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(54) **AIR FILTRATION SYSTEM FOR ANTIMICROBIAL REFRIGERATORS**

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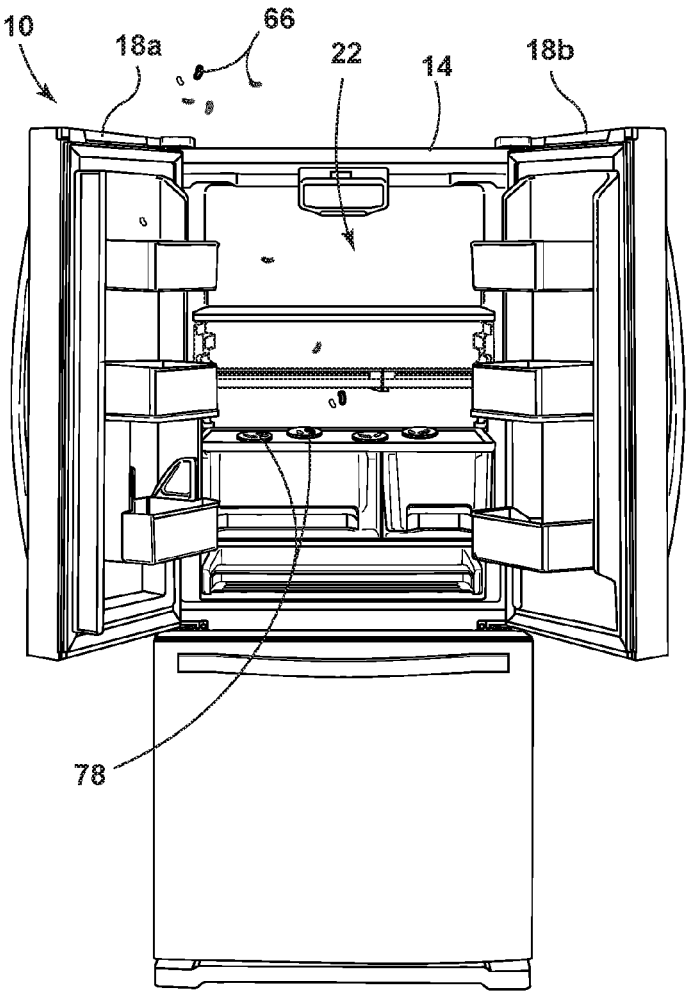
(57) **ABSTRACT**

A refrigerator includes a cabinet coupled to one or more doors forming a storage compartment. The refrigerator additionally includes a first fan assembly positioned on an interior surface of a first cabinet wall, and a second fan assembly positioned on the interior surface of a second cabinet wall. The first and second fan assemblies each include: two or more circulation fans; a filter coupled to a photocatalyst to form an activated filter; and a plurality of UV LEDs positioned to project light on the activated filter. An air circulation path is configured to direct air born bacteria and particulate matter within the storage compartment contemporaneously into the first and second fan assemblies using the two or more circulation fans and circulate filtered air into the storage compartment through the activated filter disposed in the air circulation path.



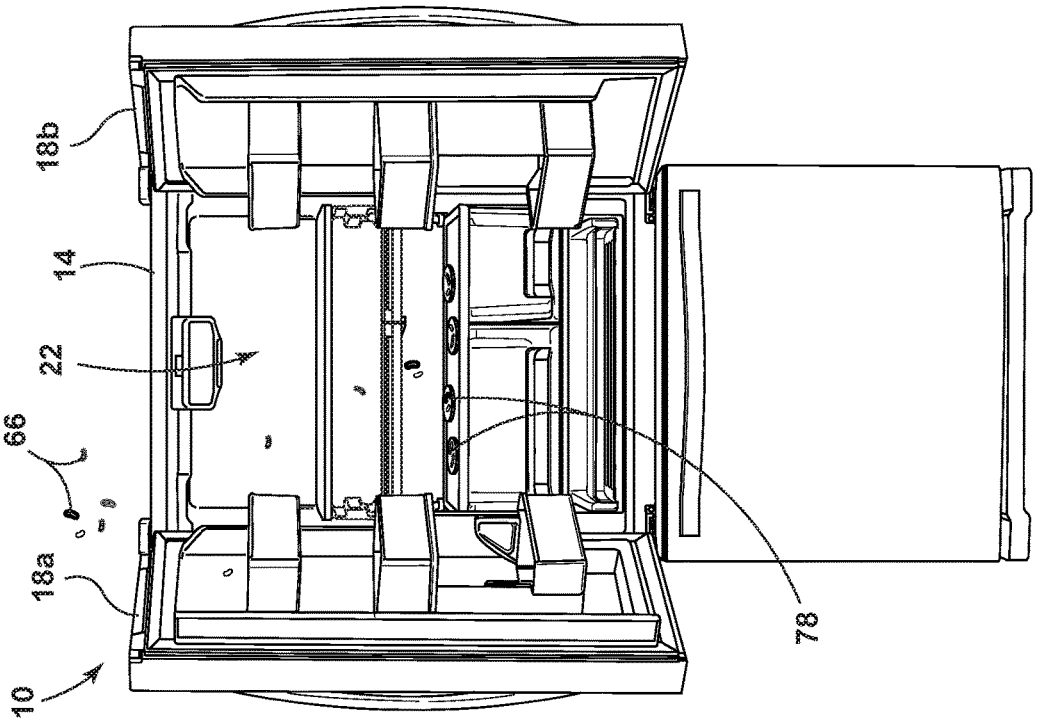


FIG. 1B

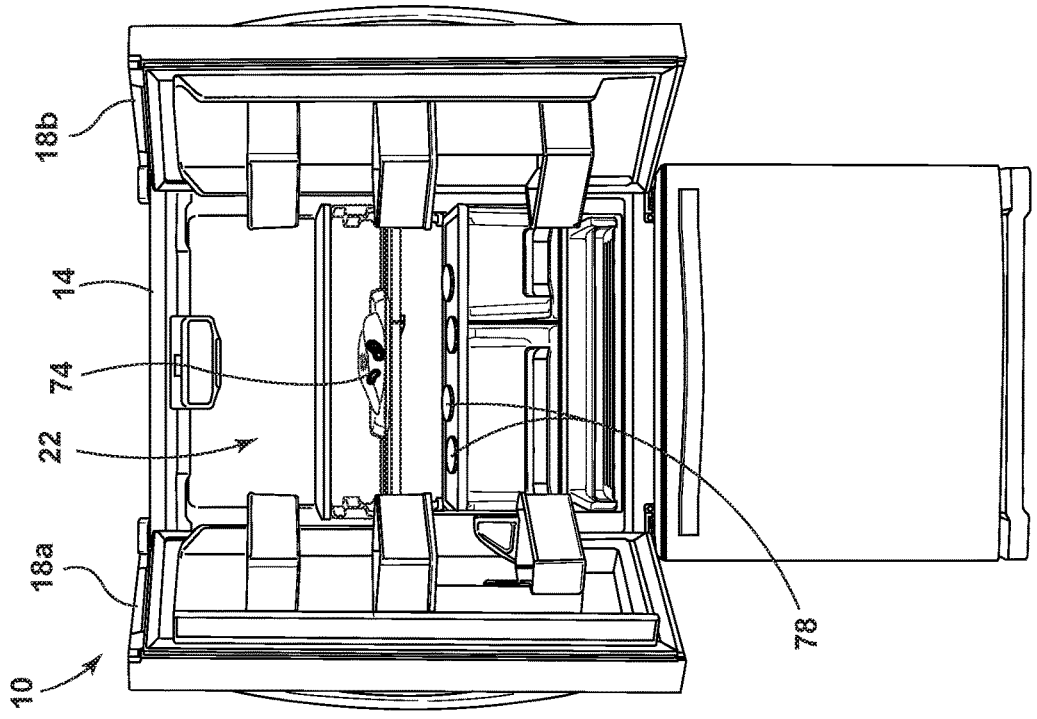


FIG. 1A

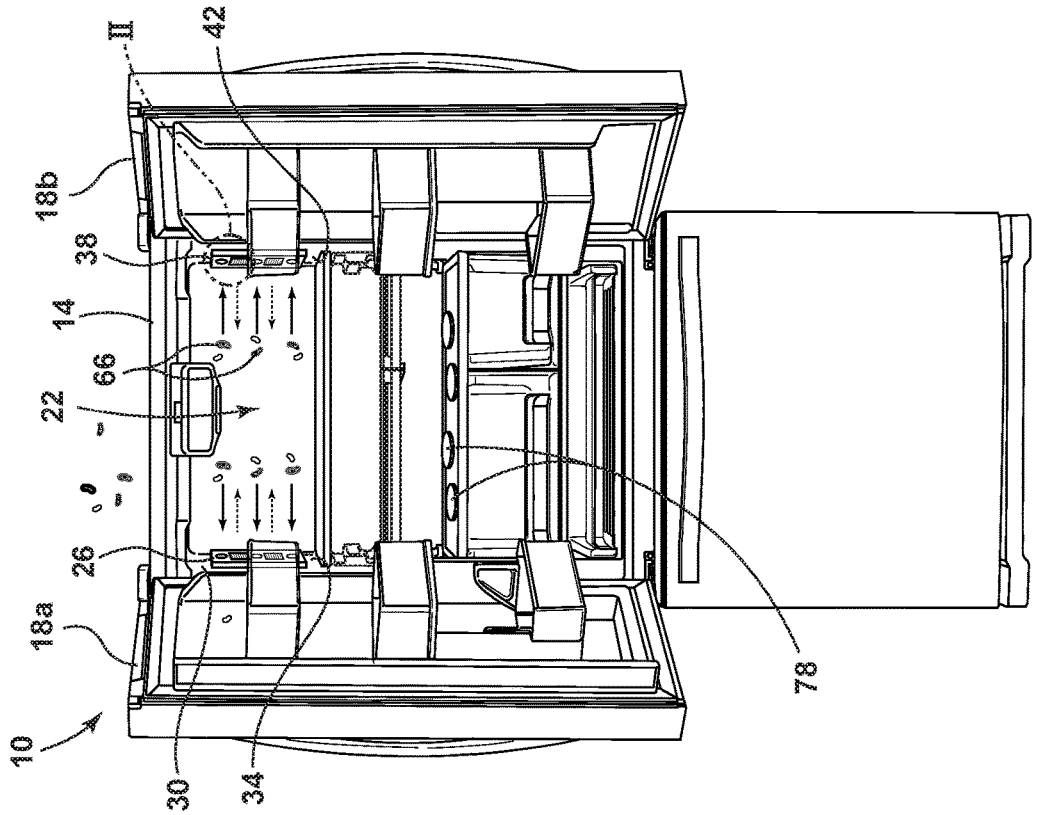


FIG. 1D

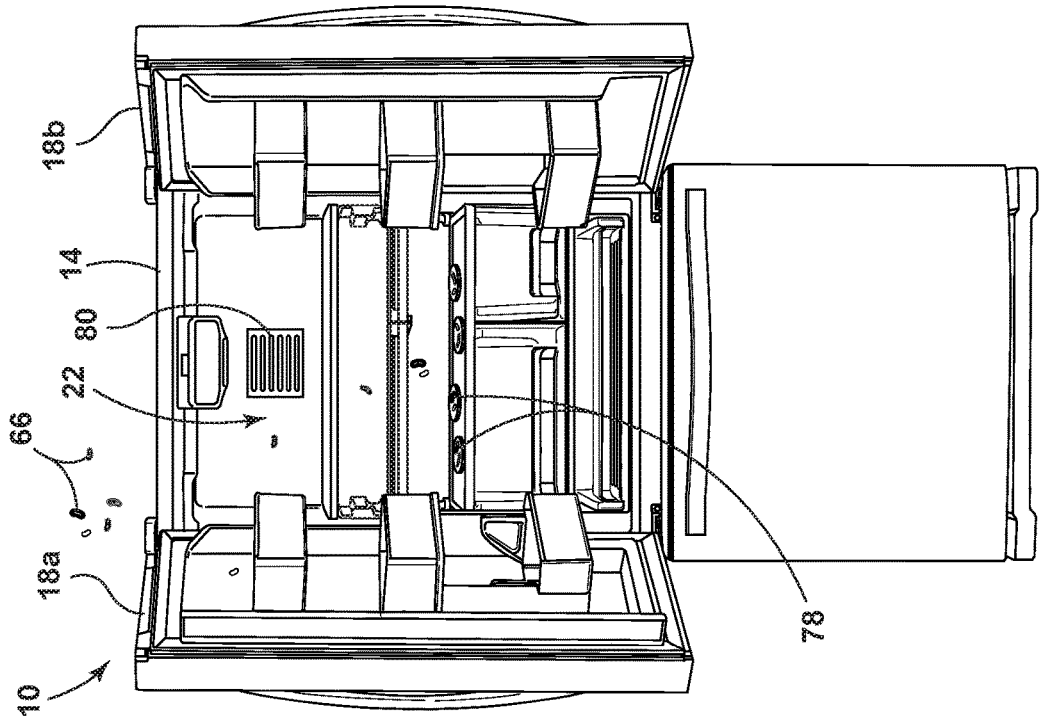


FIG. 1C

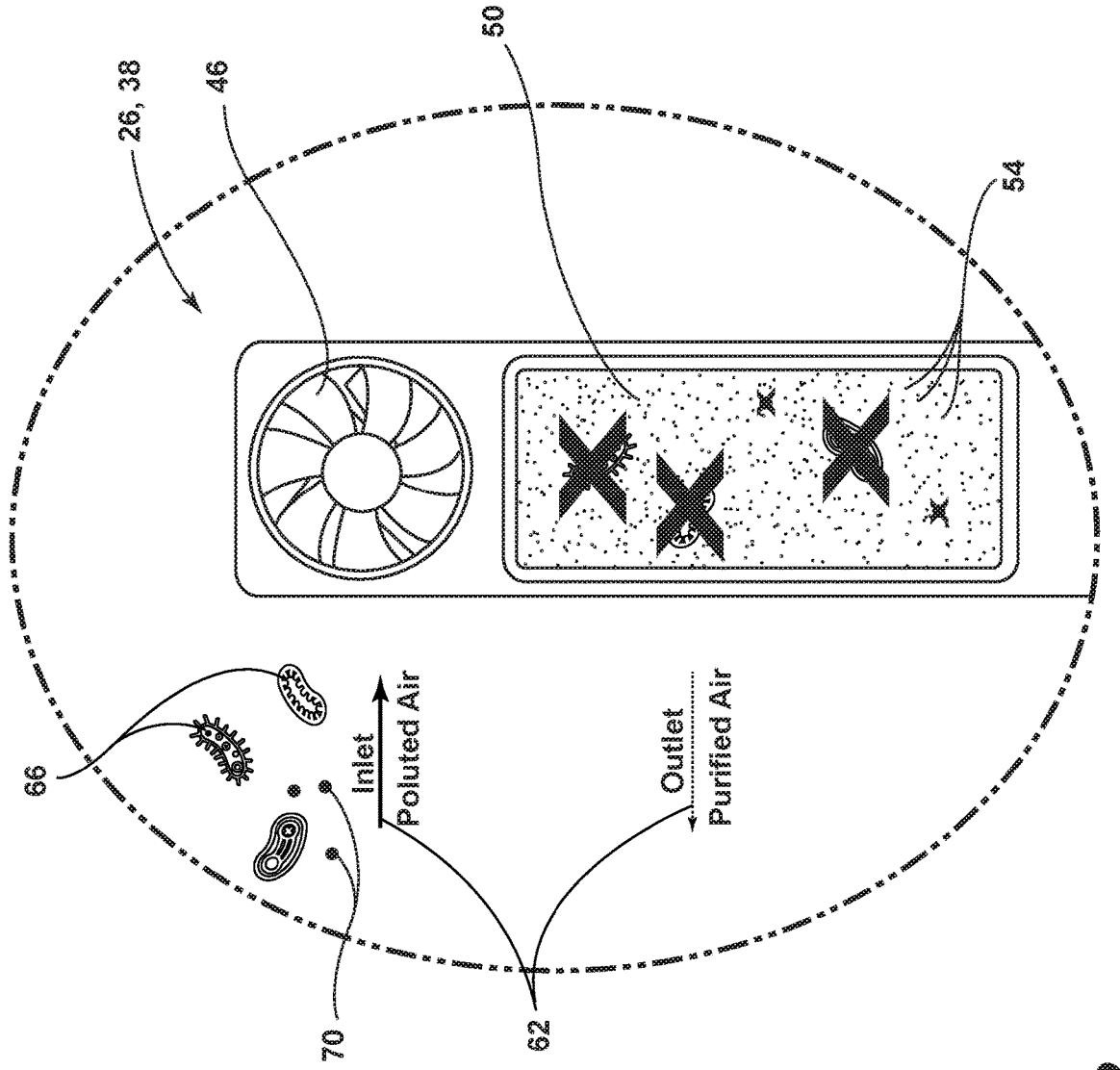


FIG. 2

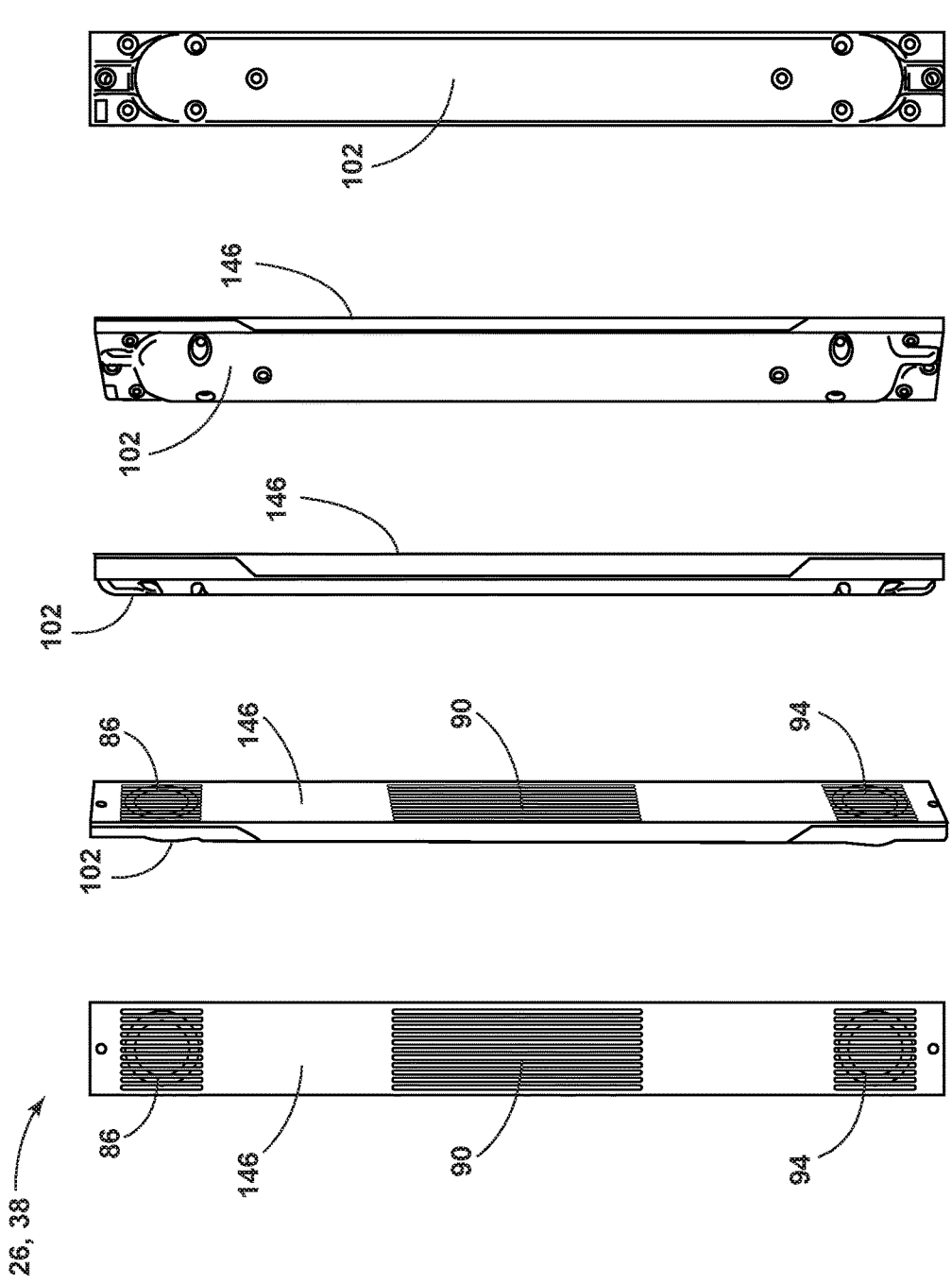


FIG. 3

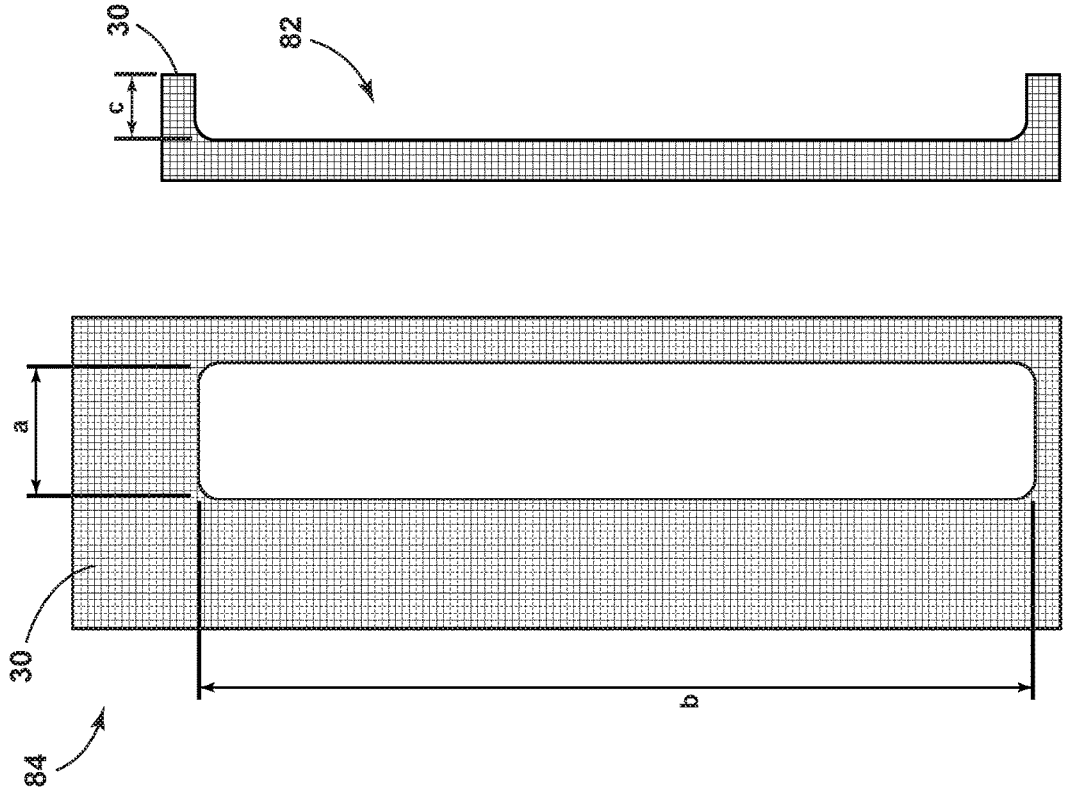

30
82
c
a
30
b
84

FIG. 4B

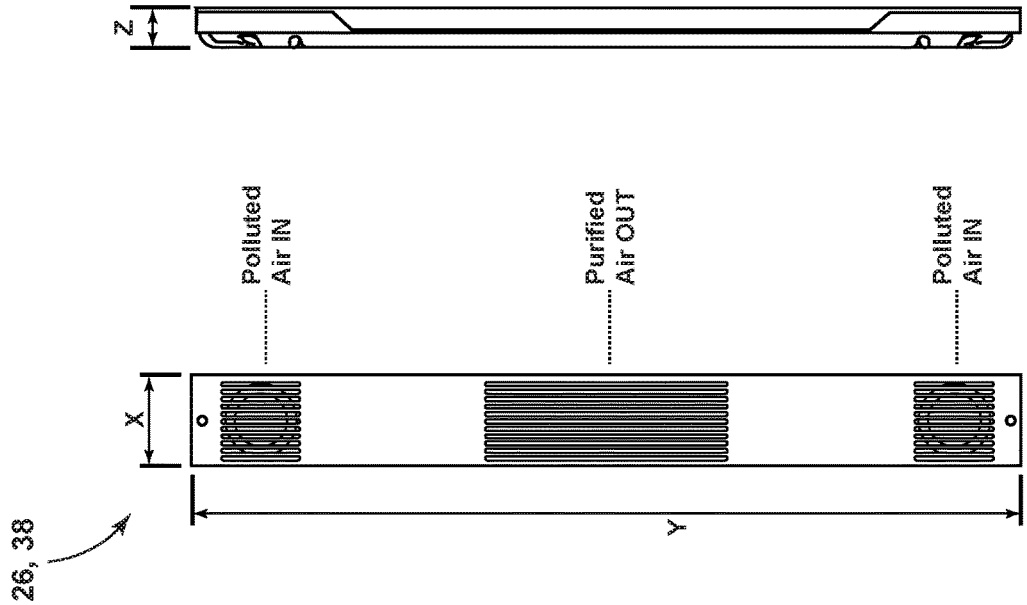

z
Polluted Air IN
Purified Air OUT
Polluted Air IN
X
Y
26, 38

FIG. 4A

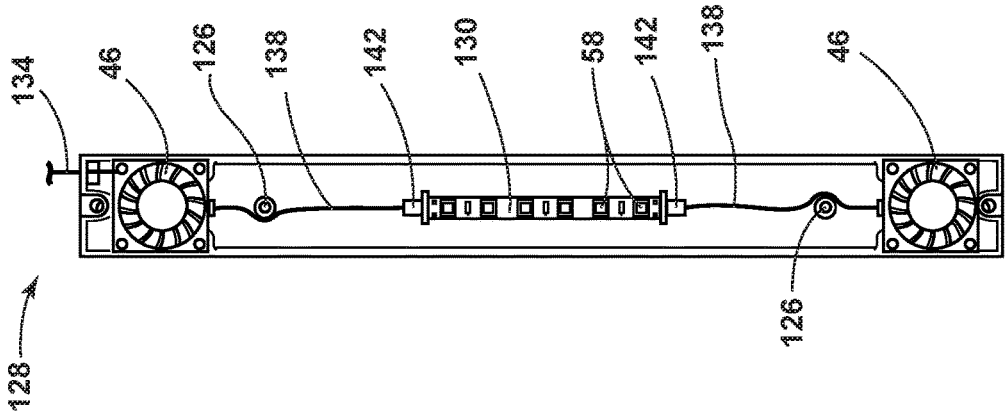

134
46
126
138
142
130
58
142
138
46
126
128

FIG. 5B

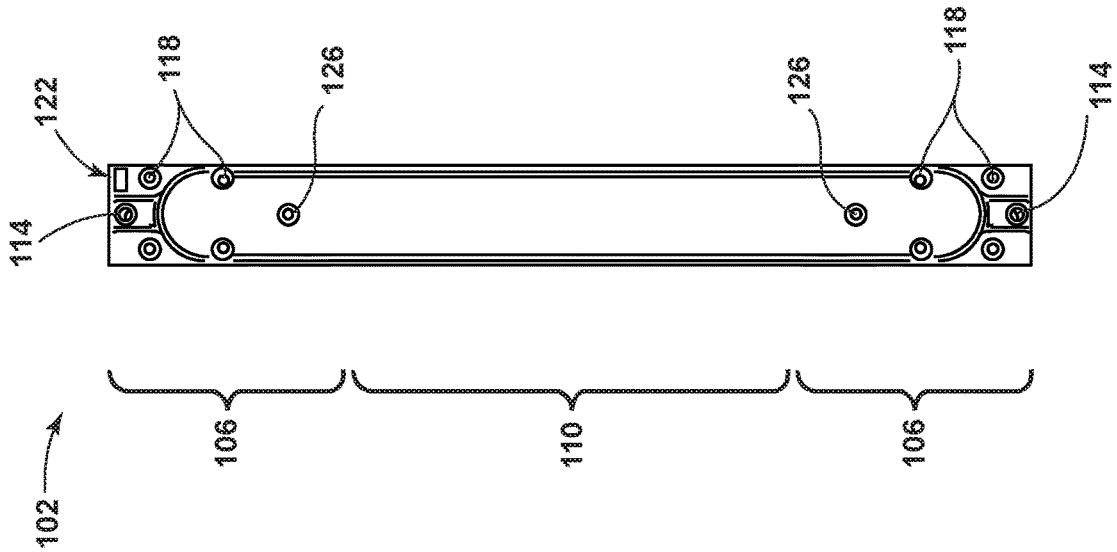

122
118
126
126
118
114
114
106
110
106
102

FIG. 5A

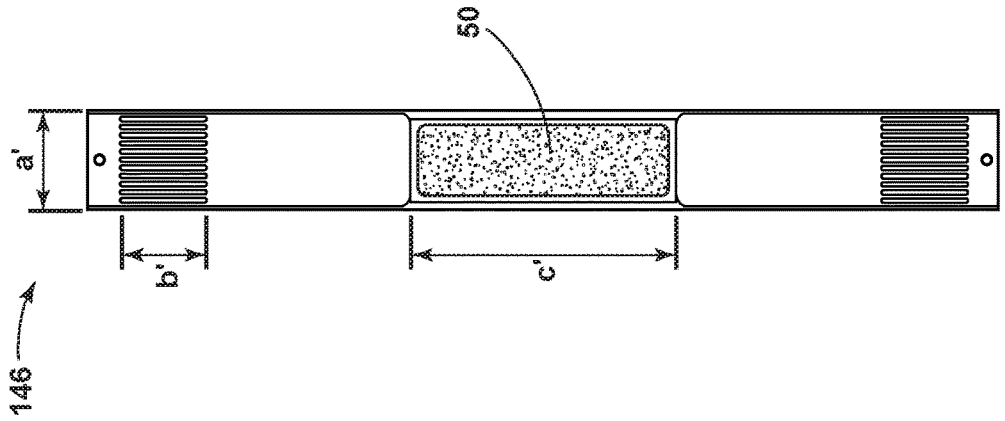


FIG. 6B

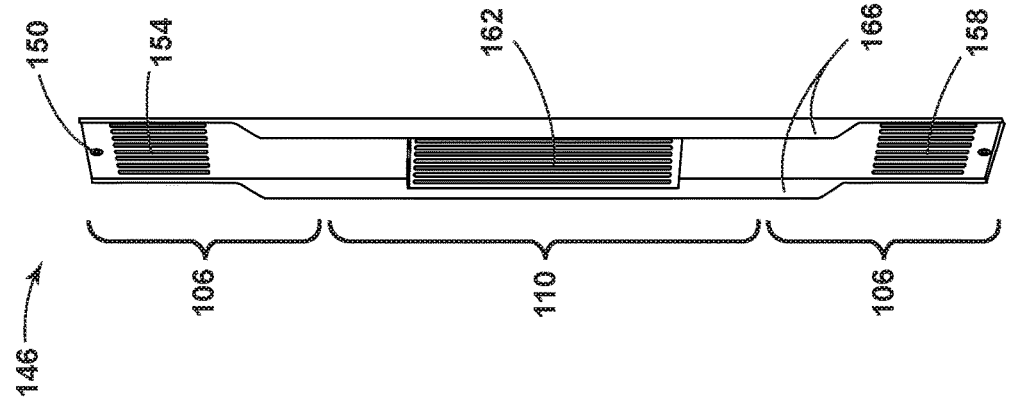


FIG. 6A

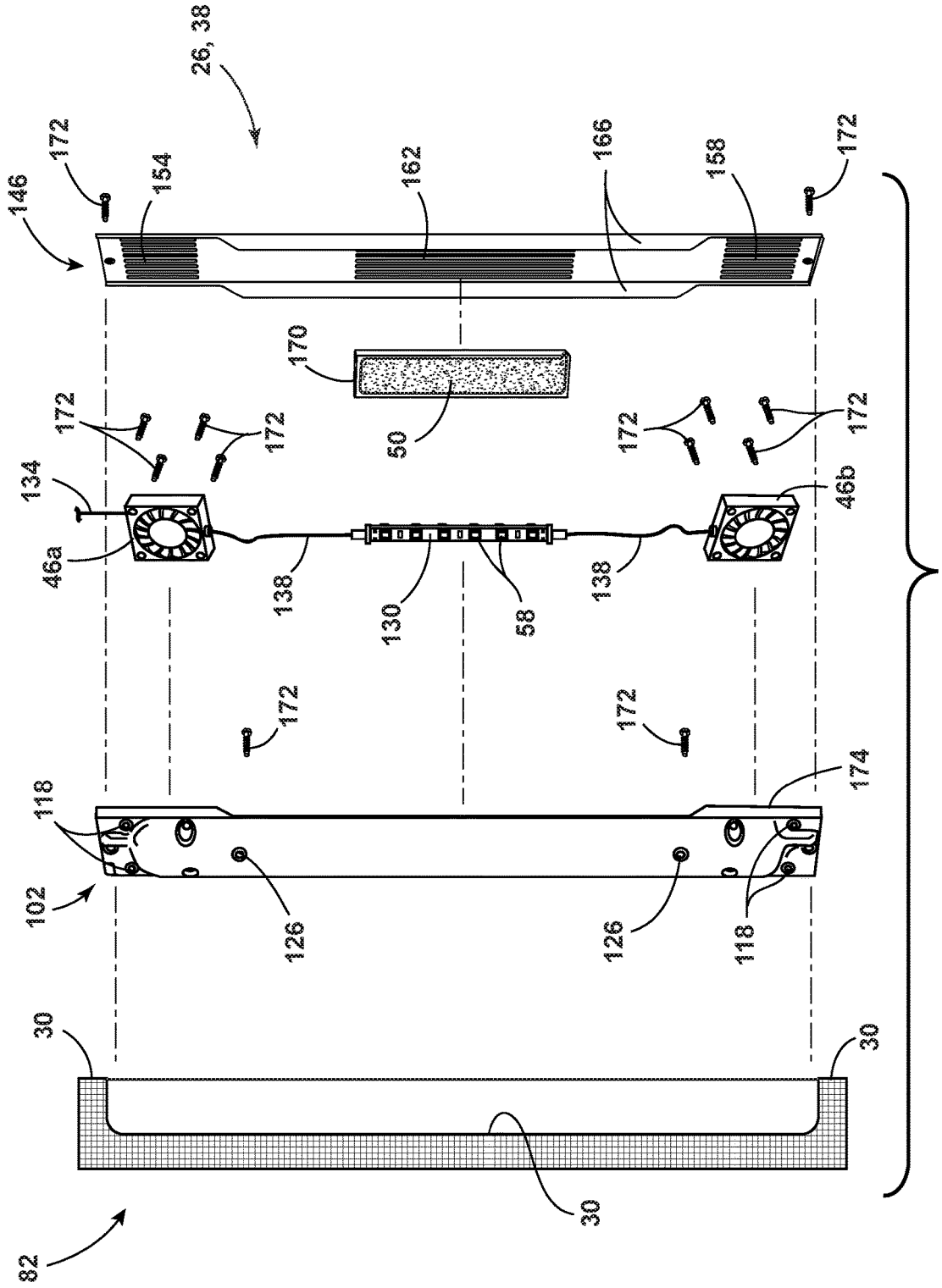

26, 38
146
172
154
162
166
158
172
170
50
172
172
172
172
134
46b
46a
138
130
58
138
172
172
174
118
102
126
126
118
30
30
30
82

FIG. 7

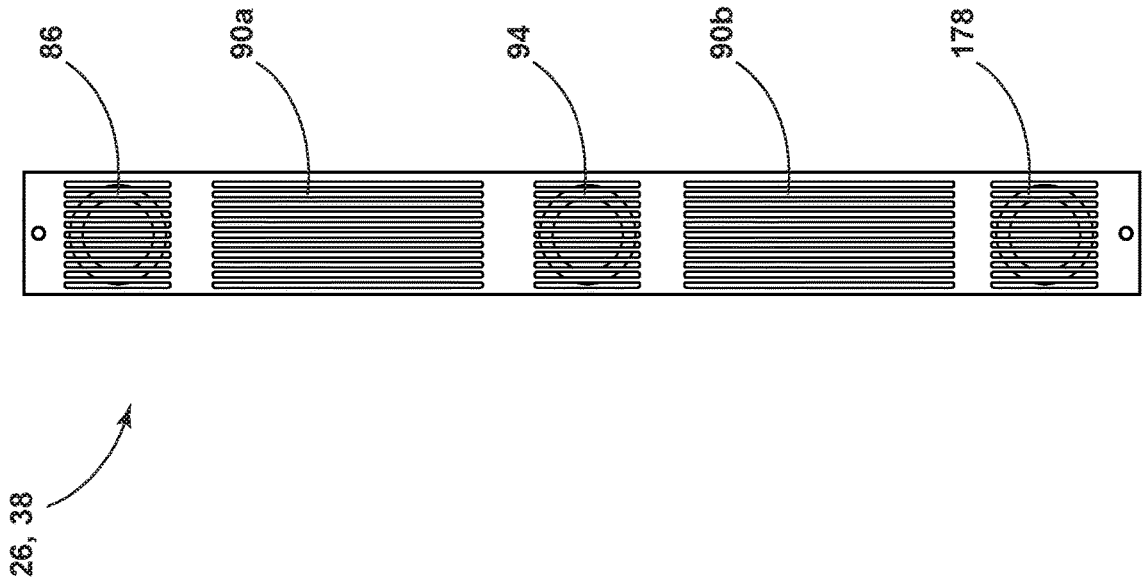


FIG. 8A

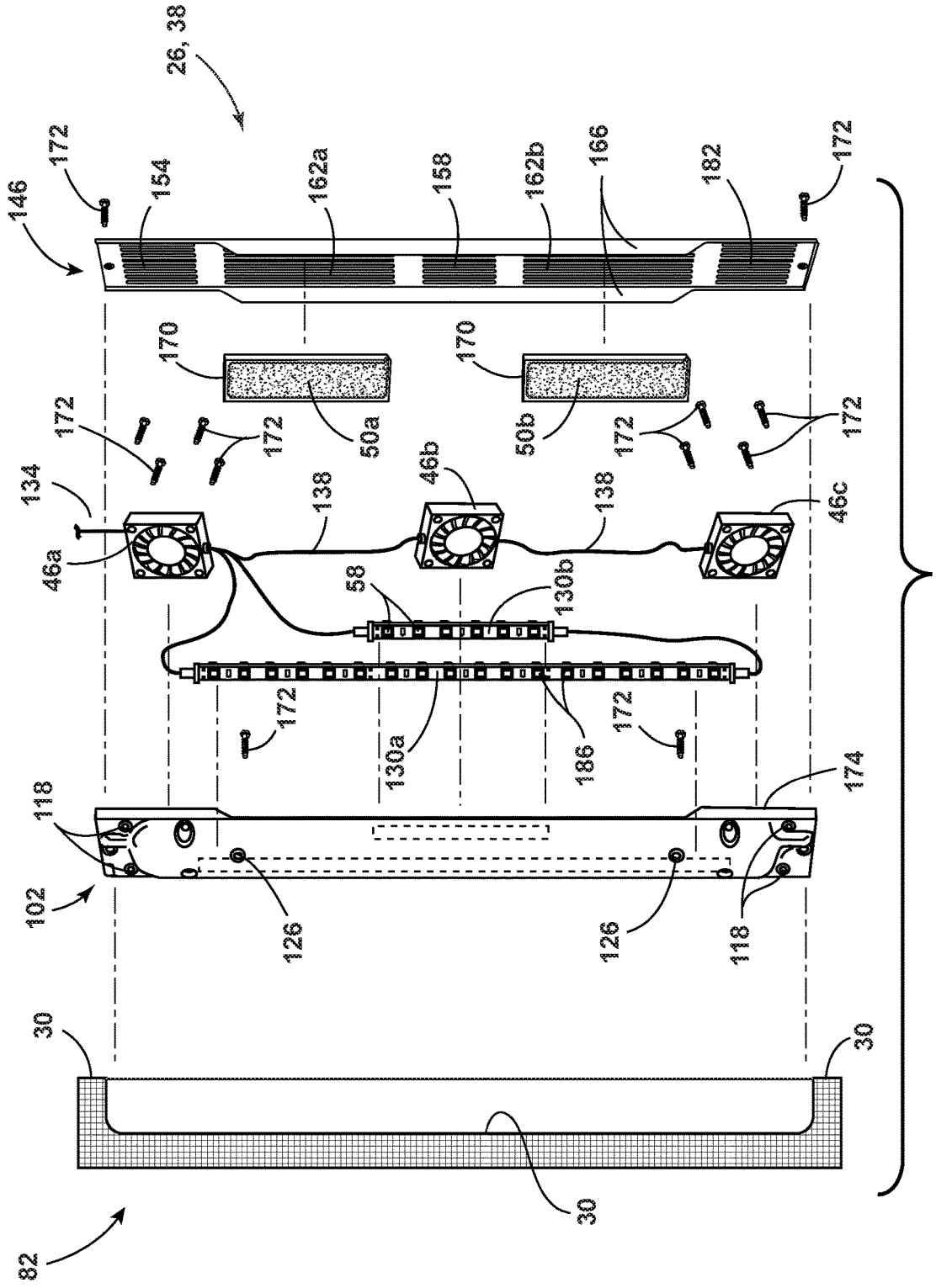

26, 38
172
154
162a
158
162b
166
182
172
146
170
170
172
172
172
172
50a
50b
172
134
46b
138
138
46c
46a
58
130b
172
172
130a
186
174
118
102
126
126
118
30
30
30
82

FIG. 8B

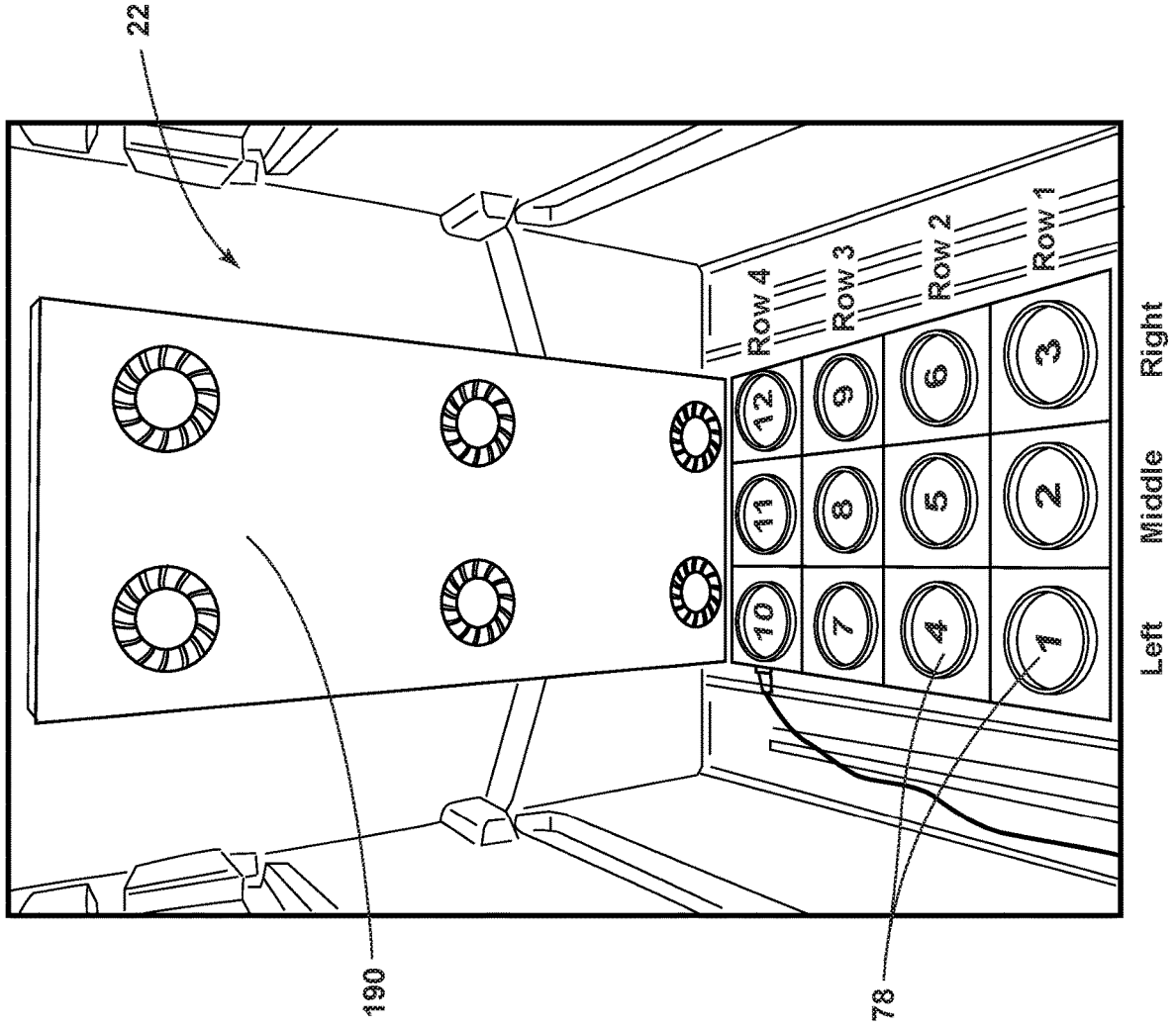

22
Row 4
Row 3
Row 2
Row 1
12
9
6
3
11
8
5
2
10
7
4
1
Left
Middle
Right
190
78

FIG. 9A

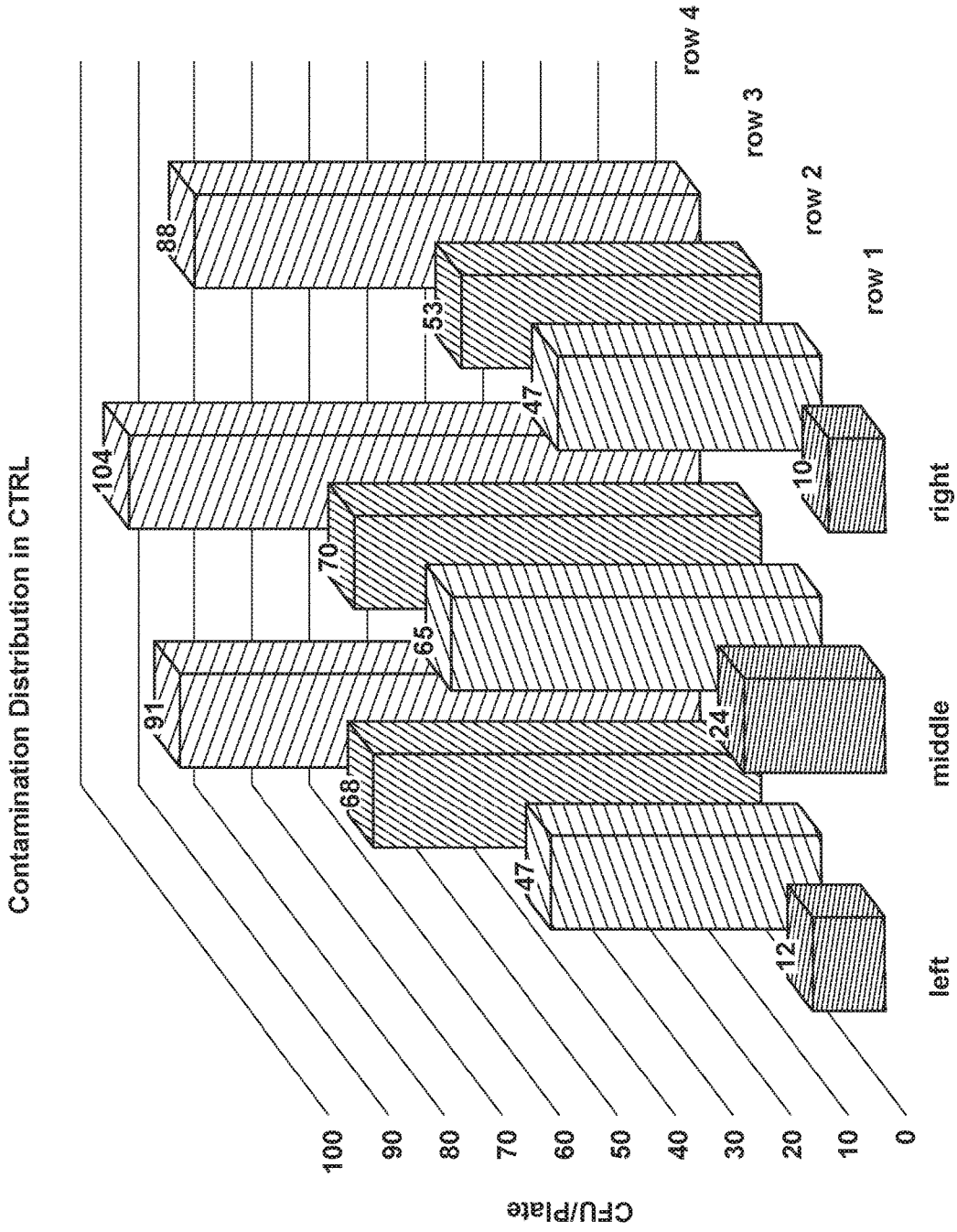

Contamination Distribution in CTRL
CFU/Plate
0
10
20
30
40
50
60
70
80
90
100
left
middle
right
row 1
row 2
row 3
row 4
12
47
68
91
10
47
24
65
70
104
53
88

FIG. 9B

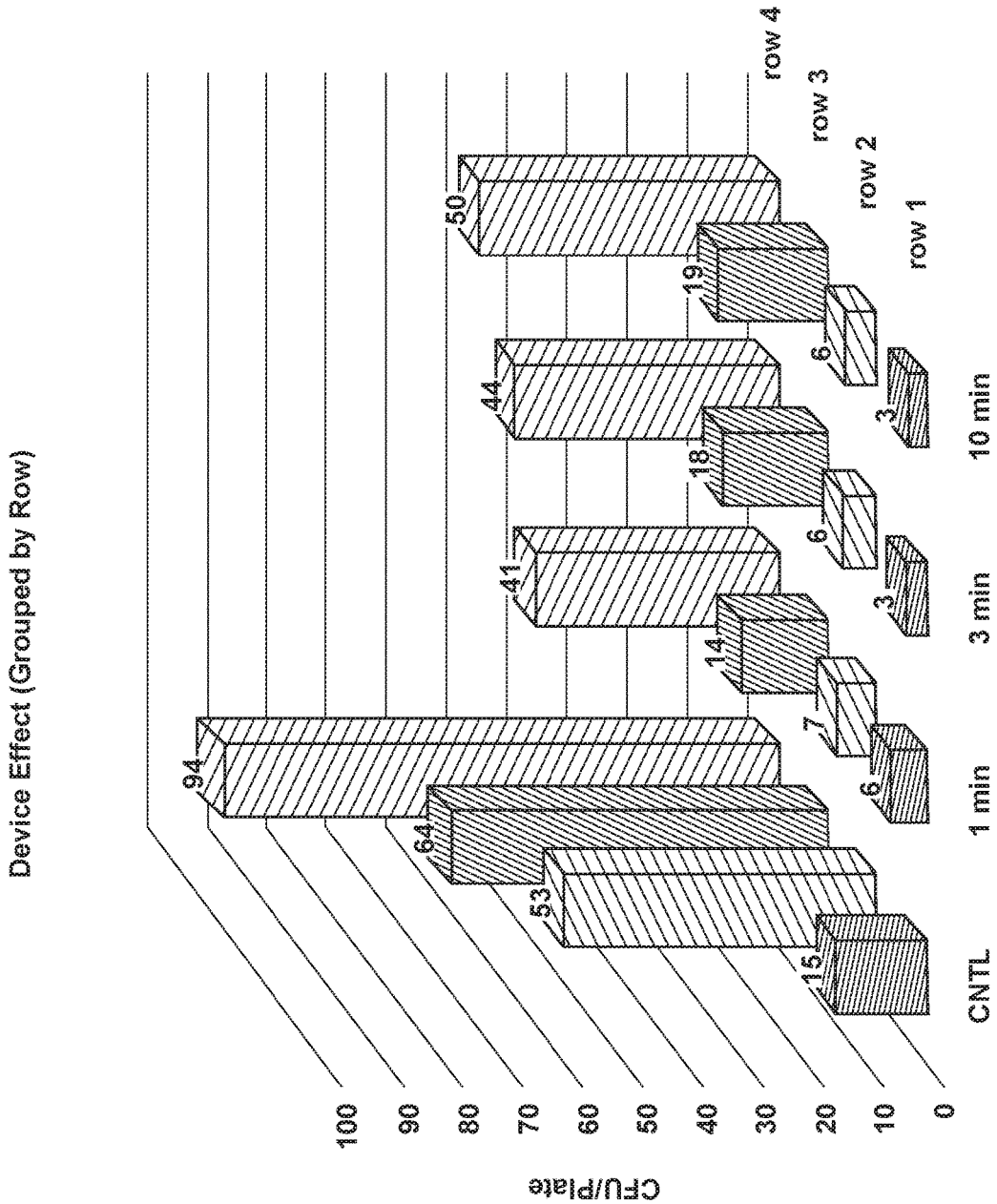

Device Effect (Grouped by Row)
CFU/Plate
100
90
80
70
60
50
40
30
20
10
0
CNTL
1 min
3 min
10 min
row 1
row 2
row 3
row 4
94
64
53
15
50
19
6
3
44
18
6
3
41
14
7
6

FIG. 9C

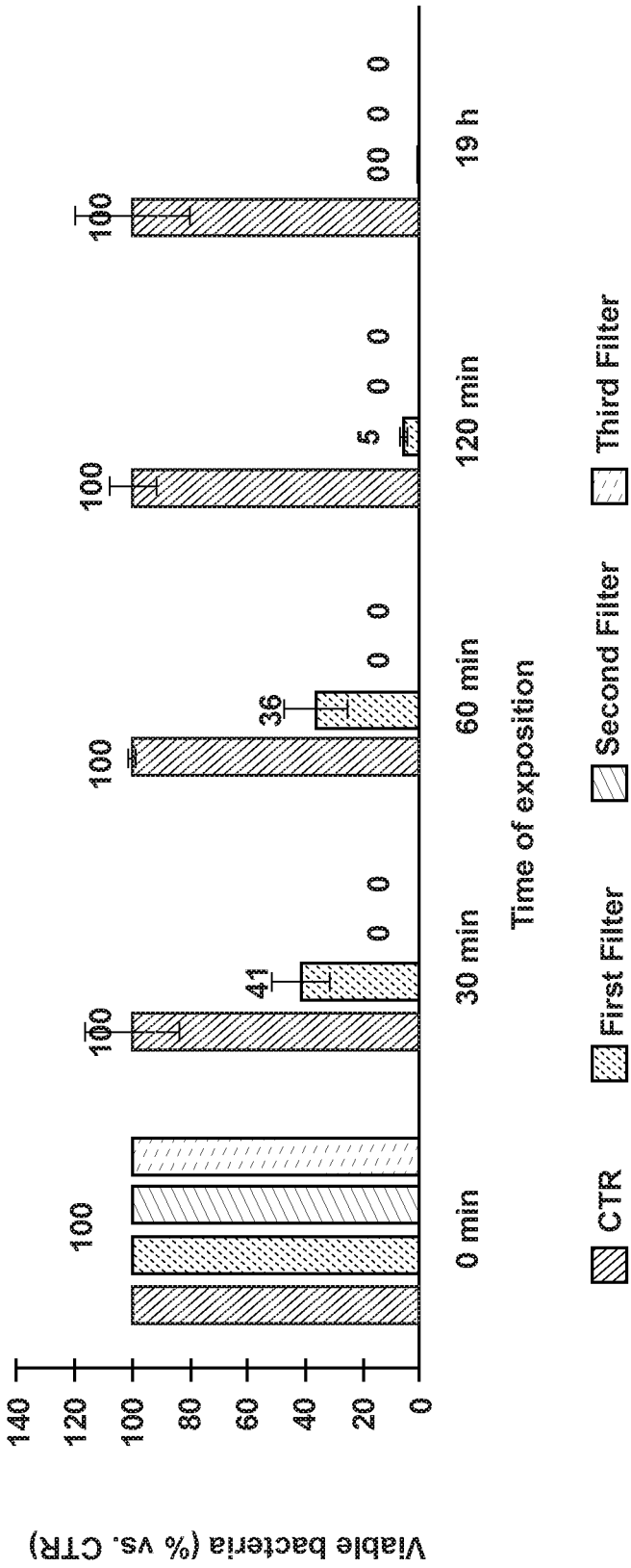

Filter Effect on Bacterial (E. coli) Survival at 4°C
Viable bacteria (% vs. CTR)
140
120
100
80
60
40
20
0
100
100
41
0
0
100
36
0
0
100
5
0
0
100
0
0
0
0 min
30 min
60 min
120 min
19 h
Time of exposition
CTR
First Filter
Second Filter
Third Filter

FIG. 10

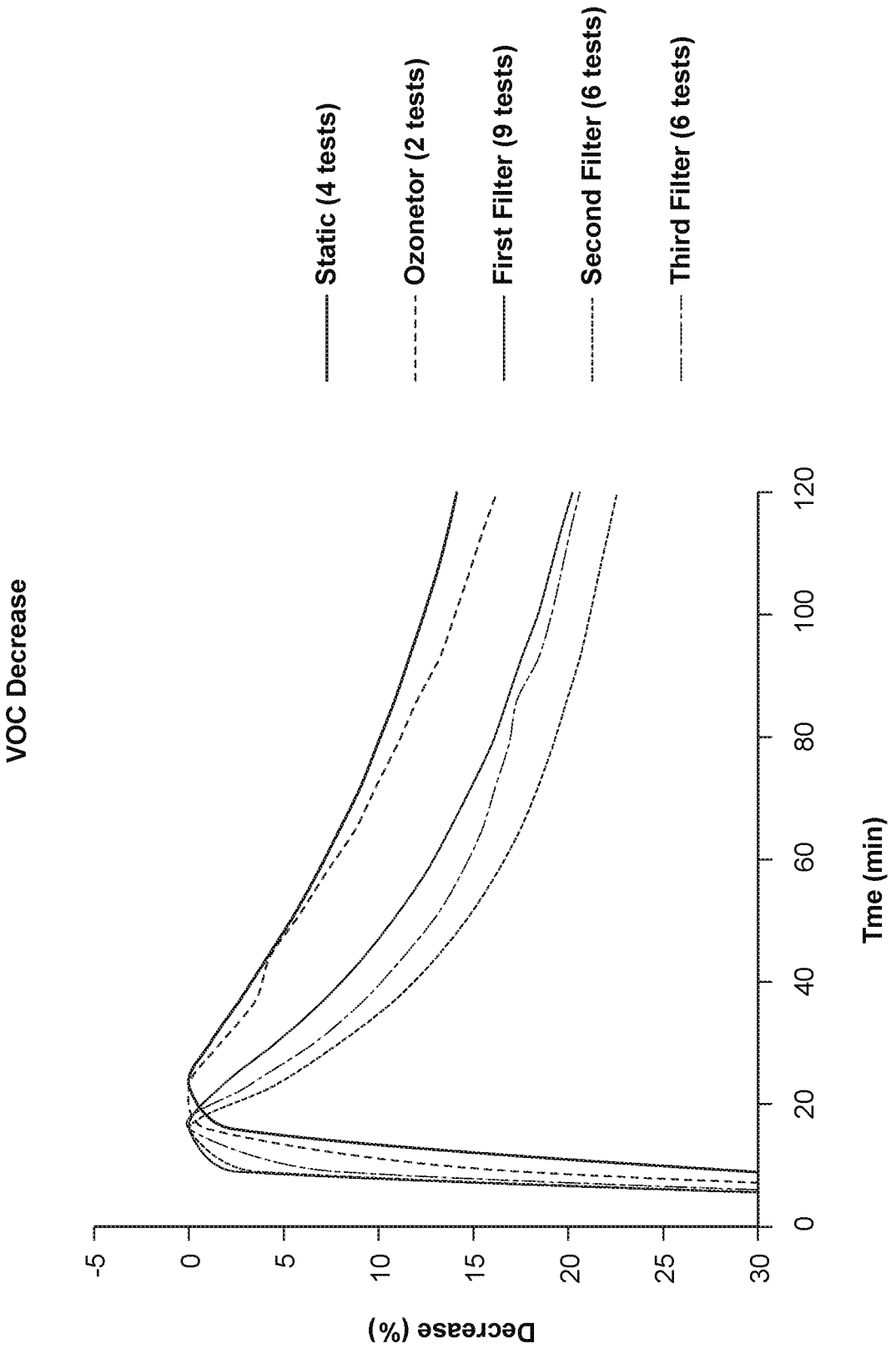

VOC Decrease
Static (4 tests)
Ozonetor (2 tests)
First Filter (9 tests)
Second Filter (6 tests)
Third Filter (6 tests)
-5
0
5
10
15
20
25
30
Decrease (%)
0
20
40
60
80
100
120
Tme (min)

FIG. 11A

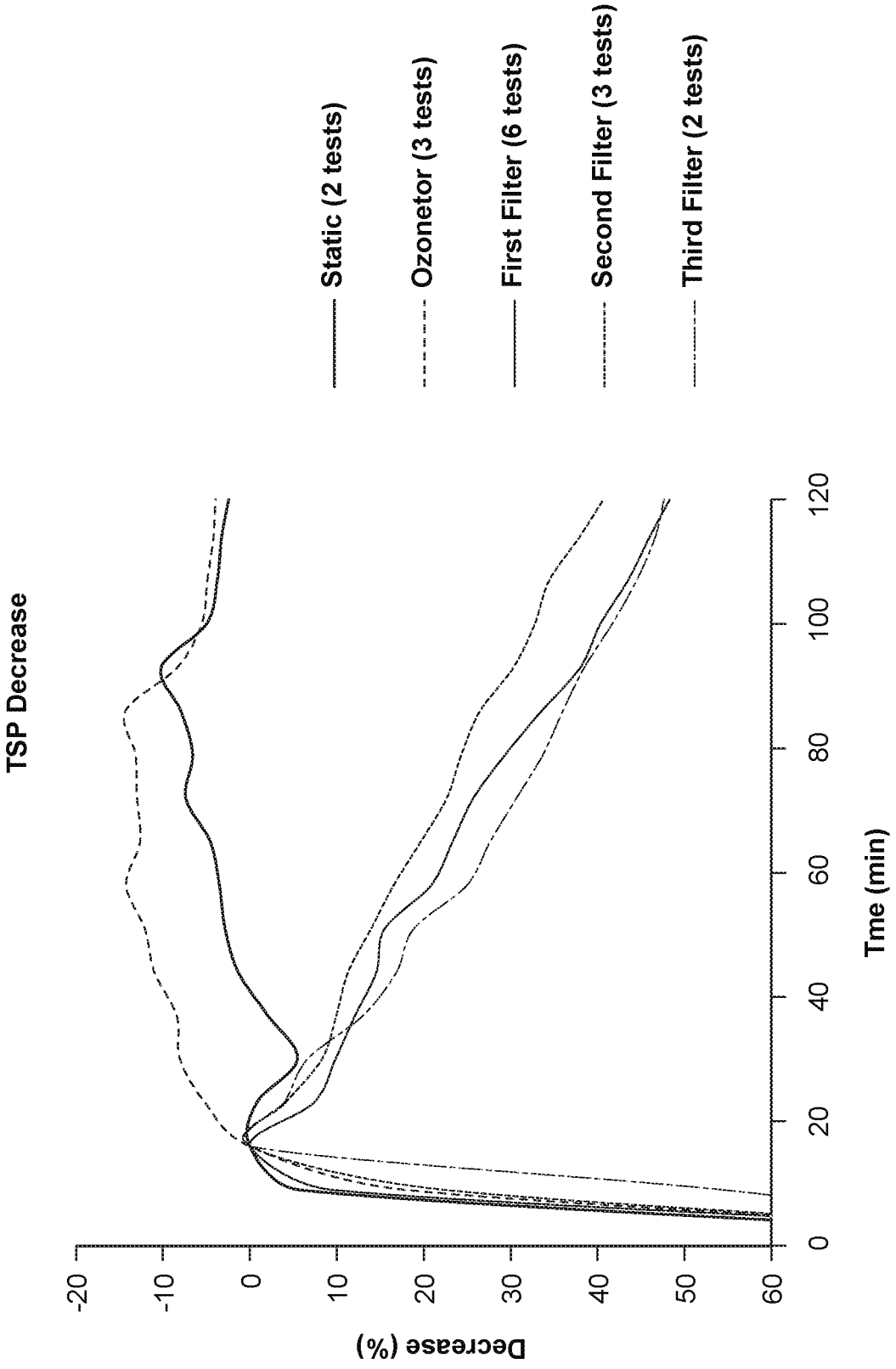

TSP Decrease
Static (2 tests)
Ozonetor (3 tests)
First Filter (6 tests)
Second Filter (3 tests)
Third Filter (2 tests)
Decrease (%)
-20
-10
0
10
20
30
40
50
60
Tme (min)
0
20
40
60
80
100
120

FIG. 11B

AIR FILTRATION SYSTEM FOR ANTIMICROBIAL REFRIGERATORS

FIELD OF THE INVENTION

[0001] The present device generally relates to an air filtration system for a refrigerator, and more specifically, to air purifying assemblies used in conjunction to filter microbes, volatile organic compounds, and particulate matter from a refrigerator.

BACKGROUND OF THE INVENTION

[0002] With the latest development of extra-large capacity refrigerators, there has been an emerging demand for highly robust antimicrobial technology such as air disinfection systems for food preservation and related features. Such systems are used to avoid the spoilage of food and produce stored in refrigerators for extended periods. Due to the unavailability of adequate antimicrobial technology, huge amounts of food, including produce, can go wasted even when stored in adequately low temperature refrigerators. Moreover, because of the increasing cost of commodities and food product costs, consumers are demanding efficient food storage technology for its longevity without compromise to its freshness.

[0003] One food preservation technique currently being used includes titanium dioxide (TiO_2) charged using a mercury lamp lighting system but due to the harmful effects of the mercury lamp integrated in this system, it could not meet the specifications or expectations for an antimicrobial application. In addition, the use of mercury in these types of UV lamp systems could be extremely dangerous due to health hazards and other handling issues associated with mercury. Other preservation and antimicrobial techniques being used include ozonizer systems that are directly integrated into the refrigerator. However, with time, significant decline in ozonizer performance is reported and their high cost makes these applications prohibitively expensive. Nano-misting techniques have also been studied but due to the harmful nature of the zinc and silver used in the applied nano-particles; these materials also did not meet consumer market requirements.

[0004] Accordingly, the need for an efficient and affordable antimicrobial filtration system is required in the market place for consumers to better accommodate food safety and longer storage times for valuable foodstuffs.

SUMMARY OF THE DISCLOSURE

[0005] According to one aspect of the present disclosure, a refrigerator is provided. The refrigerator includes a cabinet coupled to one or more doors forming a storage compartment; a first fan assembly positioned on an interior surface of a first cabinet wall; and a second fan assembly positioned on the interior surface of a second cabinet wall. The first and second fan assemblies each include: two or more circulation fans; a filter coupled to a photocatalyst to form an activated filter; and a plurality of LEDs positioned to project light on the activated filter. The refrigerator also includes an air circulation path configured to direct airborne bacteria and particulate matter within the storage compartment contemporaneously into the first and second fan assemblies using the two or more circulation fans and circulate filtered air into the storage compartment through the activated carbon filter disposed in the air circulation path.

[0006] According to another aspect of the present disclosure, a refrigerator is provided. The refrigerator includes a cabinet coupled to one or more doors. The cabinet includes a storage compartment; two or more fan assemblies positioned on an interior surface of the cabinet, the one or more doors, or a combination thereof. The fan assemblies each include: one or more circulation fans; a photocatalyst coupled to one or more filters to form an activated filter; and a plurality of LEDs positioned to project light on the activated filter. An air circulation path is configured to direct airborne bacteria and particulate matter within the storage compartment contemporaneously into the two or more fan assemblies using the one or more circulation fans and circulate filtered air into the storage compartment through the activated filter disposed in the air circulation path.

[0007] According to still another aspect of the present disclosure, an antibacterial fan assembly is provided. The antibacterial fan assembly includes a rear assembly panel and an assembly cover panel wherein the assembly cover panel includes one or more air intakes and one or more air exhausts. The antibacterial fan assembly further includes one or more circulation fans positioned between the rear assembly panel and the assembly cover panel and an activated filter having a photocatalyst and an activated carbon. The activated filter is positioned in circulation with the one or more air exhausts. The antibacterial fan assembly also includes one or more LEDs positioned to project light on the activated filter.

[0008] These and other aspects, objects, and features of the present disclosure will be understood and appreciated by those skilled in the art upon studying the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In the drawings:

[0010] FIG. **1**A is a front isometric view of a refrigerator having bacteria contaminated food;

[0011] FIG. **1**B is a front isometric view of a refrigerator having no food;

[0012] FIG. **1**C is a front isometric view of a refrigerator having a standard circulation fan;

[0013] FIG. **1**D is a front isometric view of a refrigerator having a first fan assembly and a second fan assembly according to some aspects of the disclosure;

[0014] FIG. **2** is a partially schematic fragmentary view of the fan assembly taken at location II in FIG. **1**D;

[0015] FIG. **3** is a rotating isometric view of a fan assembly according to some aspects of the present disclosure;

[0016] FIG. **4**A provides front and side view images of the fan assembly according to some aspects of the present disclosure;

[0017] FIG. **4**B provides front and side views of a refrigeration cabinet cavity according to some aspects of the present disclosure;

[0018] FIG. **5**A is a front view of a rear assembly panel according to some aspects of the present disclosure;

[0019] FIG. **5**B is a front view of an assembled rear panel assembly according to some aspects of the present disclosure;

[0020] FIG. **6**A is a rear isometric view of an assembly cover panel according to some aspects of the present disclosure;

[0021] FIG. **6**B is a rear view of the assembly cover panel provided in FIG. **6**A according to some aspects of the present disclosure;

[0022] FIG. **7** is an exploded side view of a fan assembly and refrigeration liner according to some aspects of the present disclosure;

[0023] FIG. **8**A is a front view of an alternative embodiment of a fan assembly according to some aspects of the present disclosure;

[0024] FIG. **8**B is an exploded side view of the fan assembly provided in FIG. **8**A according to some aspects of the present disclosure;

[0025] FIG. **9**A is a picture of the experimental set up of the nebulization of an inoculum solution using a fan assembly for fan filtration according to some aspects of the present disclosure;

[0026] FIG. **9**B is a distribution of microbial populations in a control using one fan assembly;

[0027] FIG. **9**C provides averages of the distribution of microbial populations at various different times;

[0028] FIG. **10** is a quantification of viable bacteria after incubation with different air filters at different time intervals;

[0029] FIG. **11**A provides a plot of the percentage of volatile organic compounds over a period of time using different air filters according to some aspects of the present disclosure; and

[0030] FIG. **11**B provides the percentage of total solid particulates over a period of time using different filtration systems according to some aspects of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] For purposes of description herein the terms "upper," "lower," "right," "left," "rear," "front," "vertical," "horizontal," and derivatives thereof shall relate to the device as oriented in FIG. **1**. However, it is to be understood that the device may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

[0032] As used herein, the term "and/or," when used in a list of two or more items, means that any one of the listed items can be employed by itself, or any combination of two or more of the listed items can be employed. For example, if a composition is described as containing components A, B, and/or C, the composition can contain A alone; B alone; C alone; A and B in combination; A and C in combination; B and C in combination; or A, B, and C in combination.

[0033] Referring to FIGS. **1**A-**11**B, the reference numeral **10** refers to a refrigerator. The refrigerator **10** includes a cabinet **14** coupled to one or more doors **18** forming a storage compartment **22**. The refrigerator **10** additionally includes a first fan assembly **26** positioned on an interior surface **30** of a first cabinet wall **34**, and a second fan assembly **38** positioned on the interior surface **30** of a second cabinet wall **42**. The first and second fan assemblies **26**, **38** each include: two or more circulation fans **46**; a filter coupled to a photocatalyst **54** to form an activated filter **50**; and a plurality of light emitting diodes (LEDs) **58** positioned to project light on the activated filter **50**. An air circulation path **62** configured to direct air born bacteria **66** and particulate matter **70** within the storage compartment **22** contemporaneously into the first and second fan assemblies **26**, **38** using the two or more circulation fans **46** and circulate filtered air into the storage compartment **22** through the activated filter **50** disposed in the air circulation path **62**.

[0034] The first and second fan assemblies **26**, **38** and/or the air purifying duct assembly **192** provide an antimicrobial technology for in-vitro time-dependent reduction of microbial populations after exposure to the activated filter **50** and corresponding UV and/or visible light LEDs **58**. The technology incorporated into these fan assemblies **26**, **38** includes the activated filter **50** and LEDs **58** providing an efficient air treatment capability that may interact with the deoxyribonucleic acid (DNA) and/or trigger a cascade of other biological reactions in harmful bacteria responsible for the spoilage of food stored at low temperatures in refrigerators. The disclosure herein provides a series of experiments performed according to the ASTM E 2315 and ISO 22196 international standards using minor modifications. In some aspects, the activated filter **50** includes the photocatalyst **54** made up of a photocatalytic nanostructured titanium dioxide (TiO_2) film, coating, or membrane deposited using sol-gel. The sol-gel is doped to impart the titanium dioxide (TiO_2) as the photocatalyst **54** that may be activated using visible light and/or an ultraviolet wavelength less than 833 nanometers (e.g., 280-700 nanometer wavelengths) using a 12 volt UV LED strip or panel (see FIG. **5**B) is provided. In some aspects, the activated filter **50** and corresponding photocatalyst **54** may be activated using an ultraviolet wavelength less than about 400 nm and/or visible light ranging from about 390 nm to about 700 nm.

[0035] Referring now to FIGS. **1**A-**1**D, a variety of different refrigerator environments were studied to determine how bacteria and other particulate matter may be introduced into the storage compartment **22** of the refrigerator **10**. Each of the refrigerators **10** is shown having the cabinet **14** with the storage compartment **22** enclosed by the cabinet **14** and a first and second door **18***a*, **18***b*. In the first test environment illustrated in FIG. **1**A, the introduction of bacterial contamination to the storage compartment **22** was accomplished by positioning a contaminated chicken breast **74** containing many different types of bacteria. The test environment provided in FIG. **1**A demonstrated that the bacteria growing on the contaminated chicken breast **74** did not spread to or reach any of plurality of petri dishes **78** proving that refrigerator bacterial contamination is likely not due to food cross-contamination, except for direct food contact.

[0036] In the second test environment illustrated in FIG. **1**B, the introduction of bacterial contamination to the storage compartment **22** was accomplished by circulating air from outside the refrigerator **10** by opening and closing the first and second refrigerator doors **18***a*, **18***b*. By opening and closing the refrigerator doors **18***a*, **18***b*, airborne bacteria **66** was introduced to the storage compartment **22** and was able to contact and grow in the petri dishes **78**. The refrigerator **10** in FIG. **1**B did not include any air filtration or circulation system. The test environment provided in FIG. **1**B demonstrates that bacteria introduced into the refrigerator **10** and corresponding foodstuffs is likely determined by the introduction of airborne bacteria **66** during refrigerator door **18** opening and closing.

[0037] In the third test environment illustrated in FIG. **1**C, the introduction of bacterial contamination to the storage compartment **22** was accomplished as described in FIG. **1**B, by opening and closing the refrigerator doors **18***a*, **18***b*. The additional variable introduced in FIG. **1**C includes a standard air filtration system **80** using only a single fan assembly which is currently implemented in many refrigerators. The test environment provided in FIG. **1**C demonstrated that the single fan assembly air filtration system had minimal to no noticeable effect on the airborne bacteria **66** introduced into the storage compartment **22** of the refrigerator **10**.

[0038] In the fourth test environment illustrated in FIG. **1**D, the introduction of bacterial contamination to the storage compartment **22** was accomplished as described in FIGS. **1**B and **1**C, by opening and closing the refrigerator doors **18***a*, **18***b*. The refrigerator **10** in FIG. **1**D additionally includes first and second fan assemblies **26**, **38**, each assembly equipped with circulation fans **46** and at least one activated filter **50** (see FIG. **2**) initiated by at least one UV LED **58** (see FIG. **5**B). The test environment provided in FIG. **1**D demonstrated that the combination of two fan assemblies **26**, **38** using UV activated filters **50** are able to reduce bacterial contamination in the storage compartment **22** by up to 70% more when compared to the environments provided in FIGS. **1**B and **1**C.

[0039] Referring now to FIG. **2**, a partially schematic fragmentary view of the fan assembly **26**, **38** is taken from the position marked II in FIG. **1**D. As shown, airborne bacteria **66** and/or particulate matter **70** scattered throughout the storage compartment **22** are directed along the air circulation path **62** into one of the two fan assemblies **26**, **38**. The air circulation path **62** generally flows between the area of the storage assembly **22** and the two fan assemblies **26**, **38** using two or more circulation fans **46** in each fan assembly **26**, **38**. As provided in FIG. **1**B, **1**C, and **1**D, the air introduced into the storage compartment **22** when opening the refrigerator doors **18***a*, **18***b* can include airborne bacteria **66** and/or particulate matter **70**. Once the refrigerator doors **18***a*, **18***b* and corresponding storage compartment **22** are closed, the air circulation path **62** formed by the fan assemblies **26**, **38** directs the airborne bacteria **66** and/or particulate matter **70** in through the circulation fans **46** and out through the activated filter **50** coupled to the photocatalyst **54**. As the airborne bacteria **66** and/or particulate matter **70** contact the activated filter **50**, one or more LEDs **58** (see FIG. **5**B) can project UV and/or visible light onto the photocatalysts **54** of the activated filter **50**. The photocatalyst **54** is activated by the UV light, which can then kill and/or damage the airborne bacteria **66**. The particulate matter **70** can additionally be removed by the activated filter **50**. The corresponding or resultant filtered air continues along the air circulation path **62** out through the filter **50** and back into the storage compartment **22** of the cabinet **14**. In some aspects, a controller (not shown) drives the circulation fans **46** and LED's **58** (see FIG. **5**B) as triggered by a pre-programmed schedule, the opening and closing of the refrigerator doors **18**, the detection of odor, bacteria **66**, and/or particulate matter **70** using, for example, a bio-sensor, and/or other triggers or factors known by one skilled in the art.

[0040] Referring now to FIG. **3**, a rotating isometric view of the fan assemblies **26**, **38** is provided. As shown, in some aspects, the fan assemblies **26**, **38** include a first intake **86**, an exhaust **90**, and a second intake **94**. The fan assemblies **26**, **38** are rotated 180° to show the various structural features and shape of the device according to some aspects of the present disclosure. As illustrated, the fan assemblies **26**, **38** each include a rear assembly panel **102** coupled to an assembly cover panel **146** that define the one or more intakes and exhausts in addition to the fixing members used to mount the internal hardware and the fan assemblies to the refrigerator **10**, respectively.

[0041] Referring now to FIG. **4**A, front and side views of the fan assemblies **26**, **38** are provided.

[0042] In some aspects, the dimensions of the fan assemblies **26**, **38** may include a width (X) of about 20 mm to about 60 mm or about 30 mm to about 50 mm. In some aspects, the width (X) of the fan assembly may be about 30 mm, about 40 mm, about 50 mm. The height (Y) of the fan assembly **26**, **38** may range from about 200 mm to about 600 mm or about 300 mm to about 500 mm. In some aspects, the height (Y) of the fan assembly may be about 300 mm, about 350 mm, about 398 mm, about 425 mm, or about 450 mm. The depth (Z) of the fan assembly **26**, **38** may range from about 5 mm to about 25 mm or about 10 mm to about 20 mm. In some aspects, the depth (Z) of the fan assembly may be about 10 mm, about 15 mm, or about 20 mm. In some aspects, the height (Y) is 398 mm, the width (Z) is about 40 mm, and the depth (Z) is about 16 mm.

[0043] Referring to FIG. **4**B, the front and side views of the cabinet cavity **82** is provided. In some aspects, the dimensions of the cabinet cavity **82** may include a width (a) from about 20 mm to about 60 mm or from about 30 mm to about 50 mm. In some aspects, the width (a) of the cabinet cavity **82** may be about 30 mm, about 40 mm, or about 50 mm. The height (b) of the cabinet cavity **82** may range from about 200 mm to about 600 mm or from about 300 mm to about 500 mm. In some aspects, the height (b) of the cabinet cavity **82** may be about 300 mm, about 350 mm, about 398 mm, about 425 mm, or about 450 mm. The depth (c) of the cabinet cavity **82** may range from about 5 mm to about 25 mm, or from about 10 mm to about 20 mm. In some aspects, the depth (c) of the cabinet cavity **82** may be about 10 mm, about 15 mm, or about 20 mm. In some aspects, the height (b) is 399 mm, the width is about 41 mm, and the depth is about (c) is about 17 mm.

[0044] Referring now to FIG. **5**A, a front view of the rear assembly panel **102** is provided according to some aspect of the present disclosure. The rear assembly panel **102** includes a distal portion **106** at each end of the rear assembly panel **102** and a central portion **110**. The rear assembly panel **102** further includes one or more cover fixing members **114**, two or more fan fixing members **118**, a power cable pass through **122** and an assembly fixing member **126**. The one or more cover fixing members **114** may be used to couple the assembly cover panel **146** (see FIG. **6**A) when used in combination with one or more coupling members. The coupling members **172** (see FIG. **7**) may include any means known in the art used for coupling different members together, for example, but not limited to screws, bolts, nails, clips, snaps, and/or ties. The two or more fan fixing members **118** may be used to couple the two or more circulation fans **46** to the rear panel assembly when used in combination with one or more coupling members **172**. The assembly fixing members **126** may be used to couple the rear assembly panel **102** to the cabinet cavity **82** of the storage compartment **22**. One or more coupling members **172** may be used in com-

bination with the assembly fixing members **126** to position and retain the rear assembly panel **102** in the cabinet cavity **82**.

[0045] Referring now to FIG. **5**B, a front view of an assembled rear panel assembly **128** is provided. The assembled rear panel assembly **128** includes the rear assembly panel **102** coupled to the circulation fans **46** positioned at each distal portion **106** of the rear assembly panel **102**. In addition, the rear assembly panel **102** is coupled to an LED panel **130** having one or more LEDs **58**. The one or more LEDs **58** may project visible light, UV-A light, UV-B light, UV-C light, or a combination thereof onto the photocatalyst **54**. The assembled rear assembly panel **128** is simplified by being able to weld both an external power supply cable **134** and device wiring **138** to LED conductive tracks **142** of the LED panel **130** and the circulation fans **46**. Construction and wiring in this manner allows the assembled rear panel assembly **128** to be achieved using only six tin solders. In some aspects, one or more LED panels **130** having one or more UV LEDs **58** and/or white light LEDs **58** may be coupled and wired into the rear assembly panel **102**. For example, in some aspects, the assembled rear panel assembly **128** may include one LED panel **130** having white light LEDS for ambient lighting in the refrigerator **10** and a second LED panel **130** having UV LEDs **58** used to activate the photocatalyst **54** of the activated filter **50** (see FIG. **2**). The number of LED panels **130** and/or corresponding LEDs (both UV and other wavelengths) are not meant to be limiting and may be varied depending on the final design and corresponding functionality of the refrigerator **10**.

[0046] Referring now to FIG. **6**A, a rear isometric view of the assembly cover panel **146** is provided. The assembly cover panel **146** includes two distal portions **106** and the central portion **110**. The assembly cover panel **146** additionally includes a cover fixing member **150**, a first distal vent **154**, a second distal vent **158**, and a central vent **162**. The assembly cover panel **146** also includes two or more side panels **166** to help couple and position the assembly cover panel **146** to the assembled rear panel assembly **102** (see FIG. **5**B) in addition to forming side walls.

[0047] Referring now to FIG. **6**B, a rear view of the assembly cover panel **146** is illustrated coupled to the activated filter **50**. In some aspects, the first and second distal vents **154**, **158** may have a square shape with a height and width designed to match the size, intake and/or pull of the circulation fans **46**. In some aspects, the height and width of the first and second distal vents **154**, **158** may range from about 20 mm to about 250 mm, from about 20 mm to about 150 mm, or from about 20 mm to about 50 mm. In some aspects, the height and width of the first and second distal vents **154**, **158** may be about 50 mm, about 40 mm, or about 30 mm. The length of the activated filter may range from about 100 mm to about 130 mm. In some aspects, the activated carbon filter may have a length of about 115 mm and a width of about 38 mm. The shape and associated dimensions of the distal vents **154**, **158** and central filter vent **162** are not meant to be limiting and may be changed to meet the desired design and properties of the refrigerator **10**.

[0048] Referring now to FIG. **7**, an exploded side view of the fan assemblies **26**, **38** and corresponding refrigeration liner **82** is provided. As illustrated, the assembly cover panel **146** is coupled to the activated filter **50**. In some aspects, the activated filter **50** may include a framing member **170** used to stabilize the edges of the activated filter **50** and facilitate coupling of the activated filter **50** to the assembly cover panel **146**. A first circulation fan **46***a* and a second circulation fan **46***b* are coupled to the rear assembly panel **102** through the fan fixing members **118** and coupling member **172** in addition to the LED panel **130** including the plurality of LEDs **58**. The side panels **166** and end side panels **174** are positioned with respect to each other to butt up against each other to form a uniform side wall for the fan assemblies **26**, **38**. The fan assemblies **26**, **38** are then positioned into the cabinet cavity **82** where the fan assembly **26**, **38** may be positioned flush with the interior surface **30** of the cabinet walls **34**, **42** or refrigerator doors **18***a*, **18***b* (see FIG. **1**D). In some aspects, the cabinet cavity **82** may be coupled to a flat interior surface **30** on the cabinet walls **34**, **42** where the installed fan assemblies **26**, **38** would stick out from the interior surface **30** to form a ledge or protrusion from the cabinet walls **34**, **42**. In other aspects, the cabinet cavity **82** may be a cutout or indentation in the cabinet walls **34**, **42** where the interior surface **30** forms an indentation formed to receive the fan assemblies **26**, **38** to form an even or flat surface on the cabinet walls **34**, **42**. In some aspects, the first and second fan assemblies **26**, **38** are each positioned in the cabinet cavity **82** on the interior surface **30** of the first and second cabinet walls **34**, **42**. In other aspects, the first and second fan assemblies **26**, **38** may each be positioned on a front lip or edge of the cabinet cavity **82** on the interior surface **30** of the first and second cabinet walls **34**, **42** configured to direct the air circulation path **62** (see FIG. **2**) and corresponding fresh outside air into the first and second fan assemblies **26**, **38** before entering the cabinet cavity **82**.

[0049] The activated filter **50** may be formed by coating, coupling, and/or adsorbing the photocatalyst **54** onto a filter. In some aspects, the filter or filter membrane may be made from a polymer fiber, a glass fiber, a ceramic fiber, or a combination thereof. The polymer fiber may include polyethylene (PE), polypropylene (PP), polyester, polyamide, polyvinylpolypyrrolidone (PVPP), polystyrene, polyimides, naturally occurring polymers, thermoplastics, thermosets, or combinations thereof. In some aspects, the polymer fiber used to make the filter is polyethylene or a blend of polyethylene. In some aspects, wherein the activated filter **50** is a polymeric filter coupled to a UV activated photocatalyst. The photocatalyst **54** and UV activated photocatalyst may include titanium dioxide (TiO_2), zinc oxide (ZnO), tin oxide (SnO_2), cesium oxide (CeO_2), zinc titanium dioxide ($ZnTiO_2$), copper titanium dioxide ($CuTiO_2$), silver titanium dioxide ($AgTiO_2$), iron titanium dioxide ($FeTiO_2$), or combinations thereof. In some aspects, the photocatalyst **54** includes titanium dioxide (TiO_2). The photocatalyst **54** may be coated, coupled, and/or adsorbed onto the filter using a variety of techniques including, for example, a sol gel approach. In some aspects, the activated filter **50** includes a polyethylene filter having a photocatalytic titanium dioxide (TiO_2) film deposited on its surface forming a nanostructured TiO_2 layer using sol gel. In other aspects, the activated filter **50** may further include an activated carbon and/or carbon black particles used to help filter the polluted air. In some aspects, the activated filter **50** is an activated carbon filter coupled to a titanium oxide (TiO_2) doped sol gel. The TiO_2 or other photocatalyst **54** doped sol gel may include any sol gel or sol gel technique or method known in the art. In some aspects, the rear assembly panel **102** and the assembly cover panel **146** may both be coupled to the photocatalyst **54** to provide an activated surface. The pho-

tocatalyst **54** may be operatively coupled to the rear assembly panel **102** and/or the assembly cover panel **146** using sol gel techniques or any other coating applications known by one skilled in the art (e.g., spin coating, solvent evaporation, spray coating, brushing, etc.).

[0050] The LEDs **58** mounted on the LED panel **130** may be positioned or spaced apart from the activated filter **50** by from about 0.5 cm to about 4 cm or from about 1 cm to about 3 cm. In some aspects, the LEDs **58** may be spaced apart from the activated filter **50** by about 0.5 cm, about 1 cm, about 1.5 cm, about 2 cm, about 2.5 cm, about 3 cm, about 3.5 cm, or about 4 cm. In some aspects, the LED panel **130** and corresponding LEDs **58** may be mounted or positioned directly in front of the activated filter **50** having the photocatalyst **54**. In some aspects, the LEDs **58** generate UV light that can kill bacteria without the use of the photocatalyst **54**. In other aspects, the photocatalyst **54** is activated when exposed to UV and/or visible light generated and projected by the LEDs **58** where the activated photocatalyst **54** may be able to kill and/or damage the bacteria. In some aspects, the LEDs **58** can project a wavelength from about 100 nm to about 405 nm, from about 250 nm to about 405 nm, from about 280 nm to about 405 nm, from about 315 nm to about 405 nm, from about 365 nm to about 405 nm, or from about 395 nm to about 405 nm. In some aspects, the plurality of LEDs **58** are UV-A LEDs that are positioned to project UV-A light on the activated filter **50**. In other aspects, the plurality of LEDs **58** are UV-B LEDs that are positioned to project UV-B light on the activated filter **50**. In still other aspects, the plurality of LEDs **58** are UV-C LEDs that are positioned to project UV-C light on the activated filter **50**. In some aspects, the plurality of LEDs **58** are positioned to project UV-A light (315 nm to 400 nm), UV-B light (280 nm to 315 nm), UV-C light (100 nm to 280 nm), or a combination thereof on the activated filter **50**. In other aspects, the LEDs **58** may project UV-A, UV-B, UV-C, or a combination of light thereof and/or visible light in the range from about 400 nm to about 700 nm. In still other aspects, the LEDs **58** may project visible light in the range from about 400 nm to about 700 nm.

[0051] As will be provided in more detail in the description for FIGS. **9**A-**9**C, two or more fan assemblies **26**, **38** may be required to provide the air circulation path **62** necessitated to remove a higher percentage of airborne bacteria **66**, particulate matter **70**, volatile organic compounds (VOCs), and molds from the storage compartment **22** of the refrigerator **10**. As provided in FIGS. **1**C, **9**B, and **9**C, the use of just one circulation fan or fan assembly may be unable to provide an air circulation path that can effectively eliminate enough of the airborne bacteria **66** and particulate matter **70**. In some aspects, two or more fan assemblies **26**, **38** may be positioned on opposing first and second cabinet walls **34**, **42**, positioned on the first and second doors **18***a*, **18***b*, or positioned on any two opposing interior surfaces where the first and second fan assemblies **26**, **38** work in a complementary manner to provide the improved air circulation path **62**. In some aspects, the first and second cabinet walls **34**, **42** are opposing walls or walls that are facing each other to complementary circulate the air present in or coming into the storage compartment **22**. The air circulation path **62** may better direct the airborne bacteria **66**, particulate matter **70**, volatile organic compounds (VOCs), and molds into the first and second fan assemblies **26**, **38** to be filtered. In some aspects, the first cabinet wall **34** opposes the second cabinet wall **42**. In some aspects, the air circulation path **62** is configured to direct bacteria throughout the central area of the storage compartment **22**

[0052] Unlike the limited filtering ability provided using the single standard filtration system **80** (see FIG. **1**C), the combination of the first and second fan assemblies **26**, **38** are configured to provide the air circulation path **62** that directs the airborne bacteria **66**, particulate matter **70**, volatile organic compounds (VOCs), and/or molds simultaneously or contemporaneously into the fan assemblies **26**, **38** using the two or more circulation fans **46** to direct the polluted air through the activated filter **50** irradiated by UV and/or visible light projected from the LEDs **58** to filter and clean the polluted air to circulate filtered air into the storage compartment **22** of the refrigerator **10**. In some aspects, the two or more circulation fans **46** are configured to direct the air circulation path **62** in through the two or more circulation fans **46** and out through the activated filter **50** where the air circulation path **62** is configured to direct bacteria positioned in the central area of the storage compartment **22** into the first and second fan assemblies **26**, **38**.

[0053] Although the various aspects of the fan assemblies **26**, **38** disclosed herein generally direct the air circulation path **62** into the fan assemblies **26**, **38** using the two or more circulation fans **46**, in other aspects, the two or more circulation fans **46** are configured to direct the air circulation path **62** in through the activated filter **50** and out through the two or more circulation fans **46**. The reversal of the air circulation path **62** is considered to be within the scope of the disclosure of the present invention.

[0054] In some aspects, the first and second fan assemblies **26**, **38** are able to provide at least a 50% microbial reduction in one minute, at least a 50% microbial reduction in three minutes, or at least a 50% microbial reduction in ten minutes. In other aspects, the first and second fan assemblies **26**, **38** are able to provide at least a 60% microbial reduction in one minute, at least a 60% microbial reduction in three minutes, or at least a 60% microbial reduction in ten minutes. In still other aspects, the first and second fan assemblies **26**, **38** are able to provide at least a 70% microbial reduction in one minute, at least a 70% microbial reduction in three minutes, or at least a 70% microbial reduction in ten minutes. In other aspects, the first and second fan assemblies **26**, **38** are able to provide at least an 80% microbial reduction in one minute, at least an 80% microbial reduction in three minutes, or at least an 80% microbial reduction in ten minutes.

[0055] Referring now to FIG. **8**A, a front view of an alternative aspect of the fan assemblies **26**, **38** is provided. The fan assemblies **26**, **38**, according to other aspects of the current disclosure, may include the first intake **86**, a first exhaust **90***a*, the second intake **94**, a second exhaust **90***b*, and a third intake **178**. In some aspects, the number of intakes and the number of exhausts may be limited to the number of circulation fans **46** and activated filters **50** incorporated into the fan assembly **26**, **38** based on the design and/or final air circulation properties desired for the refrigerator **10**. In some aspects, the number of intakes may be two, three, four or more while the number of exhausts may include one, two, three, four, or more where the intakes and exhausts may be positioned with respect to each other in any combination.

[0056] Referring now to FIG. **8**B, an exploded side view of the fan assemblies **26**, **38** provided in FIG. **8**A and corresponding refrigeration liner **82** is provided. As illus-

trated, the assembly cover panel **146** is coupled to two activated filters **50***a*, **50***b* having framing members to stabilize the edges and facilitate coupling of the activated filters **50***a*, **50***b* to the assembly cover panel **146**. The assembly cover panel **146** includes a first fan vent **154**, a first filter vent **162***a*, a second fan vent **158**, a second filter vent **162***b*, and a third filter vent **182**. The first circulation fan **46***a*, second circulation fan **46***b*, and a third circulation fan **46***c* are coupled to the rear assembly panel **102** using coupling members **172** in addition to a first LED panel **130***a* having a plurality of white light LEDs **186**. In addition, a second LED panel **130***b* having the plurality of UV LEDs **58** is also positioned on the rear panel assembly **102** to project UV light on the photocatalyst **54** of the activated filters **50***a*, **50***b*. The side panels **166** and end side panels **174** are positioned up against each other to form solid siding portions for the fan assemblies **26**, **38**. The fan assemblies **26**, **38** may be then positioned into the cabinet cavity **82** where the fan assembly **26**, **38** may be positioned flush with the interior surface **30** of a cabinet wall **34**, **42** or refrigerator doors **18***a*, **18***b*.

[0057] According to another aspect of the present disclosure, an air purifying fan assembly **26** is provided. The air purifying fan assembly **26** includes the rear assembly panel **102** and the assemble cover panel **146**. The assemble cover panel **146** includes one or more air intakes **86**, **94** and one or more air exhausts **90***a*, **90***b;* one or more circulation fans **46** positioned inside the rear assembly panel **102** and the assemble cover panel **146** and adjacent to the one or more air intakes **86**, **94** or one or more air exhausts **90***a*, **90***b;* one or more activated filters **50** having a sol gel photocatalyst **54** and the activated carbon. The activated filter **50** is positioned in line or directly across from the one or more air exhausts and one or more LEDs **58** positioned to project light on the activated filter **50**.

[0058] It is understood that the descriptions outlining and teaching the first and second fan assemblies **26**, **38** previously discussed, which can be used in any combination, apply equally well to the air purifying fan assembly **26** described herein.

EXAMPLES

[0059] The following examples and their corresponding data represent certain non-limiting examples of the first and second fan assemblies **26**, **38** used in conjunction with each other to effectively filter air in the storage compartment **22** of the refrigerator **10**.

Materials

[0060] All chemicals, bacteria, growth media, and other constituents were obtained from commercial suppliers and used as provided.

[0061] The antibacterial refrigerator **10** and its corresponding air purifying assemblies defined by the fan assemblies **26**, **38** and/or the air purifying duct assembly **192** are designed to remove contaminants such as odor, toxic particles, and pathogens. Examples of key substances that are typically removed through this air-treatment process include parasites, bacteria, algae, viruses, fungi, ethylene, and other food related chemical pollutants.

Air Circulation and Fan Positioning Examples

[0062] Referring now to FIGS. **9**A-**9**C, a description of the experimental set up for the nebulization of an inoculum solution using the fan assemblies **26**, **38** for air filtration in the storage compartment **22** is provided. The inoculum solution used in the experiments illustrated in FIG. **9**A includes a microbial-loaded saline solution (50-70 ml) recovered during hand washing procedures. To quantify the overall microbial load of the test inoculum, the count of viable microorganisms was determined by means of the pour plate culture method. Briefly, the number of viable microorganisms was counted on Luria-Bertani broth (LB) agar petri dishes (θ=60 mm) after serial ten-fold dilutions of the test inoculum suspensions and plating. Plating was performed in duplicate, and the number of viable microorganisms was determined according to the following equation: $N=(C\times D)/V$ where N=number of viable bacteria per ml; C=average plate count for the duplicate plates (e.g., number of colony forming units, CFU, determined in each LB-agar plate); D=dilution factor for the plate counted; and V=volume of test inoculum (in ml).

[0063] As illustrated in FIG. **9**A, the inner compartment of a refrigerator (Whirlpool, BLFV8121W model) and the antibacterial device were first cleaned to remove any gross contamination using a quaternary benzyl ammonium disinfectant where the same cleaning procedure was performed on the storage compartment **22** in between each experiment. Following the cleaning procedure, the antibacterial device was placed inside the refrigerator and the refrigerator was left to equilibrate at 40° C. for at least 24 hours. Before nebulization of the inoculum solution was provided, 12 sterile LB-agar petri dishes **78** (θ=60 ml, N=12) were placed inside the refrigerator compartment. The experiments included the nebulization of 450 microliters (μL) of inoculum inside the refrigerator through a small hole made on the front wall of the refrigerator door (θ=1.2 cm). Immediately upon the nebulization of the inoculum solution, a test air filtration device **190** was switched on and kept running for a variety of different time periods (e.g., 1 min, 3 min, 10 min) after a microbial nebulization. Control experiments were carried out in the same conditions, but the test air filtration device **190** was not activated. In each of the experiments, the LB-agar petri dishes **78** were closed about 10 minutes after the microbial nebulization and incubated for the first 24 hrs at 37° C., and then for an additional 48 hrs at room temperature (RT). The number of viable microorganisms was then counted on LB-agar petri dishes. All of the experiments noted were performed in triplicate. Data was normalized with respect to the number of viable counts and control samples (CTRL, e.g., air filtration device turned off), considering the number of microorganisms in such condition as 100%. Results are expressed as mean±standard deviation (SD).

[0064] Referring now to FIG. **9**B, the distribution results of the microbial population measured in colony forming units (CFU) for the cultured control experiments are provided. A homogeneous distribution was found for each respective row, which seemed to be dependent on the distance from the nebulization inlet port and/or the test air filtration device **190**. When the test air filtration device **190** was permitted to run for longer durations, the number of microorganisms decreased from about 50% eliminated to about 75% eliminated after one minute, and this decrease in CFU was maintained over time. This corresponding decrease was shown to be at least partly dependent on the distance from the test air filtration device **190**. The row of LP-agar petri dishes **78** positioned closest to the test air

filtration device **190** (Row **4**) contained the highest microbial population relative to Rows **1-3** while lowest microbial population was observed in the row furthest from the test air filtration device **190** (Row **1**). The uniform difference and disparity in microbial populations based on the difference in distance between the corresponding rows and the test filtration device **190** supports the need for two or more air filtration devices **26**, **38** as described herein.

[0065] Referring now to FIG. **9**C, the viable CFU counts for each of the four rows (Rows **1-4**) were averaged and plotted against time as the test air filtration device **190** was operated to filter the storage compartment **22**. Consistent with the data provided in FIG. **9**B, when the filtration device was run for a longer period of time (e.g., 10 min vs. 3 min vs 1 min), the number of microorganisms decreased from about 50 to about 75% already after one minute and was generally maintained over the longer periods of time. Again consistent with the data provided in FIG. **9**B, the decrease in CFU counted is dependent on the distance from the test air filtration device **190** where the decrease in CFU was more pronounced or greater at distances further away from the test air filtration device **190**.

Filter Reduction of Microbial Populations

[0066] Referring now to FIG. **10**, an assessment of the in vitro time-dependent reduction of a microbial population after exposure to different activated filters **50** having the photocatalyst **50** including a TiO_2 doped sol gel. The antibacterial effectiveness of a variety of filters was assessed using three different filters: 1) Filter 1, a polymeric filter having no photocatalyst **50** incorporated, 2) Filter 2, a polymeric filter treated with a first TiO_2 doped sol gel as the photocatalyst **50**; and 3) Filter 3, a polymeric filter treated with a second TiO_2 doped sol gel as the photocatalyst **50**. The activated filters **50** were put in contact with *E. coli* Gram-negative bacteria that, together with *Pseudomonas* and *Salmonellas*, are well-known food contaminants. All the experiments were performed according to the ASTM E 2315 and ISO 22196 international standards with minor modifications as described herein. For example, the bacterial load was increased in order to mimic the effect of the long-term exposure to food contaminants. The antibacterial activity of the devices was assessed at 4° C. and at some sampling intervals (i.e., 30 min, 60 min, 120 min, and 19 h). The results demonstrated that Filters 2 and 3 were found fully effective in killing all detectable bacteria within 30 minutes of incubation. In addition, antimicrobial efficiency was also displayed for Filter 1 although a slower kinetic pattern was observed relative to Filters 2 and 3.

[0067] The study was performed using three different air filters/devices: 1) Filter 1; 2) Filter 2; and 3) Filter 3. Disc-shaped specimens (Ø=15 mm, surface area=1.75 cm2) were cut from each kind of polymeric filter and transferred into a sterile 24-well plate.

[0068] An aliquot of Gam-negative *E. coli* (strain JM109, cat. 53323, ATCC) was transferred onto a sterile Lysogeny broth agar (LB-A) plate and incubated at 37° C. for 20 hrs to allow bacterial colonies to grow. After incubation, using a sterile inoculating loop, a single colony was transferred into a 50 mL polypropylene tube (Corning) filled with 5 mL of sterile LB liquid growth medium and incubated overnight (ON) at 37° C. under shacking, to produce sufficient microbial suspension. The number of bacteria within the microbial suspension was roughly estimated by measuring the optical density of the suspension at λ=600 nm (OD_{600nm}) by means of a Nanodrop 2000 spectrophotometer (Thermo Scientific). Afterwards, the inoculum was prepared diluting the microbial suspension in sterile LB to an OD_{600nm}=0.02. Bacteria were next allowed to grow until they reached an OD_{600nm}=0.6 (exponential growth phase). The inoculum was finally centrifuged for 10 min at 4,000 g, washed once in sterile deionized water (dH2O), pelleted again and the cells suspended in dH2O to give a bacterial concentration of $\approx 5\times10^8$ bacteria/mL.

[0069] Following a pre-incubation at 4° C., the test specimens were brought into contact with the inoculum suspension. The experiments were carried out according to the ASTM E 2315 (Assessment of Antimicrobial Activity Using a Time-Kill Procedure) [1] and ISO 22196 (Measurement of antibacterial activity on plastics and other non-porous surfaces) [2] standards, with slight modifications that are in the 10^3 times higher bacterial load and the temperature at which the experiments were performed (e.g., 4° C. instead of 35±1° C.).

[0070] Each test specimen (Filter 1 samples, n=3; Filter 2, n=2; Filter 3, n=2) was inoculated with 1 mL of the bacterial inoculum and incubated at 4° C. for different durations (i.e., 30 min, 60 min, 120 min and 19 h). During the experiments, the Filters 2 and 3 having the photocatalyst 54 added using a sol gel approach underwent UV irradiation (i.e., the final device setup). Bacteria inoculated in wells without any filter were used as positive controls (untreated bacteria).

[0071] At different time intervals, a 30 μL aliquot of bacterial suspension kept in contact with the test specimens was removed from each well, serially diluted in sterile dH2O (1:10, 1:100, 1:1,000), plated onto LB-A P60 plates and incubated ON at 37° C. to allow bacterial colonies to grow. After incubation, the number of viable bacteria was evaluated by counting the colony forming units (CFU) grown on agar plates. The number of viable cells was standardized to the plated area (cm^2) and the dilution factor. Finally, data were normalized with respect to the number of viable cells in control samples at each time step, considering the number of untreated bacteria as 100%. Results were expresses as mean±standard error of means (SEM).

[0072] The antibacterial effectiveness of the three filters/devices was evaluated using the Time-Kill procedure, assessed by measuring the reduction of the microbial population over time. The results are illustrated in FIG. **10**. Upon analyzing the graph, the highest antimicrobial activity was observed for the Filter 2 and 3 activated filters **50** having the photocatalyst **54**. After 30 min of incubation for Filters 2 and 3, no viable bacteria was detected. As the maximum efficiency was found at the shortest duration, this antibacterial behavior was maintained thereafter for Filters 2 and 3. A time-killing effect was observed for the Filter 1 samples, although when in contact with this kind of filter having no active photocatalyst incorporated, the number of viable cells decreased up to ≈40% already after 30 min of incubation, and it dropped to 5% after 120 min. After 19 hrs of incubation, only 0.2% of bacteria were viable.

Reduction of Volatile Organic and Particulate Matter Examples

[0073] Referring now to FIGS. **11**A and **11**B, a test monitoring the Total Solid Particulate (TSP) and Volatile Organic Compounds (VOC) in a confined environment that is arti-

ficially polluted to evaluate the effectiveness of different decontamination devices for household refrigerators is illustrated.

[0074] The following five purification and air filtration devices were tested: **1**) a Static control environment using no purification and/or air filtration device; 2) Ozonetor; 3) Filter 1, a polymeric filter having no photocatalyst **50** incorporated, 4) Filter 2 activated using UV LEDs, a polymeric filter treated with a first TiO_2 doped sol gel as the photocatalyst **50**; and 5) Filter 3 activated using UV LEDs, a polymeric filter treated with a second TiO_2 doped sol gel as the photocatalyst **50**.

[0075] Tests were performed in a Glove Box (100 liters per volume) that was polluted by burning about ¼ of a Marlboro cigarette that was able to rapidly generate a large amount of TSP and VOC. The following testing procedure was used: ignition of cigarette, immediate closure of the Glove Box, cigarette combustion, waiting for 15 minutes, switching on the Ozonetor or filter fan, monitoring of up to 120 minutes of TSP content using an Aerocet 531, Met One Instruments, Inc., or monitoring up to 120 minutes of VOC content using a DSIAQ-PLUS-PPC, Gray Wolf Sensing Solutions.

[0076] Referring still to FIGS. **11**A and **11**B, the static control and Ozonetor treatments each were able to reduce the VOC by up to 15% over 120 minutes and had no significant decrease in the TSP during the duration of the experiment. The Filter 1 polymeric filter having no photocatalyst **50** incorporated was able to reduce the VOC by up to about 20% over 120 minutes and the TSP by up to 40% over 120 minutes. The Filter 2 activated with UV LEDs using a polymeric filter treated with a first TiO_2 doped sol gel as the photocatalyst **50** was able to reduce the VOC by up to about 20% over 120 minutes and the TSP by up to 50% over 120 minutes. The Filter 3 activated with UV LEDs using a polymeric filter treated with a first TiO_2 doped sol gel as the photocatalyst **50** was able to reduce the VOC by up to about 20% over 120 minutes and the TSP by up to 50% over 120 minutes.

[0077] In some aspects, the activated filter **50** coupled to the photocatalyst **54** (e.g. TiO_2) that is activated using UV LEDs **58** may be able to reduce the VOCs in the storage compartment **22** of the refrigerator **10** by up to about 10%, about 15%, about 20%, or about 25% in 40 minutes, 60 minutes, 80 minutes, 100 minutes, or 120 minutes or less. In some aspects, the activated filter **50** coupled to the photocatalyst **54** (e.g. TiO_2) that is activated using UV LEDs **58** may be able to reduce the TSP in the storage compartment **22** of the refrigerator **10** by up to about 10%, about 15%, about 20%, about 25%, about 30%, about 35%, about 40%, or about 45%, in 40 minutes, 60 minutes, 80 minutes, 100 minutes, or 120 minutes or less.

[0078] It will be understood by one having ordinary skill in the art that construction of the described device and other components may not be limited to any specific material. Other exemplary aspects of the device disclosed herein may be formed from a wide variety of materials, unless described otherwise herein.

[0079] For purposes of this disclosure, the term "coupled" (in all of its forms, couple, coupling, coupled, etc.) generally means the joining of two components (electrical or mechanical) directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two components (electrical or mechanical) and any additional intermediate members being integrally formed as a single unitary body with one another or with the two components. Such joining may be permanent in nature or may be removable or releasable in nature unless otherwise stated.

[0080] It will be understood that any described processes or steps within described processes may be combined with other disclosed processes or steps to form structures within the scope of the present device. The exemplary structures and processes disclosed herein are for illustrative purposes and are not to be construed as limiting.

[0081] It is also important to note that the construction and arrangement of the elements of the device as shown in the exemplary embodiments is illustrative only. Although only a few embodiments of the present innovations have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements shown as multiple parts may be integrally formed, the operation of the interfaces may be reversed or otherwise varied, the length or width of the structures and/or members or connector or other elements of the system may be varied, the nature or number of adjustment positions provided between the elements may be varied. It should be noted that the elements and/or assemblies of the system may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Accordingly, all such modifications are intended to be included within the scope of the present innovations. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the desired and other exemplary embodiments without departing from the spirit of the present innovations.

[0082] It is also to be understood that variations and modifications can be made on the aforementioned structure without departing from the concepts of the present invention, and further it is to be understood that such concepts are intended to be covered by the following claims unless these claims by their language expressly state otherwise.

[0083] The above description is considered that of the illustrated embodiments only. Modifications of the device will occur to those skilled in the art and to those who make or use the device. Therefore, it is understood that the embodiments shown in the drawings and described above is merely for illustrative purposes and not intended to limit the scope of the device, which is defined by the following claims as interpreted according to the principles of patent law, including the Doctrine of Equivalents.

What is claimed is:

1. A refrigerator comprising:

a cabinet coupled to one or more doors forming a storage compartment;

a first fan assembly positioned on an interior surface of a first cabinet wall;

a second fan assembly positioned on the interior surface of a second cabinet wall wherein the first and second fan assemblies each comprise:

two or more circulation fans;

a filter coupled to a photocatalyst to form an activated filter; and

a plurality of LEDs positioned to project light on the activated filter; and

an air circulation path configured to direct airborne bacteria and particulate matter within the storage compartment contemporaneously into the first and second fan assemblies using the two or more circulation fans and circulate filtered air into the storage compartment through the activated filter disposed in the air circulation path.

2. The refrigerator according to claim **1**, wherein the plurality of LEDs project visible light, UV-A light, UV-B light, UV-C light, or a combination thereof onto the photocatalyst.

3. The refrigerator according to claim **1**, wherein the activated filter is an activated carbon filter coupled to a titanium oxide (TiO_2) doped sol gel.

4. The refrigerator according to claim **1**, wherein the activated filter is a polymeric filter coupled to a UV activated photocatalyst.

5. The refrigerator according to claim **1**, wherein the second cabinet wall opposes the first cabinet wall.

6. The refrigerator according to claim **1**, wherein the two or more circulation fans are configured to direct the air circulation path in through the two or more circulation fans and out through the activated filter.

7. The refrigerator according to claim **1**, wherein the two or more circulation fans are configured to direct the air circulation path in through the activated filter and out through the two or more circulation fans.

8. The refrigerator according to claim **1**, wherein the first and second fan assemblies are each positioned in a cabinet cavity on the interior surface of the first and second cabinet walls.

9. The refrigerator according to claim **1**, wherein the airborne bacteria and particulate matter are reduced by at least 60% within one minute.

10. A refrigerator, comprising:

a cabinet coupled to one or more doors wherein the cabinet includes a storage compartment;

two or more fan assemblies positioned on an interior surface of the cabinet, the one or more doors, or a combination thereof, wherein the fan assemblies each comprise:

one or more circulation fans;

a photocatalyst coupled to one or more filters forming an activated filter; and

a plurality of LEDs positioned to project light on the light activated photocatalyst;

an air circulation path configured to direct airborne bacteria and particulate matter within the storage compartment contemporaneously into the two or more fan assemblies using the one or more circulation fans and circulate filtered air into the storage compartment through the activated filter disposed in the air circulation path.

11. The refrigerator according to claim **10**, wherein the photocatalyst is titanium dioxide (TiO_2).

12. The refrigerator according to claim **10**, wherein the plurality of LEDs project visible light, UV-A light, UV-B light, UV-C light, or a combination thereof onto the photocatalyst.

13. The refrigerator according to claim **10**, wherein the two or more fan assemblies are positioned on two or more interior surfaces of opposing cabinet walls or proximate an edge of the cabinet.

14. The refrigerator according to claim **10**, wherein the one or more circulation fans are configured to direct the air circulation path in through one or more intakes of the fan assembly and out through one or more exhausts.

15. The refrigerator according to claim **10**, wherein the one or more circulation fans include two, three, or four circulation fans.

16. The refrigerator according to claim **10**, wherein the airborne bacteria and/or odor are reduced by at least 60% within ten minutes.

17. An antibacterial fan assembly comprising:

a rear assembly panel and an assembly cover panel wherein the assembly cover panel includes one or more air intakes and one or more air exhausts;

one or more circulation fans positioned between the rear assembly panel and assembly cover panel;

an activated filter having a photocatalyst and an activated carbon wherein the activated filter is positioned in circulation with the one or more air exhausts; and

one or more LEDs positioned to project light on the activated filter.

18. The antibacterial fan assembly of claim **17**, wherein the LEDs are positioned to illuminate the activated filter using a UV wavelength from about 280 nm to about 405 nm.

19. The antibacterial fan assembly of claim **17**, wherein the one or more circulation fans are configured to direct an air circulation path configured to direct airborne bacteria and particulate matter within a storage compartment contemporaneously into two or more of the antibacterial fan assemblies using the one or more circulation fans and circulate filtered air into the storage compartment through the activated filter disposed in the air circulation path.

20. The antibacterial fan assembly of claim **17**, wherein the photocatalyst is a titanium oxide (TiO_2) doped sol gel.

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