.

[0066] Advantageously, in a system of the invention, the temperature of the CO₂ trapping structure (4) (or porous member) moved to (or into) the environment (6), or placed in the environment (6), is controlled by the temperature of the environment (6).

[0067] Advantageously, the environment (6) is a vessel (or container) from which the sidewall is heated up.

[0068] More advantageously, the environment (6) is a resealable vessel from which the sidewall is heated up.

[0069] More particularly, the temperature of the CO₂ trapping structure (4) (or porous member) moved to (or into) the environment (6), or placed in the environment (6), is controlled by the temperature of the sidewall of the environment (6) through

thermal conductivity.

[0070] Advantageously, in a system of the invention, a means for heating the (sidewall of the) environment (6) is provided.

[0071] Advantageously, the (sidewall of the) environment (6) is heated by heat obtained from a renewable energy source, or by energy obtained from stored (excess) energy.

[0072] More advantageously, the (sidewall of the) environment (6) is heated by heat obtained from a renewable energy source, advantageously by solar energy.

[0073] Alternatively, the (sidewall of the) environment (6) can be heated by waste heat from industrial plants.

[0074] Advantageously, in a system of the invention, a means for filling the sidewall of the environment (6) with water is provided. Said means is coupled to the sidewall of the environment (6).

[0075] More advantageously, a water tank for filling the sidewall of the environment (6) with water is coupled to the sidewall of the environment (6).

[0076] More advantageously, the sidewall of the environment (6) is filled with water and heated up.

[0077] More advantageously, the temperature of (or inside) the environment (6) is controlled by the temperature of the water present in the sidewall of the environment (6) through thermal conductivity.

[0078] Advantageously, the sidewall of the environment (6) is filled with water and is heated up by heat obtained from a renewable energy source.

[0079] More advantageously, the sidewall of the environment (6) is filled with water and is heated up by (heat obtained from) solar energy.

[0080] More advantageously, the sidewall of the environment (6) is filled with water and is heated up by energy obtained from stored (excess) energy.

[0081] Alternatively, the sidewall of the environment (6) is filled with water and is heated up by waste heat from industrial plants.

[0082] Advantageously, in the present invention, the sidewall of the environment (6) is dark-coloured or black, so as to promote the heating up.

[0083] Glycol can be added to the water in the sidewall of environment (6) so as to avoid freezing of the water at low temperature (i.e. at a temperature lower than (about) 0°C).

[0084] Advantageously, a water tank is coupled to the sidewall of the environment (6) so as to add (heated or cooled) water to the sidewall to control the temperature of the sidewall. In turn, the temperature of the sidewall of the environment (6) controls the temperature of (or inside) the environment (6), or the temperature of the

CO₂ trapping structure (4) moved to (or into) the environment (6), through thermal conductivity.

[0085] More advantageously, a separate water tank comprising a dark-coloured or black outer surface is coupled to the sidewall of the environment (6) so as to add (heated or cooled) water to the sidewall to control its temperature to be comprised between (about) 60°C to (about) 100°C, advantageously between (about) 65°C to (about) 95°C, advantageously between (about) 65°C to (about) 80°C. The temperature of the sidewall can thus be controlled by circulating (heated or cooled) water in the sidewall.

[0086] The separate water tank can comprise water heated up by solar energy, or by energy obtained from stored (excess) energy.

[0087] Alternatively, the separate water tank can comprise water heated up by waste heat from industrial plants.

[0088] In the context of the present invention, 'being coupled to' refers to 'being in communication with', 'being connected to', 'being in fluid communication', or, 'being in fluid connection', so as to allow a fluid (e.g. water or CO₂) to pass through.

[0089] Advantageously, the system (1) comprises a means for collecting the released carbon dioxide.

[0090] More advantageously, a collection vessel (7) is connected to environment (6). More particularly, the collection vessel (7) is in fluid communication with environment (6). The released CO₂ is collected in said collection vessel (7).

[0091] Advantageously, system (1) comprises a means (not shown in figure 1) for liquefying (at elevated pressure) the released carbon dioxide (collected in collection vessel (7)), thereby obtaining highly purified, liquid carbon dioxide.

[0092] Advantageously, vessel (9) is connected to collection vessel (7). More particularly, vessel (9) is in fluid communication with vessel (7). The liquefied CO₂ is collected (under pressure) in vessel (9).

[0093] Advantageously, the (liquefied) CO₂ captured (removed) from ambient air is stored, or (further) used in industrial processes.

[0094] More advantageously, the (liquefied) CO₂ captured (removed) from ambient air is (further) used in industrial processes.

[0095] Advantageously, system (1) comprises a means (not shown in figure 1) for moving the CO₂ trapping structure (4) (or porous member) back again, once released from the carbon dioxide, (out of, or from, the environment (6)) to the air conducting structure (2) to recycle (re-use) said CO₂ trapping structure (4) (or porous member) (for passing influent ambient air through and) for binding carbon dioxide from (influent) ambient air (3).

[0096] A suitable means for moving the CO₂ trapping structure (4) (or porous member) back to the air conducting structure (2) will be apparent for those skilled in the art.

[0097] For instance, such a means can be a mechanical system for moving the CO₂ trapping structure (4) (or porous member) back to the air conducting structure (2) through (via) a rotation in the horizontal plane.

[0098] Advantageously, the CO₂ trapping structure (4) (or porous member) is cooled down to ambient temperature by the (influent) ambient air (3) passing through the CO₂ trapping structure (4) (or porous member) again when positioned back again with respect to (the top of) the air conducting structure (2). No extra cooling step is to be included.

[0099] The present invention provides a system (1) for capturing carbon dioxide from ambient air (3) which consumes less energy to release the bonded CO₂ and to further re-use the CO₂ trapping structure (4) (or porous member), compared with systems available in the art operating at higher temperatures and requiring an extra cooling step before re-use of their sorbent material.

[00100] The present invention thus provides a more efficient, cost-effective system for capturing carbon dioxide from ambient air, compared with systems available in the art.

[00101] A system (1) according to an aspect of the present invention, schematically illustrated in **figure 1**, can be used for capturing (removing) carbon dioxide from ambient air (3). As such, CO₂ can be captured directly, and practically anywhere, from the open air.

[00102] Using the system (1) of the invention can reduce the existing CO₂ levels in the atmosphere.

[00103] The system (1) can be used (or integrated) in, or on top of, existing cooling systems already positioned on top of buildings or production facilities.

[00104] The (liquefied) CO₂ captured (removed) from ambient air by using system (1) is stored, or (further) used in industrial processes. Suitable industrial processes will be apparent for those skilled in the art.

[00105] For instance, the captured carbon dioxide can be used back into liquid hydrocarbon fuels that power today's engines (of, e.g., trucks, planes, or even cars), or can be fed to algae, which absorb the gas to produce biofuel and biochar.

[00106] Advantageously, a system (1) of the present invention can be used for capturing carbon dioxide from ambient air (3), with (very) low energy consumption compared to prior art systems.

[00107] According to another aspect of the invention, there is provided a method

for capturing carbon dioxide from (or present in, comprised in) ambient air.

[00108] A method of the invention comprises:

- passing ambient air (3) (at ambient temperature and pressure) through a CO₂ trapping structure (4) comprising (or consisting of) a porous member having pores which are interconnected between opposite faces of the member, the pores having walls comprising an amine which binds carbon dioxide comprised in the ambient air (3);
- moving the CO₂ trapping structure (4) onto which carbon dioxide is bonded to an environment (6) at a temperature comprised between (about) 60°C to (about) 100°C, preferably between (about) 65°C to (about) 95°C, more preferably between (about) 65°C to (about) 80°C, and reducing the pressure in said environment (6) for releasing the carbon dioxide from the CO₂ trapping structure (4).

[00109] According to a method of the invention and referring to **figure 1**, ambient air (3) is passing through a CO₂ trapping structure (4) comprising (or consisting of) a porous member having pores which are interconnected between opposite faces of the member, the pores having walls comprising an amine which is binding carbon dioxide comprised in the ambient air (3) passing through the CO₂ trapping structure (4).

[00110] Advantageously, the CO₂ trapping structure (4) consists of said porous member.

[00111] Advantageously, the ambient air (3) is forced through the CO₂ trapping structure (4) (or porous member) by a suitable means.

[00112] Advantageously, the CO₂ trapping structure (4) (or porous member) is removable positioned (or removable arranged) with respect to an air conducting structure (2), said air conducting structure (2) comprising (or consisting of) the means for forcing the ambient air (3) through the CO₂ trapping structure (4) such that the air passing through the air conducting structure (2) passes through the pores of the CO₂ trapping structure (4) (or porous member).

[00113] More advantageously, said CO₂ trapping structure (4) is removable positioned (or removable arranged) with respect to the top of the air conducting structure (2).

[00114] Alternatively, in an embodiment as shown in figure 1, the CO₂ trapping structure (4) is removable attached to the air conducting structure (2) through (or via, using) a mechanical means, advantageously through a coupling (8).

[00115] More particularly, said CO₂ trapping structure (4) is removable attached (or removable placed) on top of the air conducting structure (2) (through a coupling (8)).

[00116] Alternatively, in another embodiment of the invention, the CO₂ trapping structure (4) is attached (or fixed) to the air conducting structure (2) through (or via, using) a mechanical means, advantageously through a coupling (8). The porous member

comprised in said CO₂ trapping structure (4) is then subsequently moved from (or out of) the (fixed) air conducting structure (2) to (or into) the environment (6) through a suitable means for moving the porous member (for instance through (via) a rotation in the horizontal plane).

[00117] Advantageously, in the present invention, said air conducting structure (2) comprises (or consists of) a natural draft (or draught) cooling tower, a fan assisted natural draft (or draught) cooling tower, or a ventilator.

[00118] More advantageously, said air conducting structure (2) comprises (or consists of) a ventilator.

[00119] Advantageously, the air conducting structure (2) is part of (is comprised in) a cooling system.

[00120] More advantageously, said air conducting structure (2) is a ventilator and is part of (is comprised in) a cooling system

[00121] More advantageously, the cooling system is an evaporative condenser.

[00122] More advantageously, said air conducting structure (2), or ventilator, is part of (is comprised in) a cooling system placed on top of a building or a production facility through which ambient air (3) is passing through in the method of the present invention.

[00123] Advantageously, the CO₂ trapping structure (4) (or the porous member) is removable positioned with respect to the top of an air conducting structure (2), or ventilator, of an existing cooling system positioned on top of buildings or production facilities, such that the air passing through the air conducting structure (2), or ventilator, passes through the pores of the CO₂ trapping structure (4) (or porous member), said pores having walls comprising an amine which binds the carbon dioxide from the ambient air.

[00124] Gwk hermeticool cooling systems, provided by gwk Gesellschaft Wärme Kältetechnik mbH to produce cold water for production facilities, are exemplary cooling systems for use in the method of the invention for passing ambient air (3) through.

[00125] Alternatively, in the method of the invention, said air conducting structure (2) is part of (is comprised in) a duct (10), schematically illustrated in **figure 2** (the air conducting structure (2) and coupling (8) not shown therein). Said duct (10) can be comprised in a cooling system. Said CO₂ trapping structure (4) can be removable arranged in, or removable positioned with respect to the top of, the duct (10) such that the air passing through the duct (10) passes through the pores of the CO₂ trapping structure (4) (or porous member).

[00126] Advantageously, the ambient air (3) is at atmospheric pressure at a temperature comprised between (about) 0°C and (about) 60°C, advantageously between

(about) 0°C and (about) 40°C.

[00127] By performing the method of the present invention, CO₂ can be captured directly, and practically anywhere, from the open air.

[00128] Performing the method of the invention can reduce the existing CO₂ levels in the atmosphere.

[00129] Advantageously, the porous member is a three-dimensional structure having a high contact surface, as described above.

[00130] Advantageously, the porous member is a monolithic or honeycomb structure; a foam; or woven or non-woven plastic or cellulosic fibers, as described above.

[00131] More advantageously, the porous member is a monolithic or honeycomb structure.

[00132] Even more advantageously, the porous member is a honeycomb structure.

[00133] Substrates produced by Corning, such as Celcor® substrates, are exemplary porous members for use in the method of the invention.

[00134] Advantageously, the porous member is prepared by (co-)extruding, molding, or 3D printing.

[00135] More advantageously, the porous member can be produced by three-dimensional (3D) fiber deposition. Three-dimensional fiber deposition refers to a 3D-printing technique, also referred to as robocasting technique. Robocasting technique is an extrusion-based robotic deposition known in the art, as for instance disclosed in US Patent No. 6,401,795, said technique incorporated herein by reference.

[00136] Advantageously, the porous member is loaded (into the pores of the porous member), (wash)coated, impregnated, or covalently bonded with amines.

[00137] More advantageously, the porous member is coated by amines using wash-coating.

[00138] Alternatively, amines are loaded in liquid form onto a structured support made from, for example, glass fibers.

[00139] Alternatively, amines can first be impregnated in, or covalently bonded to, materials such as zeolites, activated carbon, mesoporous silica or alumina, polymers, etc., after which these materials are loaded onto a structured support.

[00140] Advantageously, the three-dimensional porous member is formed from any suitable porous material including, for example, glass, ceramics, non oxide ceramics (e.g., carbides, nitrides), carbon, alloys, metals, polymers, composites, and mixtures thereof, onto which amines are subsequently loaded (into the pores of the porous member), (wash)coated, impregnated, or covalently bonded.

[00141] More advantageously, the three-dimensional porous member is formed

from a ceramic support material having an amine embedded (or loaded) therein.

[00142] Alternatively, the ceramic support material can be molded or co-extruded together with the amine to form a honeycomb substrate, for example.

[00143] Alternatively, the three-dimensional porous member is formed from zeolites, MOFs (Metallic Organic frameworks), clays, layered double hydroxides, and alkaline/alkaline earth oxides or composites containing zeolites, MOFs (Metallic Organic frameworks) or cordierite, SiC, mullite, alumina, and aluminum titanate, and carbon, onto which amines are subsequently loaded (into the pores of the porous member), (wash)coated, impregnated, or covalently bonded.

[00144] In the method of the invention, (influent) ambient air (3) is thus, advantageously forced by an air conducting structure (2), passing through the pores of the CO₂ trapping structure (4) (or porous member), coming into contact with the amines comprised in the walls of the pores of the CO₂ trapping structure (4) (or porous member), and the carbon dioxide from the ambient air (3) is bonded onto the amine functional groups comprised in the CO₂ trapping structure (4) (or porous member). After having passed through the pores of the CO₂ trapping structure (4) (or porous member), (effluent) ambient air (3') (released from CO₂) flows back to nature.

[00145] The CO₂ trapping structure (4) (or porous member) onto which carbon dioxide is bonded is then moved to an environment (6).

[00146] More particularly, the CO₂ trapping structure (4) (or porous member) onto which carbon dioxide is bonded, is moved into or placed inside an environment (6).

[00147] The environment (6) is at (or heated to) a temperature higher than the temperature of the (influent) ambient air (3) and the pressure in said environment (6) is reduced for releasing the carbon dioxide from the CO₂ trapping structure (4) (or porous member).

[00148] A suitable means (5) for moving the CO₂ trapping structure (4) (or porous member) to the environment (6) in the method of the invention will be apparent for those skilled in the art.

[00149] For instance, such a means (5) can be a mechanical system for moving the CO₂ trapping structure (4) (or porous member) to the environment (6) through (via) a rotation in the horizontal plane. In other words, the CO₂ trapping structure (4) (or porous member) can be moved to the environment (6) through (via) a rotation in the horizontal plane.

[00150] The environment (6) is (at a temperature or) heated to a temperature comprised between (about) 60°C to (about) 100°C, advantageously between (about) 65°C to (about) 95°C, advantageously between (about) 65°C to (about) 80°C.

[00151] The present invention provides a method for capturing carbon dioxide

from ambient air (3) which consumes less energy to release the bonded CO₂ (i.e. CO₂ bonded onto the amine functional groups comprised in the CO₂ trapping structure (4) or porous member), compared with methods available in the art performed at higher temperatures.

[00152] Advantageously, the pressure in said environment (6) is reduced using an exhaust pump.

[00153] Advantageously, pressure in the environment (6) is reduced to (about) the vapor pressure of CO₂ at the given temperature of the environment (6) so as to release the carbon dioxide from the CO₂ trapping structure (4) or porous member.

[00154] In a method of the invention, no steam is passed through the environment (6) nor through the CO₂ trapping structure (4) (the CO₂ trapping structure (4) being moved into or placed inside the environment (6)).

[00155] Advantageously, the interior of the environment (6) comprises air.

[00156] More particularly, in a method of the invention, the interior of the environment (6) does not comprise steam. In other words, no steam is present inside (nor passed through) the environment (6).

[00157] Advantageously, the environment (6) is a vessel (or container). More advantageously, the environment (6) is a resealable vessel.

[00158] Advantageously, the environment (6) is heated up.

[00159] Advantageously, the environment (6) is a vessel (or container) from which the sidewall is heated up.

[00160] More particularly, the CO₂ trapping structure (4) (or porous member) comprising the CO₂ attached to the amine functional groups comprised in the CO₂ trapping structure (4) (or porous member) is moved into the environment (6).

[00161] More advantageously, the environment (6) is a resealable vessel from which the sidewall is heated up.

[00162] More particularly, the CO₂ trapping structure (4) (or porous member) comprising the CO₂ attached to the amine functional groups comprised in the CO₂ trapping structure (4) (or porous member) is moved into an open vessel after which the vessel is closed.

[00163] Advantageously, the (sidewall of the) environment (6) is heated by heat obtained from a renewable energy source, or by energy obtained from stored (excess) energy.

[00164] More advantageously, the (sidewall of the) environment (6) is heated by heat obtained from a renewable energy source, even more advantageously by solar energy.

[00165] Alternatively, the (sidewall of the) environment (6) can be heated by waste

heat from industrial plants.

[00166] Advantageously, in a method of the invention, the sidewall of the environment (6) is filled with water and heated up.

[00167] Advantageously, the sidewall of the environment (6) is filled with water and is heated up by heat obtained from a renewable energy source.

[00168] More advantageously, the sidewall of the environment (6) is filled with water and is heated up by (heat obtained from) solar energy.

[00169] More advantageously, the sidewall of the environment (6) is filled with water and is heated up by energy obtained from stored (excess) energy.

[00170] Alternatively, the sidewall of the environment (6) is filled with water and is heated up by waste heat from industrial plants.

[00171] Advantageously, in the present invention, the sidewall of the environment (6) is dark-coloured or black, so as to promote the heating up.

[00172] Glycol can be added to the water in the sidewall of environment (6) so as to avoid freezing of the water at low temperature (i.e. at a temperature lower than 0°C).

[00173] Advantageously, the sidewall of the environment (6) is filled with water through (or using) a water tank (coupled to the sidewall of the environment (6)). The temperature of the water in the sidewall controls the temperature of the sidewall. In turn, the temperature of the sidewall of the environment (6) controls the temperature of (or inside) the environment (6), or the temperature of the CO₂ trapping structure (4) moved to (or into) the environment (6), through thermal conductivity.

[00174] More advantageously, a separate water tank comprising a dark-coloured or black outer surface is coupled to the sidewall of the environment (6) so as to add (heated or cooled) water to the sidewall to control its temperature so as to be comprised between (about) 60°C to (about) 100°C, advantageously between (about) 65°C to (about) 95°C, advantageously between (about) 65°C to (about) 80°C. The temperature of the sidewall can thus be controlled by circulating (heated or cooled) water in the sidewall.

[00175] The separate water tank can comprise water heated up by solar energy, or by energy obtained from stored (excess) energy.

[00176] Alternatively, the separate water tank can comprise water heated up by waste heat from industrial plants.

[00177] By moving (placing) the CO₂ trapping structure (4) (or porous member) in the environment (6) and by reducing the pressure in the environment (6) to (about) the vapor pressure of CO₂ at a temperature of the environment (6) comprised between (about) 60°C to (about) 100°C, advantageously between (about) 65°C to (about) 95°C, advantageously between (about) 65°C to (about) 80°C, the carbon dioxide bonded to the

amine functional groups of the CO₂ trapping structure (4) (or porous member) is released from the CO₂ trapping structure (4) (or porous member).

[00178] Advantageously, collection vessel (7) is provided, in (fluid) connection with environment (6).

[00179] In the method of the invention, the released CO₂ is collected in said collection vessel (7).

[00180] The method can further comprise a step of liquefying (at elevated pressure) the released carbon dioxide, thereby obtaining highly purified, liquid carbon dioxide.

[00181] Advantageously, vessel (9) is provided and connected to collection vessel (7). More particularly, vessel (9) is in fluid communication with vessel (7). The liquefied CO₂ is collected (under pressure) in vessel (9).

[00182] Advantageously, the (liquefied) CO₂ captured (removed) from ambient air is stored, or further used in industrial processes.

[00183] More advantageously, the (liquefied) CO₂ captured (removed) from ambient air is (further) used in industrial processes.

[00184] The method can further comprise a step of moving back the CO₂ trapping structure (4) (or porous member), being released from carbon dioxide, (out of, or from, the environment (6)) to be recycled for passing (influent) ambient air (3) through again and binding carbon dioxide from the ambient air (3) (at ambient temperature and pressure).

[00185] A suitable means for moving the CO₂ trapping structure (4) (or porous member) back will be apparent for those skilled in the art.

[00186] For instance, such a means can be a mechanical system for moving the CO₂ trapping structure (4) (or porous member) back via a rotation in the horizontal plane.

[00187] More particularly, after (the step of) releasing the carbon dioxide from the CO₂ trapping structure (4) (or porous member), (the vessel of) environment (6) is re-opened and the CO₂ trapping structure (4) (or porous member) is moved back out of, or from, (the vessel of) environment (6) to be recycled for passing (influent) ambient air (3) through again and binding carbon dioxide from the ambient air (3) (at ambient temperature and pressure).

[00188] Advantageously, the CO₂ trapping structure (4) (or porous member) is cooled down to ambient temperature by the (influent) ambient air (3) passing through the CO₂ trapping structure (4) (or porous member) again once it is placed back (to its initial position). As such, no extra cooling step is to be included in the method of the invention.

[00189] The present invention thus provides a method for capturing carbon dioxide from ambient air (3) which consumes less energy to release the bonded CO₂

(bonded to the amine functional groups of the CO₂ trapping structure (4) or porous member) and to further re-use the CO₂ trapping structure (4) or porous member, compared with methods available in the art performed at higher temperatures and requiring an extra cooling step before re-use of their used sorbent material.

[00190] The present invention thus provides a more efficient, cost-effective method for capturing carbon dioxide from ambient air, compared with methods available in the art.

[00191] From the description above, it follows that the present invention thus provides an improved system and method for capturing carbon dioxide from ambient air, which overcomes the disadvantages of prior art methods and systems.

CLAIMS

1. A system (1) for capturing carbon dioxide from ambient air (3), the system comprising:
 - a CO₂ trapping structure (4) for placement in ambient air (3), said ambient air (3) comprising carbon dioxide, said CO₂ trapping structure (4) comprising a porous member having pores which are interconnected between opposite faces of the member; and
 - an air conducting structure (2) comprising a means for forcing the ambient air (3) through the CO₂ trapping structure (4), wherein the CO₂ trapping structure (4) is removable positioned with respect to the air conducting structure (2) such that the air passing through the air conducting structure (2) passes through the pores of the CO₂ trapping structure (4), said pores having walls comprising an amine which binds the carbon dioxide from the ambient air (3);
 - an environment (6) being configured for receiving the CO₂ trapping structure (4); and
 - a means (5) for moving the CO₂ trapping structure (4) to the environment (6), wherein the environment (6) is configured for being heated to a temperature comprised between 60°C to 80°C and for being at a reduced pressure so as to release the carbon dioxide from the CO₂ trapping structure (4).
2. The system according to claim 1, wherein said CO₂ trapping structure (4) consists of said porous member.
3. The system according to claims 1 or 2, wherein said air conducting structure (2) comprises a natural draft cooling tower, a fan assisted natural draft cooling tower, or a ventilator, preferably said air conducting structure (2) consists of a ventilator.
4. The system according to any of the claims 1 to 3, wherein the CO₂ trapping structure (4) is removable positioned with respect to the top of the air conducting structure (2).
5. The system according to any of the claims 1 to 4, wherein the air conducting structure (2) is part of a cooling system.
6. The system according to claim 5, wherein said cooling system is placed on top of a building or a production facility.
7. The system according to any of claims 1 to 6, wherein the porous member is a monolithic or honeycomb structure.
8. The system according to any of claims 1 to 7, comprising a means for liquefying the released carbon dioxide.
9. The system according to any of claims 1 to 8, comprising a means for moving back the CO₂ trapping structure (4) to the air conducting structure (2) to recycle said CO₂ trapping structure (4) for binding carbon dioxide from ambient air (3).

- 10.** A method for capturing carbon dioxide from ambient air, the method comprising:
- passing ambient air (3) through a CO₂ trapping structure (4) comprising a porous member having pores which are interconnected between opposite faces of the member, the pores having walls comprising an amine which binds carbon dioxide comprised in the ambient air (3);
 - moving the CO₂ trapping structure (4) onto which carbon dioxide is bonded to an environment (6) at a temperature comprised between 60°C to 80°C and reducing the pressure in said environment (6) for releasing the carbon dioxide from the CO₂ trapping structure (4).
- 11.** The method according to claim 10, wherein said environment (6) is heated to said temperature by heat obtained from renewable energy sources, preferably by solar energy.
- 12.** The method according to any of claims 10 to 11, wherein the pressure in said environment (6) is reduced to the vapor pressure of carbon dioxide at the given temperature.
- 13.** The method according to any of claims 10 to 12, comprising a step of liquefying the released carbon dioxide.
- 14.** The method according to any of claims 10 to 13, comprising a step of moving back the CO₂ trapping structure (4), being released from carbon dioxide, to be recycled for passing ambient air (3) through and binding carbon dioxide from the ambient air (3).
- 15.** Use of the system of any of claim 1 to 9, wherein the captured carbon dioxide is stored, or used in industrial processes.

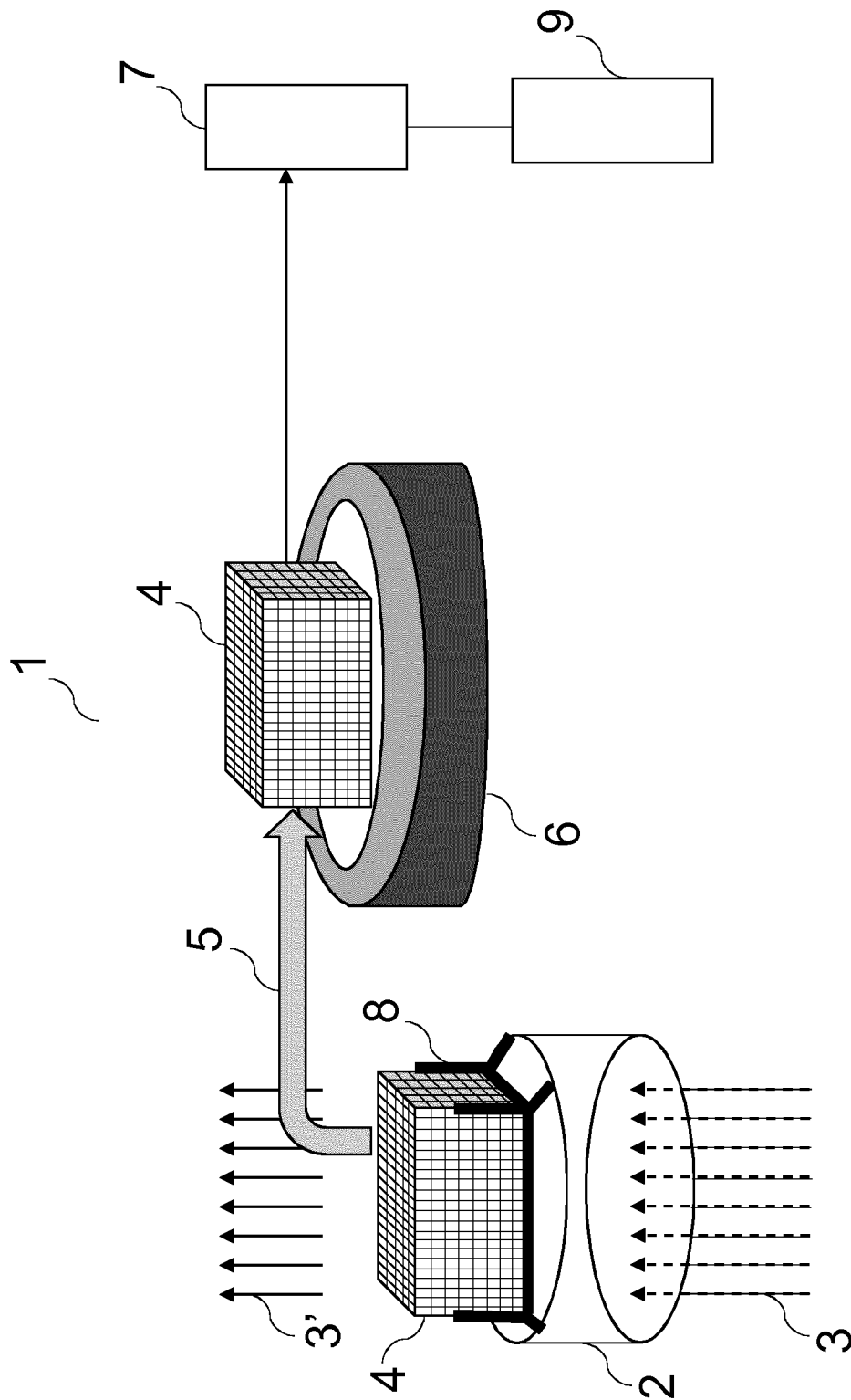


Fig. 1

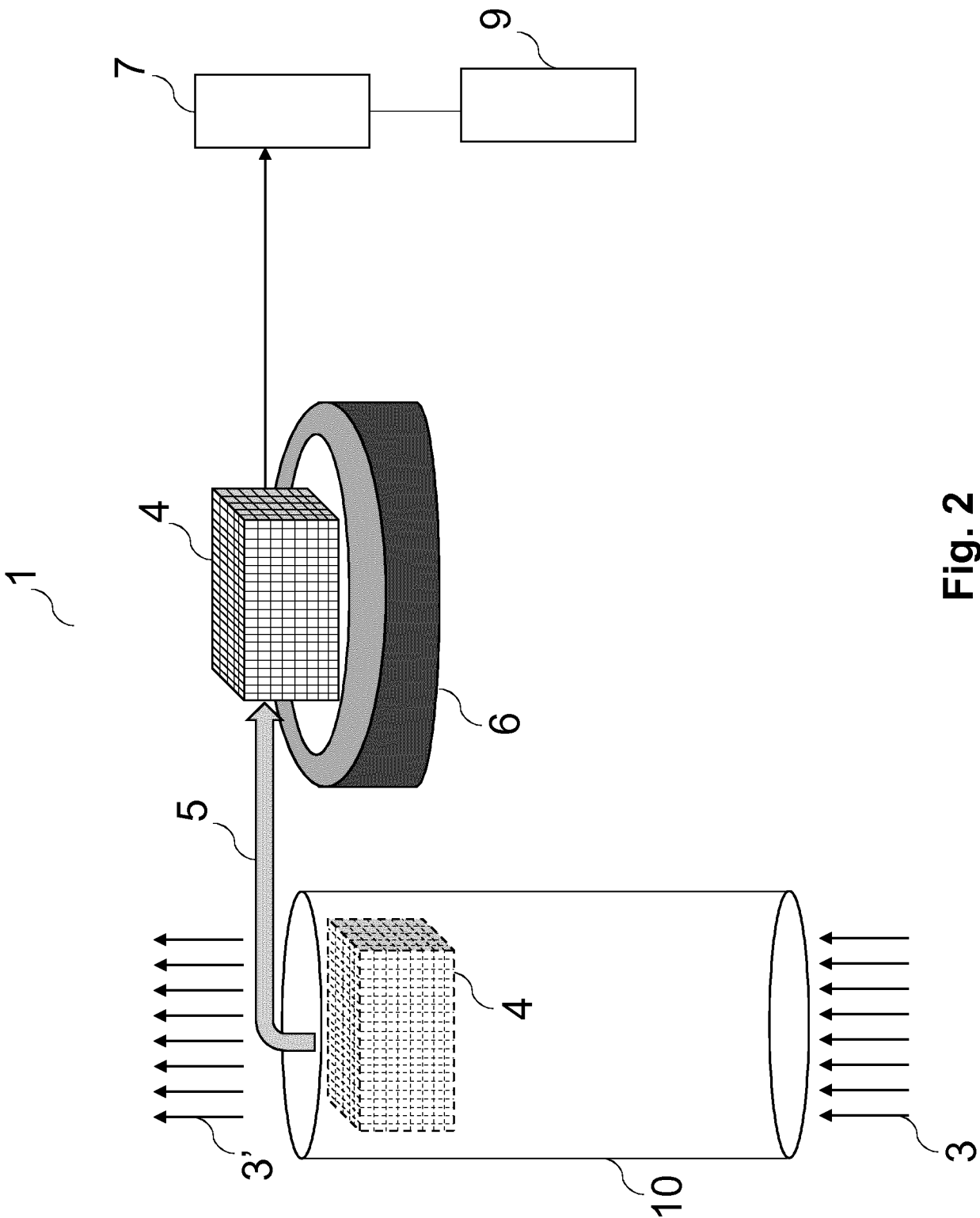


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/067801

A. CLASSIFICATION OF SUBJECT MATTER
 INV. B01D53/06
 ADD.

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)
 B01D

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/103401 A1 (EISENBERGER PETER AND CHICHILNISKY GRACIELA JOINTLY [US]) 9 July 2015 (2015-07-09) paragraphs [0001], [0032], [0033], [0034], [0035], [0042], [0043], [0052], [0064], [0065], [0068], [0084]; figures -----	1-9, 11-15
X	US 2012/174779 A1 (EISENBERGER PETER [US]) 12 July 2012 (2012-07-12) paragraphs [0001], [0038], [0039], [0050], [0051], [0060] - [0063], [0067], [0073]; figures -----	1-15
A	WO 2013/075981 A2 (CLIMEWORKS AG [CH]) 30 May 2013 (2013-05-30) the whole document -----	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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

22 September 2016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/067801

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