

AIR PURIFYING DEVICE, ARRANGEMENT AND METHOD FOR SEPARATING MATERIALS FROM A GAS FLOW

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FIELD

[0001] The present invention relates to an air purifying device.

[0002] Further, the present invention relates to an arrangement comprising an air purifying device and a flow channel.

[0003] Additionally, the present invention relates to a method for separating
10 materials from a gas flow.

BACKGROUND

[0004] Different devices and methods for separating materials from a gas flow are known, for example, document WO 2018/090990 A1 discloses an electric field device.
15 The electrostatic precipitator comprises a hollow dust collecting pole. The dust collecting pole is grounded and typically in the form of at least one cylindrical body. The device may comprise a plurality of cylindrical bodies forming an array. The device further comprises at least one corona rod fixed on a bracket, connected to a power source and being arranged within the at least one cylindrical body. The at least one corona rod is arranged on a central
20 axis of the at least one cylindrical body. The bracket may be on both sides of the at least one cylindrical body or on one side. The bracket may be a conductive metal bracket, a metal-plated plastic bracket or a non-conductive bracket.

[0005] Documents CN 105698293 A and CN 106861340 A both describe an air purifying device. The devices are directed to reducing ozone generation. The devices each
25 comprise a metal plate with openings. Thin, tapered needles are arranged in the center of the tunnel plane of the metal plate.

[0006] In view of the foregoing, it would be beneficial to provide an electrostatic precipitator or air purifying device.

SUMMARY OF THE INVENTION

[0007] The invention is defined by the features of the independent claims. Some specific embodiments are defined in the dependent claims.

[0008] According to an aspect of the present invention, there is provided an air purifying device. The device comprises a grounded honeycomb structure having a plurality of hexagonal openings, wherein the honeycomb structure is supported by a frame, a plurality of ionization needles or ionization elements arranged downstream of the honeycomb structure, wherein at least some of the needles or ionization elements are coaxially aligned with a respective center axis of an opening of the honeycomb structure, and a plurality of collector plates arranged downstream of the plurality of ionization needles, and wherein the device is configured to generate ionization corona discharge by positive ionization voltage led to the needles.

[0009] Various embodiments of the first aspect may comprise at least one feature from the following bulleted list:

- the device is configured such that corona discharge spreads from tips of the needles to the honeycomb structure
- the needles are attached to PCB rails
- the needles are partially over-molded by plastic structures
- the PCB rails are embedded in plastic structures
- each plastic structure is in the form of an aerodynamic profile
- a cross-section of each plastic structure is in the form of a NACA profile
- the material of the needles is wolfram, graphite, graphene, a noble metallic material or an inert material
- the needles are made of a material that is able to withstand a continuous corona generated oxidation and reduction of material
- the device is configured to be inserted into a flow channel
- the device is an electrostatic precipitator
- tips of the needles are arranged 5 mm to 25 mm downstream of the honeycomb structure, for example spaced apart 10 mm to 15 mm from the honeycomb structure

- each of the needles is coaxially aligned with a respective center axis of an opening of the honeycomb structure
- the device comprises a DC power source
- the device does not comprise any additional filter or filter system

5 **[0010]** According to a second aspect of the present invention, there is provided an arrangement comprising an air purifier in accordance with any one of claims 1 – 17 and a flow channel.

[0011] According to a third aspect of the present invention, there is provided a method for separating materials from an air flow, the method comprising providing a
 10 grounded honeycomb structure in a flow channel, wherein the honeycomb structure is supported by a frame, providing a plurality of ionization needles arranged downstream of the honeycomb structure, wherein at least some of the needles are coaxially aligned with a respective center axis of an opening of the honeycomb structure, generating ionization corona discharge by positive ionization voltage led to the needles arranged downstream of
 15 the honeycomb structure, and collecting the materials by collector plates comprising collection surfaces arranged downstream of the needles.

[0012] Considerable advantages are obtained by means of certain embodiments of the present invention. An air purifying device for separating materials in the form of particles or drops from a gas flow is provided.

20 **[0013]** The device meets the following technically advanced characteristic:

- particle ionization with positive polarization voltage
- a structure for low aerodynamic drag of the ionization panel
- a flat mechanical structure in order to limit the required space in flow channels or air channels
- 25 • a robust structure for harsh environment and moving platforms
- a structure for easy and quick manufacture
- simple production testing methods can be applied with clear pass/fail criteria

[0014] The ionization panel is part of the ElectroStatic Precipitator (ESP) technology air purification technology. Together with an ESP collector module the ionization panel provides easy maintenance, is washable, and provides a low air drag method of air purification. The technology is able of running with very little energy consumption and provides also the possibility to save energy in air ventilation, where a fan is typically used for overcoming fibre filter air drag. The structure of the device is scalable for different sizes, modular for maintenance and cleaning, and allows robotic assembly lines. Positive ionization voltage decreases the ozone (O₃) generation of the ionization process and enables the possibility to leave the active carbon filter out of the ESP module

[0015] The following performance requirements can be achieved according to certain embodiments of the present invention:

- air volume capacity in the range between 1200 and 1400 m³/h, or more
- front surface area in the range between 0.3 and 0.4 m²
- airflow speed in the range between 1.0 and 2.5 m/s, or more
- single pass air purification efficiency > 99% for 0.3 µm particles (for complete unit with collector)
- module is easily purged for cleaning and replacing needles
- all components and structures allow low pressurized (<100 Pa) water cleaning

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BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIGURE 1 illustrates a schematic perspective view of an air purifier in accordance with at least some embodiments of the present invention,

[0017] FIGURE 2 illustrates a schematic view of a needle of an air purifier in accordance with at least some embodiments of the present invention,

[0018] FIGURE 3 illustrates a schematic view of a frame of an air purifier in accordance with at least some embodiments of the present invention,

[0019] FIGURE 4 illustrates a schematic perspective view of another air purifier in accordance with at least some embodiments of the present invention,

[0020] FIGURE 5 illustrates an arrangement in accordance with at least some embodiments of the present invention,

5 **[0021]** FIGURE 6 illustrates a honeycomb structure of an air purifier in accordance with at least some embodiments of the present invention,

[0022] FIGURE 7 illustrates different flow channels of an arrangement in accordance with at least some embodiments of the present invention, and

[0023] FIGURE 8 illustrates details of an air purifier in accordance with at least
10 some embodiments of the present invention.

EMBODIMENTS

[0024] In FIGURE 1 a schematic perspective view of an air purifier 1 in accordance with at least some embodiments of the present invention is illustrated. The air purifying
15 device 1 comprises a grounded honeycomb structure 2. The honeycomb structure 2 is supported by a frame as e.g. shown in FIG. 3. In other words, a frame structure supports the ionization panel.

[0025] The honeycomb structure 2 comprises a plurality of hexagonal openings 5, for instance. The honeycomb structure 2 is made of a relatively thin substrate, for example
20 having a thickness between 0.5 millimeters and a few centimeters, for example 1 mm to 10 mm. Air to be purified is guided towards the honeycomb structure 2 along a flow channel (not shown) in which the air purifying device 1 is arranged and then passes through the openings 5 of the honeycomb structure 2. The gas flow to be purified may include materials in the form of particles and/or drops. The honeycomb structure 2 may be a laser
25 cut, honeycomb punctured RST metallic ground plate attached to the frame 3. The electrically grounded honeycomb structure 2 serves as a first electrode. The honeycomb structure 2 is important for providing equal shapes and full coverage of ionizing corona discharge. The honeycomb structure also minimizes the pressure drop across the ionization panel as it resists the air flow as little as possible. The honeycomb structure 2 is highly

energy efficient as it represents least air drag, in particular in comparison to rectangular or circular openings.

[0026] A plurality of ionization elements, for example ionization needles 4, is further arranged downstream of the honeycomb structure 2. The plurality of needles 4 serves as a second electrode constituting an ionizer that cooperates with the first electrode. At least some of the needles, typically each needle 4, is/are coaxially aligned with a respective center axis of an opening 5 of the honeycomb structure 2. In other words, the number of needles is typically identical with the number of openings 5 of the honeycomb structure 2. A center axis of an opening 5 of the honeycomb structure 2 is typically parallel to a direction of the gas flow. The needles 4 are typically attached to a PCB rail arranged downstream of the tips of the needles 4 as shown in FIG. 2. The needle tips 7 are typically arranged 10 mm to 25 mm, for example 15 mm, downstream of the honeycomb ground plate in order to create a corona flow that is covering each opening 5 of the honeycomb structure 2. The ionization corona discharge is generated by positive ionization voltage led to the set of sharp needles 4 arranged downstream of the honeycomb structure 2. Positive ionization voltage decreases the ozone (O_3) generation of the ionization process and enables the possibility to leave the active carbon filter out of the ESP module. The second electrode is typically energized at a high voltage of several thousand volts by a DC power supply, typically in the range between 5 kV to 20 kV, preferably 10 kV to 15 kV. The voltage may be adjustable, for instance. A corona ionization stream is formed on each tip of a needle 4 and then directed to the circumference of the corresponding opening 5 in the honeycomb structure 2. The particulate and laden air stream passes through these ionization zones.

[0027] Finally, the air stream is guided to collector plates 8 as described and shown in connection with FIGURE 4.

[0028] In FIGURE 2 a schematic view of a needle 4 of an air purifier 1 in accordance with at least some embodiments of the present invention is illustrated. As shown, the needle 4 is attached to a support structure 6, for example a PCB rail. The PCB rail may be, for example, about 5 mm to 7 mm wide and aligns the needle 4 with a respective opening 5 of the honeycomb structure 2 shown in FIG. 1. Thus, high tension can be directed to the ion yield tip 7 of the needle 4. In other words, the ionization discharge

current is generated with a positive voltage, thus limiting ozone generation to a minimum. The voltage is typically supplied to the needle 4 through copper foils of the circuit board.

[0029] The needle 4 may be partially over-molded by a plastic structure 11 and the PCB rail 6 may be embedded in said plastic structure 11. The plastic structure 11 may be in the form of an aerodynamic profile in order to reduce resistance and creation of noise. The aerodynamic profile may be, for example, in the form of a NACA profile or have a rounded leading and/or trailing edge. In particular, the combination of a honeycomb structure having hexagonal openings and PCB rails embedded in plastic structures 11 in the form of aerodynamic profiles provides beneficial properties. The material of the needle 4 is graphite, graphene, a noble metallic material or an inert material, for instance. In other words, the needle 4 is made of a material that is able to withstand a continuous corona generated oxidation and reduction of material.

[0030] In FIGURE 3 a schematic view of a frame 3 of an air purifier in accordance with at least some embodiments of the present invention is illustrated. The frame 3 may be, for example, made of plastic material. A plastic frame provides high reproducibility of dimensions when being manufactured. The plastic material is typically selected to withstand high ionization voltage and to minimize leakage currents. The frame 5 may be rectangular, circular, elliptical or polygonal, for instance. The shape of the frame 3 typically corresponds with an inner shape of a flow channel (not shown).

[0031] According to certain embodiments, the frame 3 is designed to support both the ionization part (honeycomb structure 2 and rails 6 with needles 4) and the collector plates 8. The collector plates 8 are aligned with the ionized airflow and their dimensions depend on the speed of the airflow A.

[0032] In FIGURE 4 a schematic perspective view of another air purifier 1 in accordance with at least some embodiments of the present invention is illustrated. As can be seen, a contaminated air flow is guided through the honeycomb structure 2. Subsequently, ionization corona discharge is generated by positive ionization voltage led to the needles 4 arranged downstream of the honeycomb structure 2. The needles 4 are coupled to PCB rails 6 arranged parallel to each other and face towards the honeycomb structure 2. The PCB rails 6 may be oriented in vertical or horizontal direction, for instance. However, the needles 4 may also be coupled to a grid-like support structure comprising the PCB rails 6 in order to increase stability. Finally, particles and/or drops are

collected by the collector plates 8 comprising collector surfaces 10 arranged downstream of the needles 4. The collector plates 8 are typically ESP type collector plates. The collector plates 8 are arranged parallel or substantially parallel to each other. The distance between adjacent collector plates 8 may be in the range between 3 mm to 10 mm, for example, 5 mm. The number of collector plates 8 may be e.g. in the range between 25 to 50, for example 40. The collector plates 8 are further arranged perpendicular or substantially perpendicular to a plane formed by the grounded honeycomb structure 2. Material previously contained in the contaminated airflow can be easily removed from the collector surfaces 10 of the collector plates 8, for example by washing the plates 8 with water.

[0033] Every second collector plate 8 is typically grounded and the remaining collector plates are energized at a high voltage of several thousand volts by a DC power supply, typically in the range between 2 kV to 8 kV, for example 5 kV. The voltage may be adjustable, for instance.

[0034] In FIGURE 5 an arrangement in accordance with at least some embodiments of the present invention is illustrated. As can be seen, an air purifier 1 as described above is arranged within a rectangular flow channel 9. According to certain other embodiments, the flow channel 9 may also be circular or elliptical, for instance.

[0035] In FIGURE 6 a honeycomb structure 2 of an air purifier 1 in accordance with at least some embodiments of the present invention is illustrated. As can be seen, a plurality of hexagonal openings 5 is provided in the honeycomb structure 2. The honeycomb structure 2 comprises an array of hollow openings 5 formed between very thin walls, thus forming a first grounded electrode, providing a high area through which contaminated air can pass, allowing guiding of the contaminated air flow towards the needles 4, reducing drag and allowing reduction of weight.

[0036] In FIGURE 7 different flow channels 9 of an arrangement in accordance with at least some embodiments of the present invention are illustrated. The flow channels 9 may have any size and shape, for example a rectangular, circular or hexagonal cross-section.

[0037] FIGURE 8 illustrates details of an air purifier 1 in accordance with at least some embodiments of the present invention. The needles 4 are mounted on rails 6

downstream of the honeycomb ground plate 2. Each needle 4 is aligned with a centre of a honeycomb hexagon. The corona discharge spreads from the needle tips 7 to the honeycomb structure 2. The corona discharge covers the entire airflow facing area. The rails 6 are aerodynamically shaped and provide firm structure for the needles 4. The high ionization voltage provided by a voltage source (not shown) is supplied to the needles 4 through copper foils inside the rail material, for instance.

[0038] It is to be understood that the embodiments of the invention disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

[0039] Reference throughout this specification to one embodiment or an embodiment means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Where reference is made to a numerical value using a term such as, for example, about or substantially, the exact numerical value is also disclosed.

[0040] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present invention may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations of the present invention.

[0041] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the description, numerous specific details are provided, such as examples of lengths, widths, shapes, etc.,

to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in
5 detail to avoid obscuring aspects of the invention.

[0042] While the forgoing examples are illustrative of the principles of the present invention in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the
10 principles and concepts of the invention. Accordingly, it is not intended that the invention be limited, except as by the claims set forth below.

[0043] The verbs “to comprise” and “to include” are used in this document as open limitations that neither exclude nor require the existence of also un-recited features. The features recited in depending claims are mutually freely combinable unless otherwise
15 explicitly stated. Furthermore, it is to be understood that the use of "a" or "an", that is, a singular form, throughout this document does not exclude a plurality.

INDUSTRIAL APPLICABILITY

[0044] At least some embodiments of the present invention find industrial
20 application in air purifiers and/or purifying air. Very suitable uses being particularly flow channels, for example in hospitals, isolation rooms, operating rooms, factories manufacturing microchips as well as air intakes and/or air outlets.

REFERENCE SIGNS LIST

	1	air purifying device
	2	honeycomb structure
	3	frame
5	4	needle
	5	opening
	6	support structure
	7	tip of needle
	8	collector plate
10	9	flow channel
	10	collector surface
	11	plastic structure
	A	airflow

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CITATION LIST

Patent Literature

WO 2018/090990 A1

CN 105698293 A

20 CN 106861340 A

Non Patent Literature

CLAIMS:

1. An air purifying device (1) comprising:

- a structure (2) having a plurality of openings (5), wherein the structure (2) is supported by a frame (3),
- a plurality of ionization needles (4) arranged downstream of the structure (2), wherein each of the needles (4) is coaxially aligned with a respective center axis of an opening (5) of the structure (2), and
- a plurality of collector plates (8) arranged downstream of the plurality of ionization needles (4),
- and wherein the device (1) is configured to generate ionization corona discharge by positive ionization voltage led to the needles (4),

characterized in that

- the structure (2) is grounded and the structure is a honeycomb structure having a plurality of hexagonal openings (5), and
- the needles (4) are attached to PCB rails (6) embedded in plastic structures (11) in the form of aerodynamic profiles.

2. The air purifying device (1) according to claim 1, wherein the device (1) does not comprise any additional filter or filter system.

3. The air purifying device (1) according to claim 1 or 2, wherein the device (1) is configured such that corona discharge spreads from tips (7) of the needles (4) to the honeycomb structure (2).

4. The air purifying device (1) according to any one of claims 1–3, wherein the needles (4) are partially over-molded by the plastic structures (11).

5. The air purifying device (1) according to any one of claims 1–4, wherein the material of the needles (4) is wolfram, graphite, graphene, a noble metallic material or an inert material.

6. The air purifying device according to any one of claims 1–5, wherein the needles are made of a material that is able to withstand a continuous corona generated oxidation and reduction of material.
7. The air purifying device according to one of claims 1–6, wherein the device is configured to be inserted into a flow channel.
8. The air purifying device according to one of claims 1–7, wherein the device is an electrostatic precipitator.
9. The air purifying device according to one of claims 1–8, wherein tips (7) of the needles (4) are arranged 5 mm to 25 mm downstream of the honeycomb structure (2).
10. The air purifying device according to one of claims 1–9, wherein each of the needles (4) is coaxially aligned with a respective center axis of an opening (5) of the honeycomb structure (2).
11. The air purifying device (1) according to claim 1, wherein the grounded honeycomb structure (2), the PCB rails and the plurality of collector plates (8) are supported by the frame (3).
12. The air purifying device (1) according to any one of claims 1–11, wherein every second collector plate (8) is grounded and the remaining collector plates (8) are energized at a voltage in the range between 2 kV to 8 kV.
13. The air purifying device (1) according to any one of claims 1–12, wherein the needles (4) are energized at a voltage in the range between 5 kV to 20 kV
14. An arrangement comprising an air purifier in accordance with any one of claims 1 – 13 and a flow channel (9).
15. A method for separating materials from an air flow, the method comprising:
 - providing a structure (2) having a plurality of openings (5) in a flow channel, wherein the structure (2) is supported by a frame (3),

- providing a plurality of ionization needles (4) arranged downstream of the structure (2), wherein each of the needles (4) is coaxially aligned with a respective center axis of an opening (5) of the structure (2),
- generating ionization corona discharge by positive ionization voltage led to the needles (4) arranged downstream of the structure (2), and
- collecting the materials by collector plates (8) comprising collection surfaces (10) arranged downstream of the needles (4),

characterized by

- providing a grounded structure (2) in the form of a honeycomb structure having a plurality of hexagonal openings (5), and
- attaching the needles (4) to PCB rails (6) embedded in plastic structures (11) in the form of aerodynamic profiles.