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(54) **REFRIGERATOR WITH ULTRAVIOLET
LIGHT EMITTING DIODE**

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(57) **ABSTRACT**

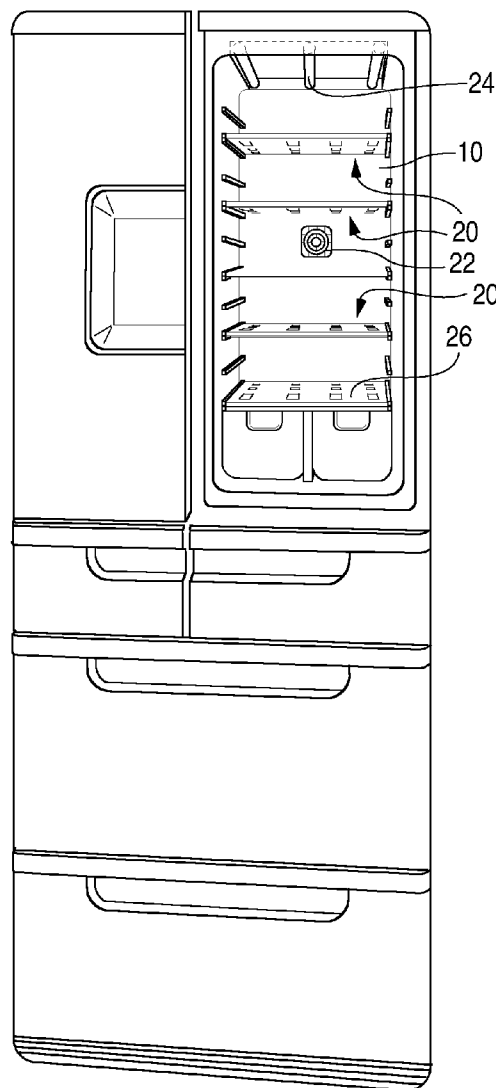
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Embodiments of the invention include a sealed compartment and a door disposed on a side of the sealed compartment, and a cooler for cooling an interior of the sealed compartment. At least one light emitting diode configured to emit light having a peak wavelength in the ultraviolet range is positioned to emit ultraviolet light in the sealed compartment.



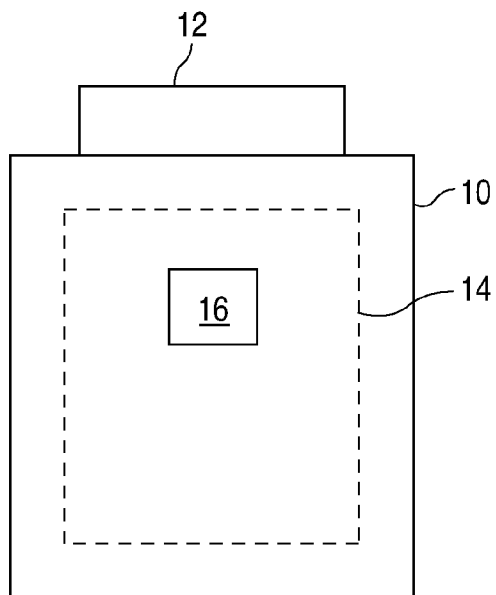


FIG. 1

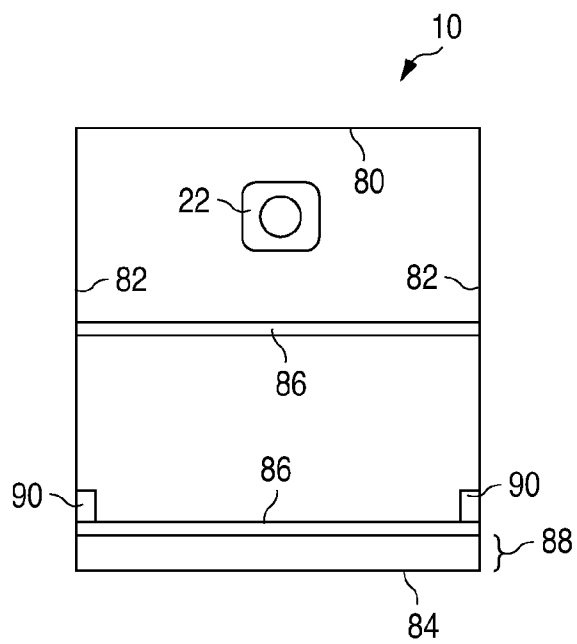


FIG. 8

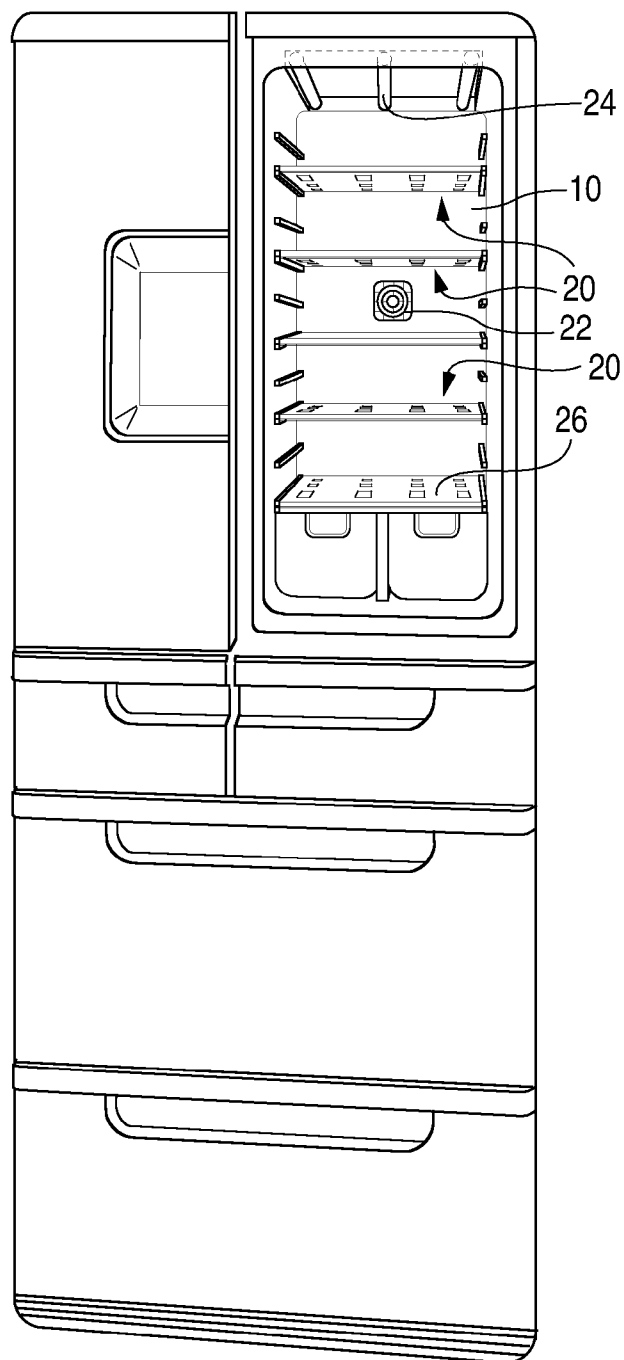


FIG. 2

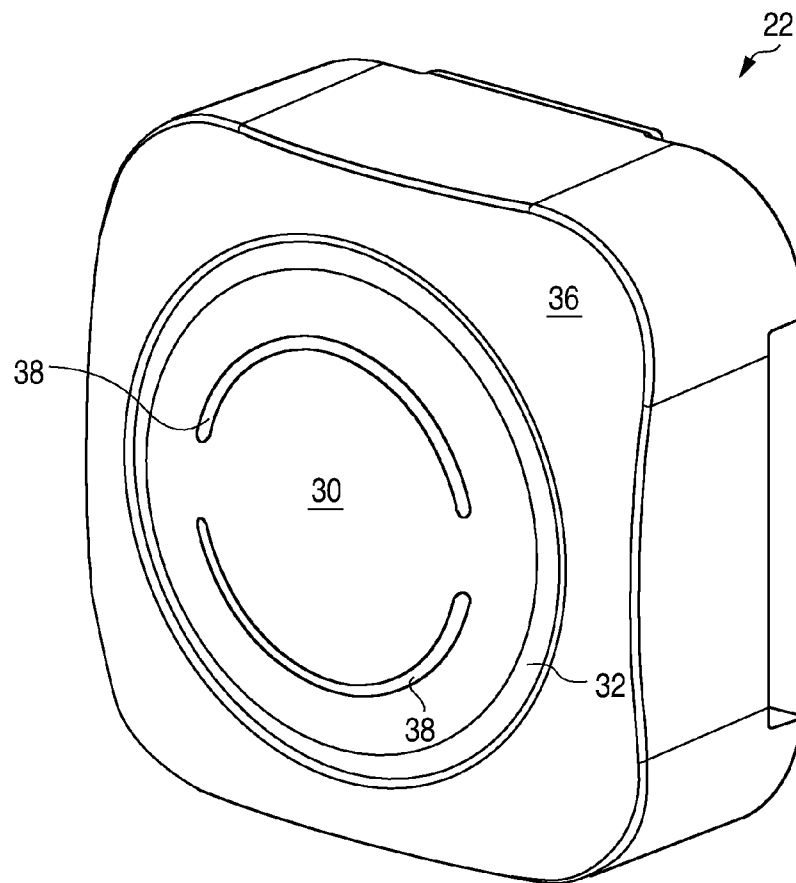


FIG. 3

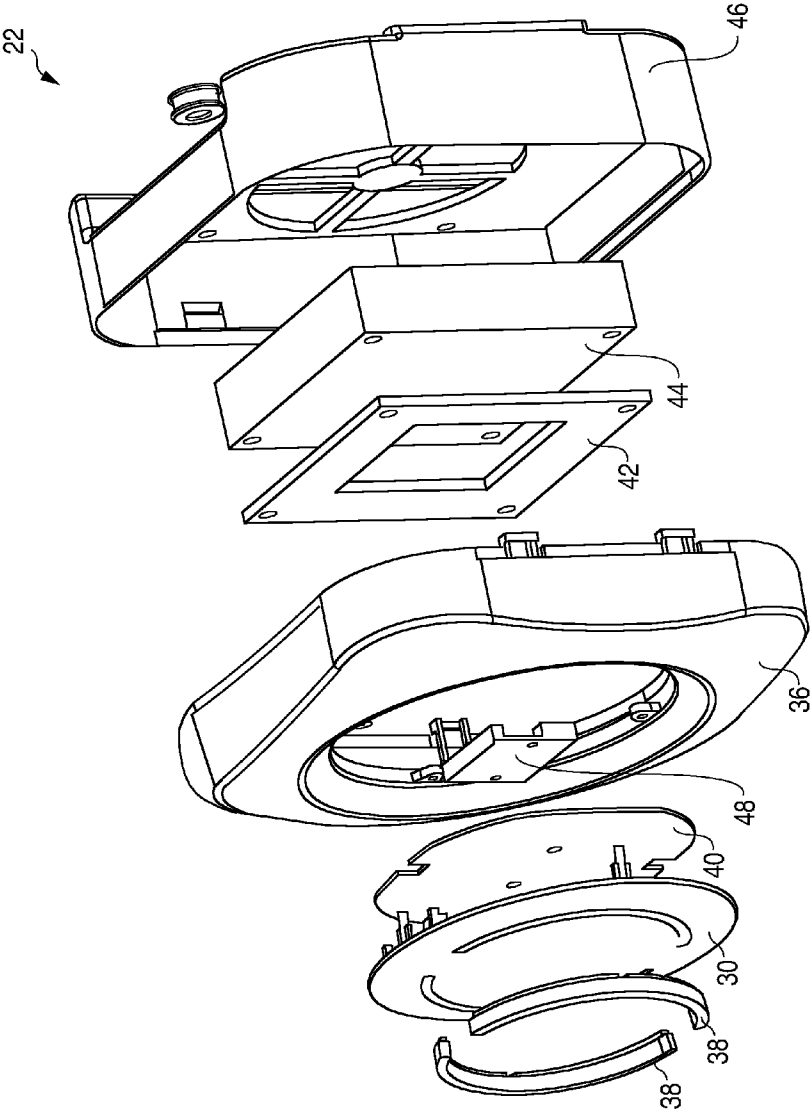


FIG. 4

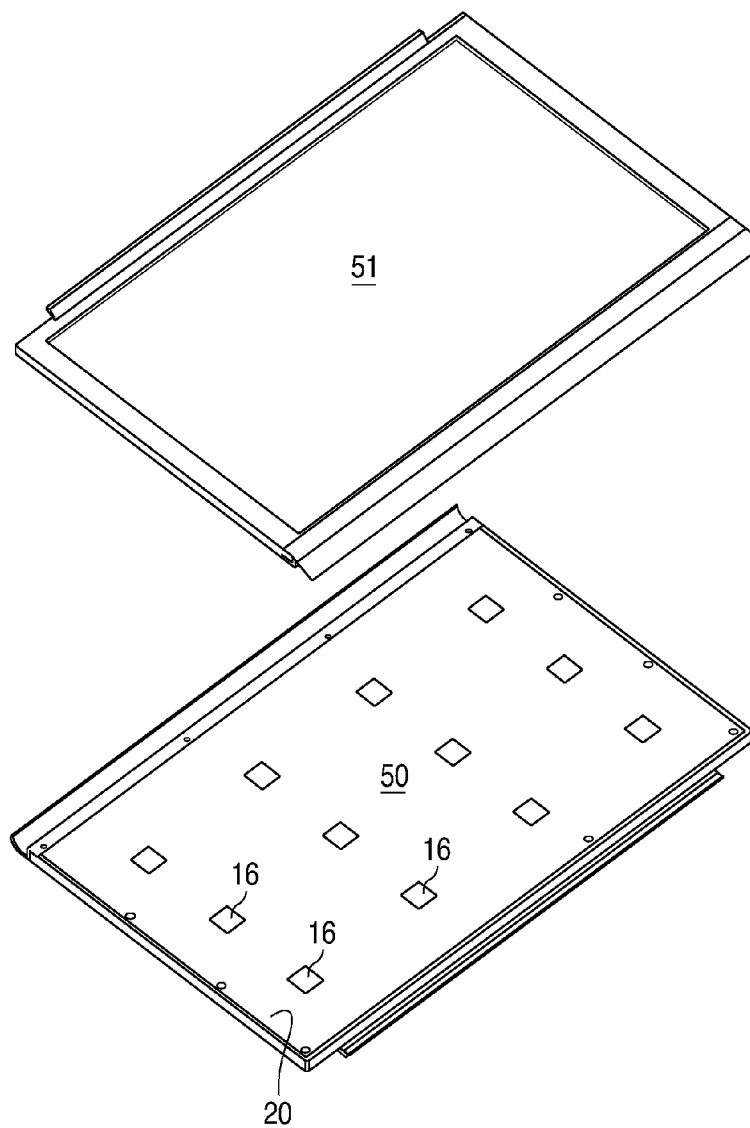


FIG. 5

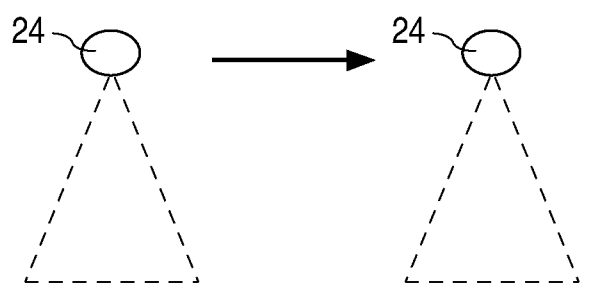


FIG. 6A

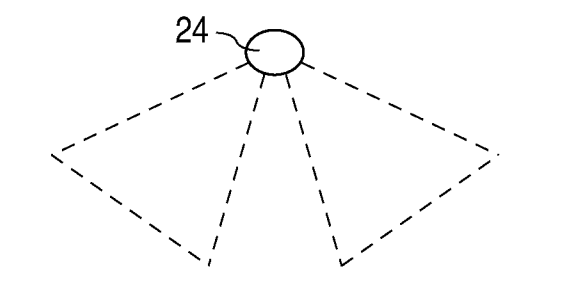


FIG. 6B

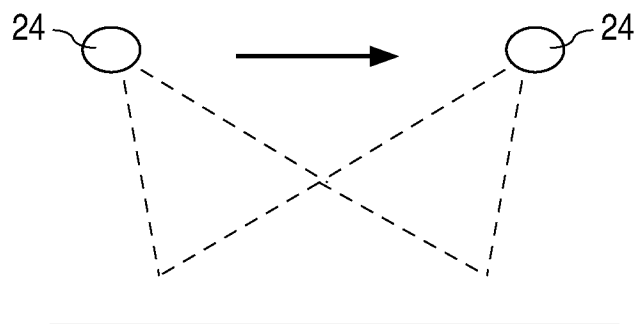


FIG. 6C

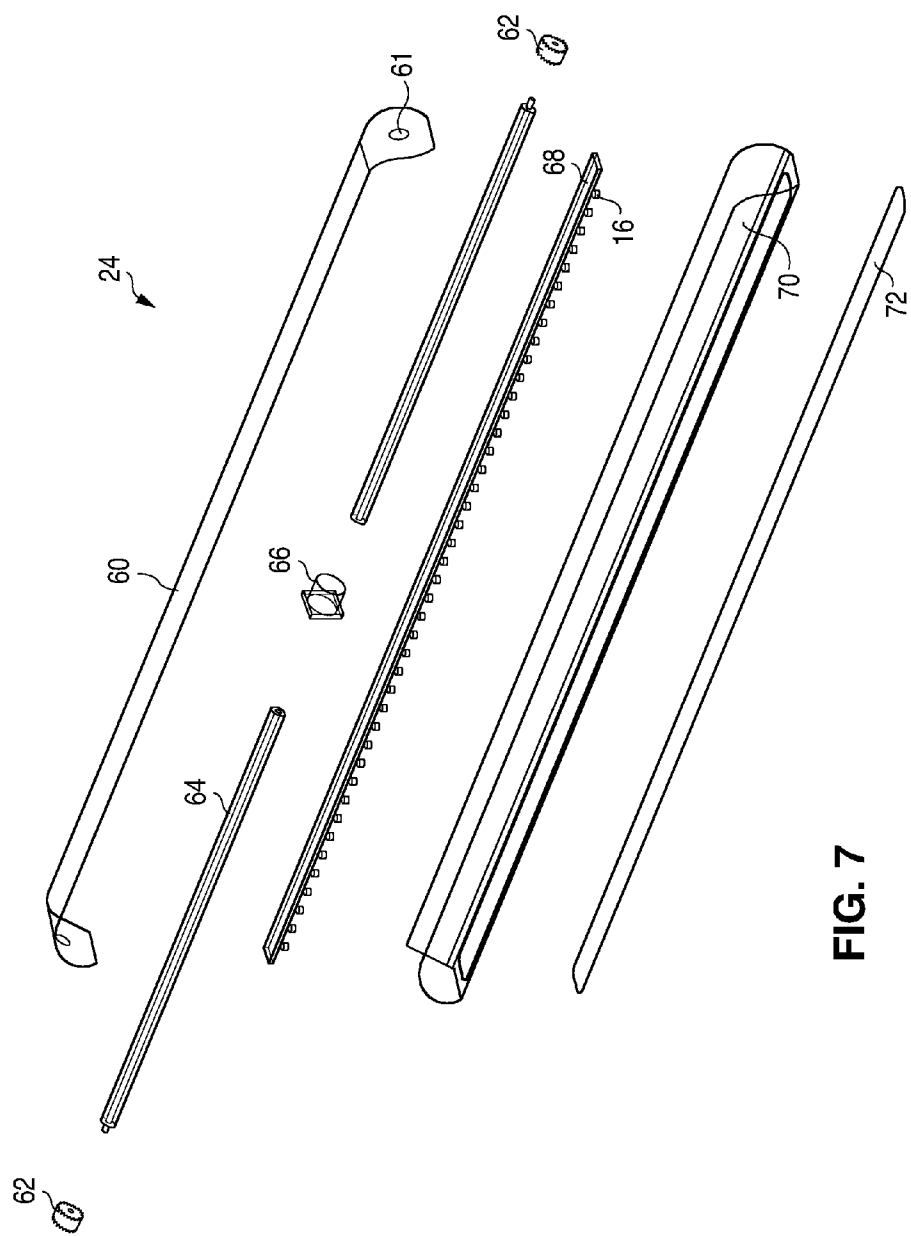


FIG. 7

REFRIGERATOR WITH ULTRAVIOLET LIGHT EMITTING DIODE

BACKGROUND

[0001] 1. Field of Invention

[0002] The present invention relates to a refrigerator including ultraviolet light emitting diodes.

[0003] 2. Description of Related Art

[0004] Current methods for reducing or eliminating growth of microbes in refrigerators used, for example, to store or display perishable food, include reducing the temperature and humidity to create conditions that reduce or eliminate microbial growth, treating the refrigerator compartment with ozone, and creating a vacuum in the refrigerator compartment. Low temperature and humidity may reduce microbial activity, but may require increased energy consumption, may not be desirable for certain foods because low temperature and humidity tend to dehydrate food, and may not entirely eliminate microbial activity. Ozone is only effective for microbial control at concentrations that are harmful to human health. In addition, ozone is a greenhouse gas; the release of ozone into the atmosphere is harmful to the environment. Vacuum refrigerators require vacuum pumps to pull air out of the refrigerator compartments and require a vacuum seal, which are expensive. In addition, vacuum conditions tend to dehydrate food. Conventional metal vapor-based ultraviolet emission sources such as mercury bulbs suffer from low efficiency in refrigerators due to reduced vapor pressure inside the bulb. Their manufacture and disposal are harmful to the environment. Breakage of such bulbs inside a refrigerator may cause food and home contamination.

SUMMARY

[0005] Embodiments of the invention include a sealed compartment and a door disposed on a side of the sealed compartment, and a cooler for cooling an interior of the sealed compartment. At least one light emitting diode configured to emit light having a peak wavelength in the ultraviolet range is positioned to emit ultraviolet light in the sealed compartment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 illustrates a compartment including a cooler and a UV light emitting diode.

[0007] FIG. 2 illustrates several examples of how UV LEDs may be incorporated into a refrigerator.

[0008] FIG. 3 is a front perspective view of an air circulation hub for a refrigerator.

[0009] FIG. 4 is an exploded view of the air circulation hub illustrated in FIG. 3.

[0010] FIG. 5 is an exploded view of a shelf with UV LEDs.

[0011] FIGS. 6A, 6B, and 6C illustrate translational scanning, rotational scanning, and combined translational and rotational scanning.

[0012] FIG. 7 is an exploded view of a movable stage which may be used for scanning.

[0013] FIG. 8 illustrates an arrangement of shelves and an air circulation hub in a sealed compartment.

DETAILED DESCRIPTION

[0014] In embodiments of the invention, a refrigerator includes at least one light emitting diode that emits UV light into the refrigerated compartment. The UV light may reduce or eliminate the growth of microbes in the refrigerator.

[0015] FIG. 1 is a simplified view of refrigerator according to embodiments of the invention. A sealable compartment 10 includes a door 14 disposed on at least one side to allow access to compartment 10. A seal may be disposed between door 14 and the rest of compartment 10. A cooler 12 may be used to cool the interior of compartment 10. Compartment 10 may be insulated. Any or all of the interior walls of compartment 10, including top, bottom, and side walls, may be UV-reflective material or coated with a UV-reflective material. Compartment 10, door 14, the seal between door 14 and compartment 10, and cooler 12 may be any suitable structure and are well known in the art. At least one ultraviolet (UV) LED 16 is disposed such that UV LED 16 may emit UV light in compartment 10. UV LED 16 is connected to a power source and may be connected to control circuitry as is known in the art.

[0016] UV LED 16 may be any suitable device that emits radiation at a wavelength that is able to disinfect the air or other fluid flowing over the UV LED. In some embodiments, UV LED 16 emits radiation with a peak wavelength less than 300 nm. In some embodiments, UV LED 16 is configured to emit light over broad angles, for example in a cone of at least 120°, such that UV radiation is emitted into as much of the volume of the chamber in which the UV LED is disposed as possible. The emission pattern may be controlled through optics, lenses, or reflectors connected to the device structure of UV LED 16 or to a package in which the device structure of UV LED 16 is disposed, as is known in the art. UV LED 16 is often disposed in a chamber and surrounded by reflective materials, such that little or no UV radiation is able to escape the chamber.

[0017] FIG. 2 illustrates several examples of how UV LEDs may be incorporated into a refrigerator, according to embodiments of the invention. UV LEDs may be included in an air circulation hub 22 which circulates air within sealed compartment 10. Air circulation hub 22 is illustrated in more detail in FIGS. 3 and 4. UV LEDs may be included on or in a shelf 20 on which food or other material is stored in sealed compartment 10. Shelf 20 is illustrated in more detail in FIG. 5. UV LEDs may be included in a movable stage 24 positioned to emit UV light into sealed compartment 10. Movable stages 24 are illustrated in more detail in FIGS. 6A, 6B, 6C, and 7. UV LEDs may be included in a portion of a drawer 26 or other compartment. The drawer 26 may be removable from the refrigerator and used separate from the refrigerator as a disinfectant box. The drawer 26 may include a self-contained battery source to power the UV LEDs in the drawer, or the drawer 26 may include structures that draw electrical current from a power source outside the refrigerator to which the refrigerator is connected such as a wall plug. A refrigerator may include only one of the examples illustrated in FIG. 2 or may include multiple examples.

[0018] FIG. 4 is an exploded view of the air circulation hub 22 shown in a perspective view in FIG. 3. Air circulation hub 22 includes a cover 36 that connects to a body 46, for example by friction fit, by glue, by screws, or any other suitable fastening method or fastener. Positioned between the cover 36 and body 46 is a fan box 44 which includes a fan for circulating air. The fan box 44 is covered by a filter 42, which may be any suitable filter such as a high efficiency particulate air (HEPA) filter.

[0019] A module 48 which includes one or more UV LEDs is attached to cover 36, or to body 46. Module 48 may be, for example, a rigid or flexible circuit board on which one or

more UV LEDs are mounted. Wiring may be formed on module **48** to electrically connect the UV LEDs to each other, for example, to other circuitry such as power conditioning or electrostatic discharge protection circuitry, and/or to a power source.

[0020] A face plate **30** attaches to cover **36**, for example by friction fit, by glue, by screws, or by any other suitable fastening method or fastener. An opening **32**, which may be a circular gap between face plate **30** and cover **36** as illustrated in FIG. **3** or any other suitable opening, allows air to flow into the air circulation hub **22**. Any suitable shape, number, and size of openings **32** may be used. Indicators **38** may be disposed on or within face plate **30**. Any suitable indicator **38** may be used, such as organic LEDs or semiconductor LEDs that emit visible light. Indicators **38** may provide visual cues, for example indicating that the refrigerator is cooling, and/or warnings, for example indicating that the UV LEDs on module **48** are emitting UV light.

[0021] Face plate **30** may position a circuit board **40** in contact with module **48**. Circuit board **40** may include, for example, driver circuitry for the UV LEDs on module **48**, timing circuits for timed operation of the UV LEDs, circuitry for a refrigerator door safety interlock, and/or driver circuitry for indicators **38**. A refrigerator door safety interlock circuit may include a sensor that senses when the door is open and a circuit that prevents power from being supplied to the UV LEDs when the door is open.

[0022] FIGS. **3** and **4** illustrate just one example of an air circulation hub **22**. The components in the air circulation hub may be arranged differently from what is illustrated in FIGS. **3** and **4**, more or fewer components may be included in the air circulation hub, and the air circulation hub may have a different appearance than is illustrated in FIGS. **3** and **4**.

[0023] In operation, a fan in fan box **44** draws air into the air circulation hub through opening **32** illustrated in FIG. **3**. The air flows into a chamber formed between cover **36** and body **46** which is irradiated with light from the one or more UV LEDs on module **48**, disposed on one side of the chamber. The interior of the chamber formed between cover **36** and body **46** may be coated with UV reflective material. Examples of suitable UV-reflective material include aluminum and palladium. A reflective coating may be plated, sputtered, or evaporated directly on the walls of the chamber, or the reflective coating may be a foil or a film attached to the surfaces of cover **36** and body **46** that form the walls of the chamber. Radiation emitted by UV LEDs is reflected by the reflective coating such that all or nearly all of the chamber formed by cover **36** and body **46** is filled with UV radiation. Accordingly, little or no air passes through the chamber without being exposed to UV radiation.

[0024] The chamber may include a structure to encourage mixing of the air. The structures may mix the incoming air and prevent laminar flow of the air, which may (1) effectively lengthen the trajectory of air within the chamber, and (2) allow air to pass closer to the surface of the LEDs where the radiation has the highest intensity, causing more exposure to stronger UV radiation, which may result in purer air. Examples of suitable structures include baffles, vanes, or other protrusions on the side walls of the chamber or within the chamber. Alternatively, the chamber can be divided into several serpentine passages to extend the distance air must travel before leaving the chamber, causing more exposure to UV radiation, which may result in purer air. Serpentine passageways may be formed by forming passageway walls on

one or both of cover **36** and body **46**, such that when cover **36** and body **46** are pressed together to form the chamber, sealed or nearly sealed passageways are formed. As the air encounters light from the UV LEDs, any pathogens in the air are killed by the UV radiation, such that the air is disinfected. The fan draws the irradiated air through filter **42**, which filters out some or all particulate matter in the air. The air may then exit the back of body **46**. Air exiting air circulation hub **22** may be vented into the sealed compartment **10** of the refrigerator or outside the sealed compartment **10** of the refrigerator.

[0025] In the refrigerator illustrated in FIG. **2**, the air circulation hub **22** illustrated in FIGS. **3** and **4** is mounted on a back wall of sealed compartment **10**. Though only one air circulation hub **22** is illustrated, multiple air circulation hubs may be used in a single refrigerator, and one or more air circulation hubs may be used in a single compartment in a refrigerator with multiple compartments. In a refrigerator including a drawer that may be removed from the refrigerator and used as a separate compartment, the removable drawer may include an air circulation hub that is powered, for example, by a battery that may be recharged when the removable drawer is replaced in the refrigerator.

[0026] FIG. **5** illustrates a shelf **20** including UV LEDs **16**. UV LEDs **16** may be embedded within or disposed on a surface of the shelf. In one arrangement, UV LEDs **16** are disposed on a module **50**, which is then covered with a UV-transparent cover **51**. Examples of suitable UV transparent covers include quartz or glass plates. The cover may serve as the surface on which food or other materials stored in the refrigerator are placed, or a shelf on which food or other materials stored in the refrigerator are placed may be spaced apart from the cover, as described below in reference to FIG. **8**. UV LEDs **16** in FIG. **5** are arranged in a **4 x 3** rectangular array. More or fewer UV LEDs **16** may be used, and the UV LEDs **16** may be arranged in any suitable arrangement. The materials surrounding UV LEDs **16**, such as the top surface of module **50** between neighboring UV LEDs, may be chosen to withstand and reflect UV rays. Examples of suitable materials include any of the reflective materials described above, barium sulfate, and Teflon. In some embodiments, UV LEDs **16** are connected to a structure that facilitates heat transfer from the UV LEDs to the surrounding environment, such as metallic heat sinks. Transferring heat away from UV LEDs **16** may improve the efficiency of the UV LEDs and may extend the lifetime of the UV LEDs.

[0027] In some embodiments, UV LEDs are disposed on or in the shelf oriented such that UV light shines both up from the top of the shelf and down from the bottom of the shelf. The shelf may include visible indicators such as organic LEDs or LEDs that emit visible light and which indicate when the UV LEDs are emitting light. Circuitry such as electrical driver circuitry for UV LEDs **16**, driver circuitry for indicators, timing circuits which dictate when UV LEDs **16** emit UV light, and/or safety interlocks may be included in module **50**, for example, or on one or more other structures disposed inside shelf **20** or inside a frame supporting shelf **20**.

[0028] In some embodiments, UV LEDs are mounted in a movable stage that changes the area that is irradiated with UV light as a function of time. FIGS. **6A**, **6B**, and **6C** illustrate examples of the types of scanning that can be done by movable stages. In FIG. **6A**, the movable stage **24** moves along an axis and irradiates the area beneath the scanning device, as illustrated by the cones. In FIG. **6B**, the movable stage rotates and irradiates different areas along the axis of rotation. In

FIG. 6C, the movable stage moves along an axis and rotates. Other ways of changing the area that is irradiated as a function of time may be used.

[0029] FIG. 7 is an exploded view of a movable stage 24 capable of translational scanning, as illustrated in FIG. 6A. The movable stage of FIG. 7 includes a housing 60 which houses one or more axles 64 connected to wheels 62. Axles 64 may connect to housing 60 through holes 61 formed in either end of housing 60. Axles 64 are connected to a motor 66 capable of moving housing 60 by turning axles 64. Motor 66 is illustrated in the center of housing 60, though motor 66 may be mounted in any suitable location. One or more UV LEDs 16 is attached to a frame 68 which is disposed in housing 60 beneath axles 64. Frame 68 may be, for example, a circuit board, which may also include, for example, driver circuitry for LEDs 16, timing and/or driver circuitry for activating motor 66 to move stage 24, circuitry for a refrigerator door safety interlock, and any other required circuitry. A cover 70 protects UV LEDs 16 and includes a window 72 that is transparent to UV light.

[0030] In operation, wheels 62 may rest on tracks positioned in the sealed compartment 10. Motor 66 turns axles 64 and wheels 62 such that the frame 68 and UV LEDs 16 roll along the tracks. The movable stage illustrated in FIG. 7 may also be used for rotational scanning as illustrated in FIG. 6B. Wheels 62 and axles 64 may be omitted from a rotational scanning device. A motor capable of turning housing 60 may be mounted on the top of housing 60 in the center. Such a rotational scanning device may be used for translational and rotational scanning as illustrated in FIG. 6C by attaching the motor capable of turning housing 60 to one or more axles connected to one or more wheels capable of rolling along a track.

[0031] FIG. 2 illustrates a movable stage 24 mounted such that the UV LEDs emit light in a generally downward direction. In some embodiments, movable stages that emit light upward can be disposed on the bottom of the sealed compartment 10, or movable stages that emit light to the side can be disposed on one or more sides of the sealed compartment 10. Movable stages may be separated from the sealed compartment 10 by a UV transparent cover or may be embedded within the top, bottom, and/or sides of the sealed compartment.

[0032] FIG. 8 illustrates an arrangement of shelves in sealed compartment 10 which may avoid the placement of food or other materials in sealed compartment 10 in areas that cannot be reached by purified air emitted from air circulation hub 22 or by UV light from UV LEDs that emit light directly into the sealed compartment. As described above, the top 80, sides 82, and bottom 84 of sealed compartment 10 are often UV-reflective. In some embodiments, the UV reflective material on the top, sides, and bottom of sealed compartment 10 acts as a diffuse reflector. A surface of food or other material placed in direct contact with these surfaces cannot be reached by the air emitted by air circulation hub 22 or by UV light from UV LEDs that emit light into the sealed compartment. Accordingly, in some embodiments, shelves 86 for the storage of food or other materials are spaced apart from the bottom 84 of sealed compartment 10 by a gap 88. Shelves 86 may be wire or other materials that do not significantly occlude the bottom surface of materials placed on the shelf, or a solid UV transparent material. In some embodiments, a face plate or other structure that prevents materials from being placed in gap 88 is positioned between bottom 84 and shelf

86. In some embodiments, shelves 86 include protrusions 90 which prevent materials from being placed in contact with the side surfaces of sealed compartment 10.

[0033] Gaps 88 and 90 allow UV light or UV-purified air coming from above shelf 86 to reflect off bottom surface 84, which may increase the likelihood the bottom surface of materials on shelf 86 is exposed to UV light or UV purified air.

[0034] Having described the invention in detail, those skilled in the art will appreciate that, given the present disclosure, modifications may be made to the invention without departing from the spirit of the inventive concept described herein. Therefore, it is not intended that the scope of the invention be limited to the specific embodiments illustrated and described.

What is being claimed is:

1. An apparatus comprising:

a sealed compartment;

a door disposed on a side of the sealed compartment;

at least one light emitting diode configured to emit light having a peak wavelength in the ultraviolet range positioned to emit ultraviolet light in the sealed compartment; and

a cooling device to cool an interior of the sealed compartment.

2. The apparatus of claim 1 further comprising an ultraviolet-reflective material disposed on a sidewall of the sealed compartment.

3. The apparatus of claim 1 further comprising a fan to circulate ambient gas in the sealed compartment.

4. The apparatus of claim 1 wherein the at least one light emitting diode is disposed on a movable stage.

5. The apparatus of claim 4 further comprising control circuitry configured to move the movable stage.

6. The apparatus of claim 1 further comprising a drawer disposed within the sealed compartment, wherein:

the at least one light emitting diode is positioned to emit ultraviolet light in the drawer; and

the drawer is removable from the sealed compartment.

7. The apparatus of claim 1 further comprising control circuitry connected to the at least one light emitting diode, wherein the control circuitry is configured to periodically activate the at least one light emitting diode.

8. The apparatus of claim 1 further comprising an indicator that indicates when the at least one light emitting diode is forward biased.

9. The apparatus of claim 1 wherein the at least one light emitting diode is disposed in an air circulation hub, the air circulation hub further comprising:

a cover;

a body, wherein the at least one light emitting diode is disposed between the cover and the body;

an opening in the cover;

a fan disposed between body and the at least one light emitting diode; and

a filter disposed between the fan and the at least one light emitting diode.

10. A method comprising:

providing a structure comprising:

a sealed compartment;

a door disposed on a side of the sealed compartment; and

at least one light emitting diode configured to emit light

having a peak wavelength in the ultraviolet range

positioned to emit ultraviolet light in the sealed com-

partment; and

cooling an interior of the sealed compartment to a tem-

perature below ambient temperature.

11. The method of claim **10** wherein the at least one light emitting diode is mounted on a movable stage, the method further comprising moving the movable stage.

12. The method of claim **11** further comprising activating the at least one light emitting diode while moving the movable stage.

13. The method of claim **10** further comprising activating a fan positioned to circulate ambient gas within the sealed compartment.

* * * * *