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(54) Title: FILTERING FACE-PIECE RESPIRATOR INCLUDING FUNCTIONAL MATERIAL AND METHOD OF FORMING SAME

(57) Abstract: Various embodiments of a filtering face-piece respirator and method of forming such respirator are disclosed. In one or more embodiments, the respirator can include a mask body that includes a first cover web, a second cover web, and filter media disposed between the first cover web and the second cover web. The mask body can also include functional material disposed in a filter region of the mask body, where the functional material can include active particles disposed on an adhesive layer; and a perimeter seal region that defines at least a portion of a perimeter of the mask body. At least two of the first cover web, second cover web, and filter media are connected together in the perimeter seal region. In one or more embodiments, the functional material is not disposed in at least a portion of the perimeter seal region.



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**FILTERING FACE-PIECE RESPIRATOR INCLUDING
FUNCTIONAL MATERIAL AND METHOD OF FORMING SAME**

BACKGROUND

5 Respirators are commonly worn over a person's breathing passages in at least one of two situations: (1) to prevent impurities or contaminants from entering the wearer's respiratory system; and (2) to protect other persons or things from being exposed to pathogens and other contaminants exhaled by the wearer. In the first situation, the respirator is worn in an environment where the air contains particles that may be harmful to the wearer, for example, in an auto body shop. In the second situation, the respirator is worn in an environment where there is risk of contamination to other persons or things, for example, in an operating room or clean room.

 A variety of respirators have been designed to be used in one or both of these situations. Some of these respirators have been categorized as being "filtering face-pieces" because the mask body itself functions as the filtering mechanism. Unlike respirators that use rubber or elastomeric mask bodies with attachable filter cartridges (*see, e.g., U.S. Patent No. RE39,493 to Yuschak et al.*) or insert-molded filter elements (*see, e.g., U.S. Patent No. 4,790,306 to Braun et al.*), respirators are designed to have the filter media cover much of the mask body so that there is no need for installing or replacing a filter cartridge. These filtering face-piece respirators commonly come in one of two configurations: molded respirators and flat-fold respirators.

 Molded filtering face-piece respirators often include non-woven webs of thermally-bonded fibers or open-work plastic meshes to furnish the mask body with its cup-shaped configuration. Molded respirators tend to maintain the same shape during both use and storage. These respirators, therefore, cannot be folded flat for storage and shipping. Examples of patents that disclose molded, filtering, face-piece respirators include U.S. Patent Nos. 7,131,442 to Kronzer et al; 6,923,182 and 6,041,782 to Angadjivand et al.; 4,807,619 to Dyrud et al.; and 4,536,440 to Berg.

 Flat-fold respirators, as the name implies, can be folded flat for shipping and storage. Such respirators can be opened into a cup-shaped configuration for use. Examples of flat-fold respirators are described in U.S. Patent Nos. 6,568,392 and 6,484,722 to Bostock et al.; and 6,394,090 to Chen et al. Some flat-fold respirators have been designed with weld lines, seams, and folds to help maintain their cup-shaped configurations during use. Stiffening members have also been incorporated into panels of the mask body. *See, e.g., U.S. Patent Publication Nos. 2011/0067700 and 2010/0154805 to Duffy et al.; and U.S. Design Patent No. 659,821 to Spoo et al.*

Flat-fold respirators have two general orientations when folded flat for storage. In one configuration—sometimes referred to as a “horizontal” flat-fold respirator—the mask body is folded crosswise such that it has an upper portion and a lower portion. A second type of respirator is referred to as a “vertical” flat-fold respirator because the primary fold is oriented vertically when the respirator is viewed from the front in an upright position. Vertical flat-fold respirators have left and right portions on opposing sides of the vertical fold or a centerline of the mask body.

Various respirators can include active or functional particulate materials that interact with fluids by sorbing (adsorbing or absorbing) components from the fluids. For example, respirators can include microporous sorbents that purify workplace breathing air. Activated carbon, i.e., an active or functional particulate having sorptive properties, is widely used to filter air to protect persons against a variety of toxic or noxious vapors, including war gases, industrial chemicals, solvents, and odorous compounds. The activated carbon is derived, for example, from coal or coconut shells and can be produced in the form of powders, granules, and shaped products.

In addition to activated carbon, there are other porous sorbent structures that can be useful for separating components in gas and liquid streams or for purifying such streams. Examples of other porous sorbent structures include silica gel and activated alumina. Other sorbents include crystalline aluminosilicates or zeolites and molecular sieve adsorbents.

SUMMARY

In general, the present disclosure provides various embodiments of a filtering face-piece respirator that includes a mask body. The mask body can include one or more cover webs and filter media. The mask body can also include functional material disposed in a filter region of the mask body. In one or more embodiments, the functional material can include active particles disposed on or in an adhesive layer. The mask body can also include a perimeter seal region that defines at least a portion of a perimeter of the mask body. In one or more embodiments, the functional material is not disposed in at least a portion of the perimeter seal region.

In one aspect, the present disclosure provides a filtering face-piece respirator that includes a mask body. The mask body includes a first cover web including an inner surface and an outer surface, a second cover web including an inner surface and an outer surface; and filter media disposed between the first cover web and the second cover web. The mask body further includes functional material disposed in a filter region of the mask body, where the functional material includes active particles disposed on an adhesive layer; and a perimeter seal region that defines at least a portion of a perimeter of the mask body, where at least two of the first cover

web, second cover web, and filter media are connected together in the perimeter seal region. The functional material is not disposed in at least a portion of the perimeter seal region.

In another aspect, the present disclosure provides a method of forming a filtering face-piece respirator that includes a mask body. The method includes forming filter media, and selectively disposing functional material in a filter region of the mask body either between a first cover web and a second cover web of the mask body or on an outer surface of at least one of the first cover web and second cover web. The functional material includes active particles disposed on an adhesive layer. The method further includes disposing the filter media between the first cover web and the second cover web, and attaching at least two of the first cover web, the filter media, and the second cover web together to form a perimeter seal region that defines at least a portion of a perimeter of the mask body. The functional material is not disposed in at least a portion of the perimeter seal region.

In another aspect, the present disclosure provides a method of forming a mask body of a filtering face-piece respirator. The method includes forming an upper panel, a central panel, and a lower panel. Forming each of the upper, central, and lower panels includes forming filter media, and selectively disposing functional material in a filter region of each of the upper panel, central panel, and lower panel either between a first cover web and a second cover web or on an outer surface of at least one of the first cover web and the second cover web. The functional material includes active particles disposed on an adhesive layer. The method further includes disposing the filter media between the first cover web and the second cover web, attaching the upper panel to the central panel to form a first seal region, attaching the lower panel to the central panel to form a second seal region, and attaching at least two of the first cover web, the filter media, and the second cover web of the upper, central, and lower panels together along a perimeter of the mask body to form a perimeter seal region. The functional material is not disposed in at least a portion of the first and second seal regions and the perimeter seal region.

All headings provided herein are for the convenience of the reader and should not be used to limit the meaning of any text that follows the heading, unless so specified.

The terms “comprises” and variations thereof do not have a limiting meaning where these terms appear in the description and claims. Such terms will be understood to imply the inclusion of a stated step or element or group of steps or elements but not the exclusion of any other step or element or group of steps or elements.

The words “preferred” and “preferably” refer to embodiments of the disclosure that may afford certain benefits, under certain circumstances; however, other embodiments may also be preferred, under the same or other circumstances. Furthermore, the recitation of one or more

preferred embodiments does not imply that other embodiments are not useful, and is not intended to exclude other embodiments from the scope of the disclosure.

In this application, terms such as “a,” “an,” and “the” are not intended to refer to only a singular entity, but include the general class of which a specific example may be used for illustration. The terms “a,” “an,” and “the” are used interchangeably with the term “at least one.” The phrases “at least one of” and “comprises at least one of” followed by a list refers to any one of the items in the list and any combination of two or more items in the list.

The phrases “at least one of” and “comprises at least one of” followed by a list refers to any one of the items in the list and any combination of two or more items in the list.

As used herein, the term “or” is generally employed in its usual sense including “and/or” unless the content clearly dictates otherwise.

The term “and/or” means one or all of the listed elements or a combination of any two or more of the listed elements.

As used herein in connection with a measured quantity, the term “about” refers to that variation in the measured quantity as would be expected by the skilled artisan making the measurement and exercising a level of care commensurate with the objective of the measurement and the precision of the measuring equipment used. Herein, “up to” a number (e.g., up to 50) includes the number (e.g., 50).

Also herein, the recitations of numerical ranges by endpoints include all numbers subsumed within that range as well as the endpoints (e.g., 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, 5, etc.).

GLOSSARY

The terms set forth herein will have the meanings as defined:

“clean air” means a volume of atmospheric ambient air that has been filtered to remove contaminants;

“contaminants” means particles (including dusts, mists, and fumes) and/or other substances that generally may not be considered to be particles (e.g., organic vapors, etc.) but which may be suspended in air;

“cup-shaped configuration” and variations thereof mean any vessel-type shape that is capable of adequately covering the nose and mouth of a wearer;

“elastic” in reference to a strap of a harness or earloop means being able to be stretched at least 100% and return essentially to the original dimension without imparting damage to the strap;

“exterior gas space” means the ambient atmospheric gas space into which exhaled gas enters after passing through and beyond the mask body and/or exhalation valve;

“exterior surface” means the surface of the mask body exposed to ambient atmospheric gas space when the mask body is positioned on the wearer’s face;

5 “face seal” means a part(s) located between the mask body and a wearer’s face at one or more locations where the mask body would otherwise contact the face;

“filtering face-piece” means that the mask body itself is designed to filter air that passes through it; there are no separately identifiable filter cartridges or insert-molded filter elements attached to or molded into the mask body to achieve this purpose;

10 “filter” or “filtration layer” means one or more layers of air-permeable material, which layer(s) is adapted for the primary purpose of removing contaminants (such as particles) from an air stream that passes therethrough;

“filter media” means an air-permeable structure, where structure means for example one or more layers, that is designed to remove contaminants from air that passes through it;

15 “filter region” means a region of the respirator that permits a transport of air from the exterior gas space to the interior gas space and *vice versa*;

“filtering structure” means a generally air-permeable construction that filters air;

“flat configuration” means the respirator is folded such that it is flat, e.g., as shown in FIG. 7;

20 “flat-fold” means that the respirator can be folded flat for storage and opened for use;

“folded inwardly” means being bent back towards the part from which it extends;

“functionally disposed” means adhesively attached, mechanically attached, and combinations thereof;

25 “functional material” means one or more materials or layers that interact with fluids by sorbing (adsorbing or absorbing) components from the fluids;

“harness” means a structure or combination of parts that assists in supporting the mask body on a wearer’s face;

“integral” means being formed together at the same time i.e., being made together as one part and not two separately manufactured parts that are subsequently joined together;

30 “interior gas space” means the space between a mask body and a wearer’s face;

“interior surface” means the surface of the mask body closest to a wearer’s face when the mask body is positioned on the wearer’s face;

“joined to” means secured to directly or indirectly;

35 “line of demarcation” means a fold, seam, weld line, bond line, stitch line, hinge line, and/or any combination thereof;

“mask body” means an air-permeable structure that is designed to fit over the nose and mouth of a wearer and that helps define an interior gas space separated from an exterior gas space (including the seams and bonds that join layers and parts thereof together);

5 “nose clip” means a mechanical device (other than a nose foam), which device is adapted for use on a mask body to improve the seal at least around a wearer’s nose;

“nose region” means the portion of the mask body that resides over a wearer’s nose when the respirator is worn;

“panel” means an area of a mask separated at least in part from another area of the mask by a line of demarcation;

10 “perimeter” means the outer edge of the mask body, which outer edge would be disposed generally proximate a wearer’s face when the respirator is being donned by a person; a

“perimeter segment” is a portion of the perimeter;

“pleat” means a portion that is designed to be or is doubled back upon itself;

15 “polymeric” and “plastic” each means a material that mainly includes one or more polymers and that may contain other ingredients as well;

“respirator” means an air filtration device that is worn by a person to provide the wearer with clean air to breathe;

20 “side” means an area on the mask body distanced from a plane that bisects the mask body centrally and vertically when the mask body is oriented in an upright position and viewed from the front;

“snug fit” or “fit snugly” means that an essentially air-tight (or substantially leak-free) fit is provided (between the mask body and the wearer’s face);

“strap” means a generally flat elongated structure;

“transversely extending” means extending generally in the crosswise dimension; and

25 “vertical flat-fold respirator” means a respirator having a primary fold that is oriented vertically when the mask is viewed from the front in an upright position.

30 These and other aspects of the present disclosure will be apparent from the detailed description below. In no event, however, should the above summaries be construed as limitations on the claimed subject matter, which subject matter is defined solely by the attached claims, as may be amended during prosecution.

BRIEF DESCRIPTION OF THE DRAWINGS

35 Throughout the specification, reference is made to the appended drawings, where like reference numerals designate like elements, and wherein:

FIG. 1 is a schematic front view of one embodiment of a filtering face-piece respirator.

FIG. 2 is a schematic rear view of the respirator of FIG. 1.

FIG. 3 is a schematic cross-section view of a portion of a mask body of the respirator of FIG. 1.

5 FIG. 4 is a schematic front view of an upper panel of the mask body of the respirator of FIG. 1.

FIG. 5 is a schematic front view of lower panel of the mask body of the respirator of FIG. 1.

10 FIG. 6 is a schematic front view of an upper panel of the mask body of the respirator of FIG. 1.

FIG. 7 is a schematic right-side view of another embodiment of a filtering face-piece respirator.

FIG. 8 is a schematic front of the respirator of FIG. 7.

15 FIG. 9 is a schematic perspective view of one embodiment of an apparatus that can be utilized to manufacture the respirator of FIG. 1.

FIG. 10 is a flowchart of one embodiment of a method of manufacturing the respirator of FIG. 1.

FIG. 11 is a flowchart of another embodiment of a method of manufacturing the respirator of FIG. 1.

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DETAILED DESCRIPTION

In general, the present disclosure provides various embodiments of a filtering face-piece respirator that includes a mask body. The mask body can include one or more cover webs and filter media. The mask body can also include functional material disposed in a filter region of the mask body. In one or more embodiments, the functional material can include active particles disposed on or in an adhesive layer. The mask body can also include a perimeter seal region that defines at least a portion of a perimeter of the mask body. In one or more embodiments, the functional material is not disposed in at least a portion of the perimeter seal region.

When manufacturing respirators, it is common that additional performance can be added to the overall capability of the article by the inclusion of additional layers to the construction. For example, a layer of a carbon-carrying (i.e., carbon-loaded) nonwoven web can be added to one or more layers of particulate filter media and one or more cover webs to aid in removing nuisance odors from the ambient air, thereby providing a “nuisance odor level” of protection. The term “nuisance odor level” commonly refers to any product that removes any low-level residual odors from an environment. Common respirators that provide at least a minimal level of

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nuisance odor protection typically include a layer or layers of carbon-loaded melt-blown microfibers along with one or more particulate filter layers.

Attaching these carbon-loaded layers to other layers of the respirator can, however, be challenging as the resulting seams or welds can be both visually and technically inferior to those found in respirators that do not include such carbon-loaded layers. Further, cutting or trimming these carbon-loaded materials can require additional processing steps to hide or obscure these seams or welds from view. And carbon particles from the loaded layers tend to leak out of the layers through edges of the respirator. Such particles can also prevent exhalation valves disposed through a body of the respirator from properly sealing, thereby reducing the effectiveness of the respirator to properly filter ambient gas.

One or more embodiments of the respirators of the present application can advantageously dispose functional material in one or more filter regions of a mask body of the respirator and not in regions of the mask body where welding or cutting operations are required for forming the respirator. For example, in one or more embodiments, such functional material is not disposed in at least a portion of a perimeter seal region or other seal regions of the mask body.

The respirators that include functional material described herein can include any suitable type of respirator, e.g., filtering face-piece respirators, shaped respirators, etc. For example, FIGS. 1-6 are various views of one embodiment of a respirator 10. The respirator 10 can include any suitable respirator, e.g., a filtering face-piece respirator. The respirator 10 includes a mask body 12 that can include one or more cover layers, e.g., a first cover layer 60 and a second cover layer 70 as shown in FIG. 3, which is a schematic cross-section view of a portion of the mask body. The first cover web 60 can include an inner surface 62 and an outer surface 64, and the second cover web 70 can include an inner surface 72 and an outer surface 74.

The mask body 12 also includes filter media 80 disposed between the first cover web 60 and the second cover web 70. In one or more embodiments, the mask body 12 can also include functional material 90 disposed in a filter region 40 of the mask body. Further, the mask body 12 can include a perimeter seal region 50 that defines at least a portion of a perimeter 30 of the mask body. In one or more embodiments, the functional material 90 is not disposed in at least a portion of the perimeter seal region as is further described herein.

The mask body 12 of the respirator 10 can take any suitable shape or combination of shapes and have any suitable dimensions. Further, the mask body 12 includes an exterior surface 11 (FIG. 1) and an interior surface 13 (FIG. 2).

The mask body 12 can also include one or more panels that are defined by one or more lines of demarcation. For example, the mask body 12 includes an upper panel 14, a central panel

16, and a lower panel 18. Each of the panels 14, 16, 18 can take any suitable shape or combination of shapes and have any suitable dimensions. Further, the mask body 12 can be adapted to engage a wearer's face at the perimeter 30. In one or more embodiments, two or more layers of the mask body 12 can be joined together at the perimeter 30, e.g., by welding, bonding, adhering, stitching, or any other suitable technique, to form the perimeter seal region 50 (FIG. 3) as is further described herein. The seal region 50 can at least partially define the perimeter 30. In the illustrated embodiment, the perimeter 30 includes an upper perimeter segment 32 and a lower perimeter segment 34. Further, in one or more embodiments, the respirator 10 can include a nose clip 100 (FIG. 1) disposed in any suitable location on or within the mask body 12.

The central panel 16 of the mask body is separated from the upper panel 14 and the lower panel 18 by first and second lines of demarcation 20 and 22. The upper and lower panels 14 and 18 can each be folded inwards towards a rear surface 28 (FIG. 2) of the central panel 16 when the respirator 10 is being folded flat for storage, thereby placing the respirator in a closed condition. Further, the upper and lower panels 14 and 18 can each be opened outwardly for placement of the respirator 10 on a wearer's face, thereby placing the respirator in an open condition (as shown in FIGS. 1-2). When the respirator 10 is manipulated from its open condition to its closed condition or *vice versa*, the upper and lower panels 14 and 18 can at least partially rotate respectively about the first and second lines of demarcation 20 and 22. In one or more embodiments, the first and second lines of demarcation 20 and 22 can act as first and second hinges or axes, respectfully, for the upper and lower panels 14 and 18.

The first and second lines of demarcation 20, 22 can be formed using any suitable technique or combination of techniques, e.g., welding (e.g., ultrasonic welding), application of pressure (with or without heat), application of adhesive, stitching, etc. Further, the first and second lines of demarcation 20, 22 can each be substantially continuous, discontinuous, straight, curvilinear, and combinations thereof. In one or more embodiments, one or both of the first and second lines of demarcation 20, 22 can include a weld line or seam. For example, in one or more embodiments, the upper panel 14 can be connected to the central panel 16 along the first line of demarcation 20 to form a first seal region 24, and the lower panel 18 can be connected to the central panel along the second line of demarcation 22 to form a second seal region 26 using any suitable technique or combination of techniques, e.g., ultrasonic welding.

The mask body 12 also includes a left tab region 130 that extends from a left side 15 of the central panel 16, and a right tab region 132 that extends from a right side 17 of the central panel. As used herein, the terms "left" and "right" refer to portions or elements of the respirator as viewed by an observer when viewing the respirator as worn by a wearer. Further, the terms "upper" and "lower" refer to portions or elements of the respirator as viewed by the wearer when

the respirator is positioned on the wearer's face. In one or more embodiments, the left and right tab regions 130, 132 can provide a region for securement of a harness 110. One exemplary tab is described, e.g., in U.S. Patent No. D449,377 to Henderson et al.

One or both of the left and right tab regions 130, 132 can be integral with the mask body 12. For example, in one or more embodiments, one or both of the left and right tabs 130, 132 can be integral with the central panel 16 of the mask body 12. In one or more embodiments, one or both of the left and right tabs 130, 132 can be manufactured separately and then attached to the mask body 12 using any suitable technique or combination of techniques. For example, in one or more embodiments, one or both of the left and right tabs 130, 132 can be manufactured separately and then attached to the central panel 16 of the mask body 12 using an adhesive.

The harness 110, which can be any suitable harness and can include one or more straps or elastic bands 112. The straps or bands 112 of harness 110 can be attached to one or both of the left and right tab regions 130, 132 using any suitable technique or combination of techniques. For example, the straps or bands 112 can be stapled, welded, adhered, or otherwise secured to the mask body 12 at each opposing tab regions 130, 132 such that the straps or bands can help to hold the mask body against the face of the wearer when the respirator 10 is being worn. An example of a compression element that could be used to fasten a harness to a mask body using ultrasonic welding is described, e.g., in U.S. Patent Nos. 6,729,332 and 6,705,317 to Castiglione. The one or more straps or bands 112 can also be welded directly to the mask body 12 without using a separate attachment element. *See*, e.g., U.S. Patent No. 6,332,465 to Xue et al. Examples of other harnesses that can be utilized are described, e.g., in U.S. Patent Nos. 5,394,568 to Brostrom et al.; 5,237,986 to Seppala et al.; and in 5,481,763 to Brostrom et al.

The perimeter 30 of mask body 12 can include any suitable shape or combination of shapes. Further, in one or more embodiments, the perimeter 30 can include one or more concave portions as is further described, e.g., in U.S. Patent Publication No. 2008/0271739 to Facer et al. the perimeter 30 includes the upper perimeter segment 32 and the lower perimeter segment 34.

The mask body 12 can include any suitable layer or layers. For example, as illustrated in FIG. 3, mask body 12 can include the first cover web 60, the second cover web 70, and filter media 80 disposed between the first cover web and the second cover web. While illustrated as including first and second cover webs 60, 70, the mask body 12 can include any suitable number of cover webs, e.g., one, two, three, or more cover webs. The first cover web 60 can be disposed nearest a face of a wearer when the respirator is donned, i.e., the first cover web can be considered an inner cover web, and the second cover web 70 can be considered to be an outer cover web. In one or more embodiments, the second cover web 70 can be considered an inner cover web and the first cover web 60 can be considered an outer cover web.

As shown in FIG. 3, the mask body 12 includes the seal region 50 and the filter region 40. The seal region 50 includes two or more layers of the mask body 12 that are connected together to form a seal or bond. In one or more embodiments, at least two of the first cover web, 60, the second cover web 70, and the filter media 80 are connected together in the seal region 50.

5 In one or more embodiments, the first and second cover webs 60, 70 are connected together in the seal region 50. In one or more embodiments, the first and second cover webs 60, 70 and the filter media 80 are connected together in the seal region 50. Any suitable technique or combination of techniques can be utilized to form the seal region 50. For example, the seal region 50 can be formed using ultrasonic welding, thermal bonding, adhesive attachment, mechanical attachment, and combinations thereof.

The seal region 50 can, in one or more embodiments, extend from the filter region 40 of the mask body 12 to the perimeter 30 and at least partially define the perimeter 30 of the mask body. The seal region 50 can take any suitable shape or combination of shapes. The seal region 50 can also include any suitable dimensions. For example, the seal region 50 can have any suitable width extending from the perimeter 30 to the filter region 40 in a direction orthogonal to a surface normal of the outer surface 64 of the first cover web 60. The seal region 50 can extend along any suitable portion or portions of the perimeter 30 of the mask body 12. In one or more embodiments, the seal region 50 can extend along the entire perimeter 30 of the mask body 12, i.e., the seal region defines the entire perimeter of the mask body. In one or more embodiments, the seal region 50 defines at least a portion of the perimeter 30 of the mask body 12.

The seal region 50 can be adapted to contact a face of a wearer. In one or more embodiments, the seal region 50 is adapted to provide a seal against the face of the wearer. Further, in one or more embodiments, a separate seal or gasket can be attached to the mask body 12 to provide a seal against the face of the wearer.

As mentioned herein, the filter media 80 can be disposed between the first cover web 60 and the second cover web 70. In one or more embodiments, the filter media 80 can extend to the perimeter 30 in any suitable portion or portions of the mask body 12. In one or more embodiments, the filter media 80 extends to the perimeter 30 along the entire length of the perimeter.

The mask body 12 can include any suitable layer or layers, including the filter media 80, the first cover web 60, and the second cover web 70. When the respirator 10 is a molded mask, the mask body can also include an optional shaping layer (not shown). *See, e.g.,* U.S. Patent Nos. 6,923,182 to Angadjivand et al.; 7,131,442 to Kronzer et al.; 6,923,182 and 6,041,782 to Angadjivand et al.; 4,807,619 to Dyrud et al.; and 4,536,440 to Berg.

In general, the filter region 40 of the mask body 12 removes contaminants from the ambient air and may also act as a barrier layer that precludes liquid splashes from entering the mask interior. The second cover web 70 (i.e., when the second cover web is the outer cover web) can act to stop or slow any liquid splashes, and the filter media 80 can then contain them if there is penetration past the other layers. The filter region 40 of the mask body 12 can include a particle capture or gas and vapor type filter. The filter region 40 can include multiple layers of similar or dissimilar filter media and one or more cover webs as the application requires.

The first and second cover webs 60, 70 can be located on the outer sides of the filter region 40 to capture any fibers that could come loose therefrom. Typically, the cover webs 60, 70 are made from a selection of fibers that provide a comfortable feel, particularly the outer surface 64 of the first cover web 60 that makes contact with the wearer's face (when the first cover web is the inner cover web). The constructions of various filter layers, shaping layers, and cover webs that may be used with a mask body used in a respirator 10 are described herein in more detail.

The first and second cover webs 60, 70 also may have filtering abilities. One or both of the first and second cover webs 60, 70 may also serve to make the respirator 10 more comfortable to wear. The cover webs 60, 70 may be made from nonwoven fibrous materials such as spun bonded fibers that contain, e.g., polyolefins, and polyesters. *See*, e.g., U.S. Patent Nos. 6,041,782 to Angadjivand et al.; 4,807,619 to Dyrud et al.; and 4,536,440 to Berg. When a wearer inhales, air is drawn through the mask body, and airborne particles become trapped in the interstices between the fibers, particularly the fibers in the filter layer.

A typical cover web may be made from polypropylene or a polypropylene/polyolefin blend that contains 50 weight percent or more polypropylene. These materials have been found to offer high degrees of softness and comfort to the wearer and also, when the filter material is a polypropylene BMF material, to remain secured to the filter material without requiring an adhesive between the layers. Polyolefin materials that are suitable for use in a cover web may include, for example, a single polypropylene, blends of two polypropylenes, and blends of polypropylene and polyethylene, blends of polypropylene and poly(4-methyl-1-pentene), and/or blends of polypropylene and polybutylene. One example of a fiber for the cover web is a polypropylene BMF made from the polypropylene resin "Escorene 3505G" from Exxon Corporation, providing a basis weight of about 25 g/m² and having a fiber denier in the range 0.2 to 3.1 (with an average, measured over 100 fibers of about 0.8). Another suitable fiber is a polypropylene/polyethylene BMF (produced from a mixture comprising 85% of the resin "Escorene 3505G" and 15 percent of the ethylene/alpha-olefin copolymer "Exact 4023" also from Exxon Corporation) providing a basis weight of about 25 g/m² and having an average fiber

denier of about 0.8. Suitable spunbond materials are available under the trade designations “Corosoft Plus 20,” “Corosoft Classic 20” and “Corovin PP S 14,” from Corovin GmbH of Peine, Germany, and a carded polypropylene/viscose material available, under the trade designation “370/15,” from J.W. Suominen OY of Nakila, Finland. Cover webs typically have
5 very few fibers protruding from the web surface after processing and therefore have a smooth outer surface. Examples of cover webs that may be used in a respirator of the present disclosure are described, e.g., in U.S. Patent Nos. 6,041,782 to Angadjivand; 6,123,077 to Bostock et al.; and PCT Publication No. WO 96/28216A to Bostock et al.

In one or more embodiments, one or both of the first cover web 60 and second cover web
10 70 can include a polymeric netting. Any suitable polymeric netting can be utilized for one or both cover webs. The netting may be made from a variety of polymeric materials. Polymers suitable for netting formation are thermoplastic materials. Examples of thermoplastic polymers that can be used to form polymer netting of the present invention include polyolefins (e.g., polypropylene and polyethylene), polyethylene-vinyl acetate (EVA), polyvinyl chloride,
15 polystyrene, nylons, polyesters (e.g., polyethylene terephthalate), and elastomeric polymers, (e.g., ABA block copolymers, polyurethanes, polyolefin elastomers, polyurethane elastomers, metallocene polyolefin elastomers, polyamide elastomers, ethylene vinyl acetate elastomers, and polyester elastomers). Blends of two or more materials also may be used in the manufacture of nettings. Examples of such blends include polypropylene/EVA and polyethylene/EVA.

20 Polypropylene may be preferred for use in the polymeric netting since melt-blown fibers are regularly made from polypropylene. Use of similar polymers enables proper welding of the support structure to the filtering structure.

Filter media 80 that may be beneficially employed in the respirator 10 are generally low in pressure drop (e.g., less than about 195 to 295 Pascals at a face velocity of 13.8 centimeters
25 per second) to minimize the breathing work of the mask wearer. Filter media 80 can also be flexible and have sufficient shear strength so that they generally retain their structure under the expected use conditions. Examples of particle capture filters include one or more webs of fine inorganic fibers (such as fiberglass) or polymeric synthetic fibers. Synthetic fiber webs may include electret-charged polymeric microfibers that are produced from processes such as
30 meltblowing. Polyolefin microfibers formed from polypropylene that has been electrically charged can provide utility for particulate capture applications.

In one or more embodiments, the filter media 80 can include one or more filtration layers. Any suitable filtration layer or layers can be included in filter media 80. The filtration layer generally will remove a high percentage of particles and/or or other contaminants from the
35 gaseous stream that passes through it. For fibrous filter layers, the fibers selected depend upon

the kind of substance to be filtered and, typically, are chosen so that they do not become bonded together during the manufacturing operation. As indicated, the filtration layer may come in a variety of shapes and forms and typically has a thickness of about 0.2 millimeters (mm) to 1 centimeter (cm), more typically about 0.3 mm to 0.5 cm, and it could be a generally planar web or it could be corrugated to provide an expanded surface area. *See*, e.g., U.S. Patent Nos. 5,804,295 and 5,656,368 to Braun et al. The filter media 80 also may include multiple filtration layers.

Essentially any suitable material that is known (or later developed) for forming a filtration layer may be used as the filtering material. In one or more embodiments, webs of melt-blown fibers, such as those taught in Wentz, Van A., *Superfine Thermoplastic Fibers*, 48 Indus. Eng. Chem., 1342 et seq. (1956), especially when in a persistent electrically charged (electret) form can be utilized (*see*, e.g., U.S. Patent No. 4,215,682 to Kubik et al.). These melt-blown fibers may be microfibers that have an effective fiber diameter less than about 20 micrometers (μm) (referred to as BMF for “blown microfiber”), typically about 1 to 12 μm . Effective fiber diameter may be determined according to Davies, C. N., *The Separation Of Airborne Dust Particles*, Institution Of Mechanical Engineers, London, Proceedings 1B, 1952. In one or more embodiments, the filtration layer can include one or more BMF webs that contain fibers formed from polypropylene, poly(4-methyl-1-pentene), and combinations thereof. Electrically charged fibrillated-film fibers as taught in U.S. Patent Re. 31,285 to van Turnhout also may be suitable, as well as rosin-wool fibrous webs and webs of glass fibers or solution-blown, or electrostatically sprayed fibers, especially in microfiber form. Electric charge can be imparted to the fibers by contacting the fibers with water as disclosed in U.S. Patent Nos. 6,824,718 to Eitzman et al.; 6,783,574 to Angadjivand et al.; 6,743,464 to Insley et al.; 6,454,986 and 6,406,657 to Eitzman et al.; and 6,375,886 and 5,496,507 to Angadjivand et al. Electric charge also may be imparted to the fibers by corona charging as disclosed in U.S. Patent No. 4,588,537 to Klasse et al., or by tribocharging as disclosed in U.S. Patent No. 4,798,850 to Brown. Also, additives can be included in the fibers to enhance the filtration performance of webs produced through the hydro-charging process (*see* U.S. Patent No. 5,908,598 to Rousseau et al.). Fluorine atoms, in particular, can be disposed at the surface of the fibers in the filter layer to improve filtration performance in an oily mist environment. *See*, e.g., U.S. Patent Nos. 6,398,847 B1, 6,397,458 B1, and 6,409,806 B1 to Jones et al. Typical basis weights for electret BMF filtration layers are about 10 to 100 grams per square meter (g/m^2). When electrically charged according to techniques described in, e.g., the ‘507 Angadjivand et al. patent, and when including fluorine atoms as mentioned in the Jones et al. patents, the basis weight may be about 20 to 40 g/m^2 and about 10 to 30 g/m^2 , respectively.

In one or more embodiments, the mask body 12 can also include functional material 90. The functional material 90 can be disposed in any suitable location on or in the mask body 12. For example, in the embodiment illustrated in FIGS. 1-6, the functional material 90 is disposed in the filter region 40 of the mask body 12. Further, the functional material 90 can be disposed between one or more of the various layers of the mask body 12. For example, as illustrated in FIG. 3, the functional material 90 is disposed between the first cover web 60 and the filter media 80. In one or more embodiments, the functional material 90 can be disposed between the second cover web 70 and the filter media 80. Further, in one or more embodiments, the functional material 90 can be disposed within at least one of the first cover web 60, the second cover web 70, and the filter media 80. In other words, the functional material 90 can be disposed between one or more layers of the filter media 80 or within one or more layers of the filter media.

In one or more embodiments, the filter media 80 can include one or more filtration layers. In such embodiments, the functional material can be disposed on or within one or more filtration layers of the filter media 80. Further, in one or more embodiments, the functional material 90 can be disposed between two or more filtration layers of the filter media 80.

In one or more embodiments, the functional material 90 can be disposed on the outer surface 64 of the first cover web 60, the outer surface 74 of the second cover web 70, or on both of the outer surfaces of the first and second cover webs. Further, in one or more embodiments, the active material 90 can be disposed on one or both of the outer surfaces 64, 74 of the first and second cover web 60, 70 and between the first and second cover webs.

The functional material 90 can include any suitable material or combination of materials that can absorb or remove one or more gases or particulates from air passing between the outer surface 11 and the inner surface 13 of the mask body 12. For example, in one or more embodiments, the functional material 90 can include a layer that includes sorptive materials such as activated carbon. Further, separate particulate filtration layers may be used in conjunction with sorptive layers to provide filtration for both particulates and vapors. The sorbent component may be used for removing hazardous or odorous gases from the breathing air. Sorbents may include powders or granules that are bound in a filter layer by adhesives, binders, or fibrous structures. *See, e.g.,* U.S. Patent Nos. 6,234,171 to Springett et al. and 3,971,373 to Braun.

For example, a variety of active particles can be employed as sorbents. In one or more embodiments, the active particles are capable of absorbing or adsorbing gases, aerosols, or liquids expected to be present under the intended service conditions. The active particles can be in any useful form including beads, flakes, granules, fibers, or agglomerates. Exemplary active particles include activated carbon, alumina, and other metal oxides, clay, hopcalite, and other catalysts, ion exchange resins, molecular sieves, and other zeolites, silica, sodium bicarbonate,

biocides, fungicides, and virucides. Mixtures of particles can be employed, e.g., to absorb mixtures of gases.

The functional material 90 can include any suitable size or combination of sizes of active particles. For example, in one or more embodiments, the active particles can have a mesh size of 6 x 8 (3.36 x 2.38 mm), 12 x 20 (1.68 x 0.84 mm), 20 x 50 (0.84 x 0.297 mm), 32 x 60 (0.545 x 0.25 mm), 40 x 200 (0.42 x 0.074 mm), 80 x 400 (0.177 x 0.037 mm), etc. In general, the functional material 90 can include any suitable distribution of particle sizes of active particles. In one or more embodiments, the functional material 90 can include a first portion of active particles having a first mesh size and a second portion of active particles having a second mesh size that is different from the first mesh size to provide a bimodal distribution of active particles. For example, in one or more embodiments, the functional material 90 can include a first portion of active particles having a mesh size of 12 x 20, and a second portion of active particles having a mesh size of 32 x 60. Further, for example, in one or more embodiments, the functional material 90 can include first, second, and third portions of active particles to provide a trimodal distribution of active particle sizes.

A sorbent layer can be formed by coating a substrate, such as fibrous or reticulated foam, to form a thin coherent layer. Sorbent materials may include activated carbons that are chemically treated or not, porous alumina-silica catalyst substrates, and alumina particles. An example of a sorptive filtering structure that may be conformed into various configurations is described in U.S. Patent No. 6,391,429 to Senkus et al.

The functional material 90 can be disposed on or within the mask body 12 using any suitable technique or combination of techniques. For example, the functional material 90 can include active particles disposed on or in an adhesive layer or layers that is disposed on or within the mask body 12. For example, the adhesive layer can be disposed, e.g., on the filter media 80, and active particles can be disposed on or within the adhesive layer using any suitable technique or combination of techniques to provide the functional material 90. The adhesive layer can be a continuous layer. In one or more embodiments, the adhesive layer can be a patterned adhesive layer that includes any suitable pattern or combination of patterns.

The adhesive layer or layers can include any suitable material or combination of materials, e.g., structural adhesives, pressure-sensitive adhesives (e.g., acrylic-based pressure-sensitive adhesives), hot melt adhesives, epoxies, etc.

The active particles can be disposed on or in an adhesive layer using any suitable technique or combination of techniques. For example, in embodiments where the functional material 90 includes a bimodal distribution of active particle sizes, a first portion of active particles having a first mesh size can be disposed on or in the adhesive layer, and a second

portion of active particles having a second mesh size can be disposed over the first portion of active particles. In one or more embodiments, the first mesh size of the first portion of active particles can be greater than the second mesh size of the second portion of active particles. While not wishing to be bound by any particular theory, in such embodiments, the active particles of the second portion that have the smaller mesh size can be disposed in one or more of the spaces between the active particles of the first portion that have a larger mesh size such that the particles of the second portion of active particles fill one or more of the spaces between the particles of the first portion of active particles. In embodiments where the functional material 90 includes a trimodal distribution of active particle sizes, a third portion of active particles having a third mesh size that is smaller than both the first and second mesh sizes can be disposed over the first and second portions of active particles. In other words, the active particles of the functional material 90 can be disposed in two or more layers of decreasing sizes of particles, two or more layers of increasing sizes of particles, or a gradient of layers of different sizes of particles.

The functional material 90 can include any suitable density or densities of active particles. In one or more embodiments, the functional material 90 can include at least 50 g/m² and no greater than 600 g/m² of active particles. In one or more embodiments, the functional material 90 can include at least 130 g/m² and no greater than 170 g/m² of active particles.

The functional material 90 can be disposed in any suitable pattern on or within the mask body 12. For example, in one or more embodiments, the functional material 90 can be disposed in a continuous layer on or within the mask body 12. Further, in one or more embodiments, the functional material 90 can include a patterned functional material that is disposed on or within the mask body 20 in any suitable pattern or patterns.

As mentioned herein, the functional material 90 can be disposed in any suitable location on or within the mask body 12. In one or more embodiments, the functional material 90 can be disposed such that it is not in at least a portion of the perimeter seal region 50. In other words, one or more portions of the perimeter seal region 50 do not include the functional material 90. For example, as illustrated in FIG. 3, the functional material 90 includes a boundary or edge 92 that is spaced apart from the perimeter seal region 50 a distance 94. The distance 94 can be any suitable distance. In one or more embodiments, distance 94 can be no greater than 4 mm. In one or more embodiments, the distance 94 can be about 0 mm. The distance 94 can include a treatment to one or more of the layers 60, 70, and 80 to reduce air flow or even be made air impermeable. This treatment may be a compression of layers, e.g., an ultrasonic weld, or an added sealant, e.g., hot melt or other adhesive.

In one or more embodiments, the functional material 90 is disposed in no greater than 50% of a total area of the perimeter seal region 50. Further, in one or more embodiments, the

functional material 90 is disposed in no greater than 10% of the total area of the perimeter seal region 50. In one or more embodiments, the functional material 90 is disposed in no greater than 5% of the total area of the perimeter seal region 50. And in one or more embodiments, the functional material 90 is disposed in no greater than 1% of the total area of the perimeter seal region.

As illustrated in FIGS. 4-6, the functional material 90 can be disposed on or in at least one of the upper panel 14, the central panel 16, and the lower panel 18 of the mask body 12. As shown in FIG. 4, the functional material 90 is disposed in a filter region 42 of the upper panel 14 such that a boundary 43 of the functional material is formed between the first line of demarcation 20 and an upper portion 52 of the perimeter seal region 50. In other words, the functional material 90 is disposed on or in the upper panel 14 such that it is not within at least a portion of the upper portion 52 of the perimeter seal region 50. Further, the functional material 90 is disposed such that it is not within at least a portion of the first line of demarcation 20. As mentioned herein, the first line of demarcation 20 can be a seal or weld line formed, e.g., when the upper panel 14 is connected to the central panel 16. The first line of demarcation 20, therefore, can form the first seal region 24 between the upper panel 14 and the central panel 16. In one or more embodiments, the functional material 90 is not disposed in at least a portion of the first seal region 24.

The boundary 43 of the functional material 90 disposed on or in the upper panel 14 can take any suitable shape or combination of shapes. Further, in one or more embodiments, the functional material 90 can be disposed in a continuous layer or layers within the boundary 43. In one or more embodiments, the functional material 90 can be disposed in one or more patterns within the boundary 43. The boundary 43 can be a physical boundary formed by the functional material 90. In one or more embodiments, the boundary 43 can be an imaginary boundary that circumscribes the functional material 90 disposed on or in the upper panel 14.

Further, the functional material 90 is disposed on or in the central panel 16 of FIG. 5 in a filter region 44 of the central panel. The functional material 90 is disposed such that a boundary 45 of the functional material is between the first line of demarcation 20 (e.g., the first seal region 24) and the second line of demarcation 22. The second line of demarcation 22 can provide a second seal region 26 where the central panel 16 is connected to the lower panel 18 using any suitable technique or combination of techniques, e.g., ultrasonic welding. In one or more embodiments, the functional material 90 is not disposed in at least a portion of the second seal region 26. The boundary 45 of the functional material 90 disposed on or in the central panel 16 can take any suitable shape or combination of shapes. Further, the functional material 90 can be disposed in a continuous layer or layers within the boundary 45. In one or more embodiments,

the functional material 90 can be disposed in one or more patterns within the boundary 45. The boundary 45 can be a physical boundary formed by the functional material 90. In one or more embodiments, the boundary 45 can be an imaginary boundary that circumscribes the functional material 90 disposed on or in the upper panel 16. Further, a second boundary 41 can be formed such that the functional material 90 at least partially encloses an opening in the central panel 120 that is formed to provide an exhalation valve. In one or more embodiments, an additional seal region can be formed along at least a portion of the boundary 41, where functional material 90 is not disposed in at least a portion of this additional seal region.

And as illustrated in FIG. 6, the functional material 90 can be disposed in a filter region 46 of the lower panel 18. A boundary 47 of the functional material is disposed between the second line of demarcation 22 (e.g., the second seal region 26) and a lower portion 54 of the perimeter seal region 50. The filter regions 42, 44, and 46 of the upper panel 14, central panel 16, and lower panel 18, provide the filter region 40 of the mask body 12 of respirator 10. In one or more embodiments, the functional material 90 is disposed on or in the lower panel 18 such that it is not within at least a portion of the lower portion 54 of the perimeter seal region 50. In one or more embodiments, the functional material 90 is not disposed in at least a portion of the second seal region 24. The boundary 47 of the functional material 90 disposed on or in the lower panel 18 can take any suitable shape or combination of shapes. Further, the functional material 90 can be disposed in a continuous layer or layers within the boundary 47. In one or more embodiments, the functional material 90 can be disposed in one or more patterns within the boundary 47. The boundary 47 can be a physical boundary formed by the functional material 90. In one or more embodiments, the boundary 47 can be an imaginary boundary that circumscribes the functional material 90 disposed on or in the lower panel 18.

As mentioned herein, the functional material 90 can be disposed such that it is not located in at least a portion of one or more additional seal regions of the mask body 12. For example, in the embodiment illustrated in FIGS. 1-6, the functional material 90 can be disposed such that it is not within the first and second seal regions 24, 26. In one or more embodiments, the mask body 12 also does not include functional material 90 disposed in at least a portion of the perimeter seal region 50. The mask body 12, therefore, includes functional areas of the mask body 12 (e.g., within the filter region 40) and nonfunctional areas (e.g., within at least a portion of the perimeter seal region 50, the first seal region 24, and the second seal region 26).

The respirator 10 can include any suitable additional elements or features that provide any desired functionality. For example, in one or more embodiments, the respirator 10 can include a nose foam 104 (FIG. 2) disposed in a nose region of the upper panel 14 of the mask body 12. The nose foam 104 can include any suitable material or combination of materials that

are adapted to engage a nose of a wearer and provide additional comfort to the wearer while providing a seal between the face and the mask body 12. Further, in one or more embodiments, the respirator 10 can include a nose clip 100 (FIG. 1) disposed in any suitable location on or within the mask body 12.

5 In one or more embodiments, an exhalation valve (not shown) may be attached to the mask body 12 to facilitate purging exhaled air from the interior gas space. The use of an exhalation valve may improve wearer comfort by rapidly removing the warm moist exhaled air from the mask interior. *See*, e.g., U.S. Patent Nos. 7,188,622; 7,028,689, and 7,013,895 to Martin et al.; 7,428,903; 7,311,104; 7,117,868; 6,854,463; 6,843,248; and 5,325,892 to Japuntich et al.; 10 7,302,951 and 6,883,518 to Mittelstadt et al.; and RE 37,974 to Bowers. Essentially any exhalation valve that provides a suitable pressure drop and that can be properly secured to the mask body 12 may be used in connection with the present disclosure to rapidly deliver exhaled air from the interior gas space to the exterior gas space. The exhalation valve can be disposed in any suitable location on or in the mask body 12. For example, the exhalation valve can be 15 disposed in the opening 120 disposed in the central panel 16 as shown in FIG. 5.

As mentioned herein, the functional material can be utilized with any suitable respirator. For example, FIGS. 7-8 are a schematic views of another embodiment of a filtering face-piece respirator 200. All of the design considerations and possibilities regarding the filtering face-piece respirator 10 of FIGS. 1-6 apply equally to the filtering face-piece respirator 200 of FIGS. 7-8. 20 The respirator 200 includes a mask body 212 having a perimeter 217. The filtering face-piece respirator 200 can include any suitable respirator, e.g., a flat-fold filtering face-piece respirator, a molded filtering face-piece respirator, etc. In the illustrated embodiment, the respirator 200 is a vertical flat-fold respirator. In one or more embodiments, the respirator 200 can be a horizontal flat-fold respirator.

25 The mask body 212 includes a right portion 202 and a left portion 204 (using the terms left, right, upper, and lower in the wearer's sense). The right and left portions 202, 204 are on each side of a centerline 201. The right and left portions 202, 204 are bounded by the perimeter 217 of the mask body 212. The mask body 212 can take any suitable shape or combination of shapes. Further, a harness 260 can be attached to the mask body 212 using any suitable technique 30 or combination of techniques. In one or more embodiments, the harness 260 can include a strap or straps 262. Further, in one or more embodiments, the respirator 200 can include a nose clip 252 disposed in any suitable location on or within the mask body 210.

The mask body 212 of the respirator 200 can also include one or more panels that can be separated by one or more lines of demarcation. For example, as shown in FIG. 8, which is a front 35 schematic view of an exterior surface 214 of the respirator 210 in an open ready-to-use

configuration, the mask body 212 of respirator 200 includes six filtration panels. Three of those panels are shown in FIG. 7 as right upper panel 220, right central panel 222, and right lower panel 224 of the right portion 202 of the mask body. The remaining three panels are shown in FIG. 8 as left upper panel 230, left central panel 232, and left lower panel 234 of the left portion 204 of the mask body 212. Vertical bisecting line or centerline 201 divides the left and right portions 202, 204 of respirator 200.

In one or more embodiments, upper right and left panels 220, 230 are connected through a first seal region 243, central panels 222, 232, are connected through a second seal region 245, and lower panels 224, 234 are connected through a vertical fold 240. As a result, the respirator 200 can be considered a vertical chin-fold respirator. In one or more embodiments, the respirator 200 can include a vertical fold line in place of the second seal region 245 that connects the right and left central panels 222, 232 such that the respirator can be considered to be a central fold respirator. In such embodiments, the right and left lower panels 224, 234 can be connected through an additional seal region. Further, in one or more embodiments, the first seal region 243 can be replaced with a fold line such that the respirator can be considered a nose fold respirator. In such embodiments, the right and left lower panels 224, 234 can be connected through an additional seal region.

In one or more embodiments, two or more of the various layers of the mask body 212 can be connected together in the first and second seal regions 243, 245. Although not shown, the mask body 212 can include a first cover web, a second cover web, and filter media disposed between the first and second cover webs. These various layers can include any suitable material or combination of materials, e.g., the same materials described regarding the first cover web 60, the second cover web 70, and the filter media 80 of mask body 12 of respirator 10. In one or more embodiments, two or more of the various layers of the mask body 212 can also be connected in a perimeter seal region 250 that defines at least a portion of the perimeter 217 of the mask body 212. In the perimeter seal region 250, at least two of the first cover web, second cover web, and filter media can be connected as is described regarding perimeter seal region 50 of respirator 10. Any suitable technique or combination of techniques can be utilized to form the perimeter seal region 250.

In one or more embodiments, the right upper panel 220 and right central panel 222 are separated by a first line of demarcation 226, and the right central panel 222 and the right lower panel 224 are separated by a second line of demarcation 228. Similarly, in one or more embodiments, the left upper panel 230 and the left central panel 232 are separated by a first line of demarcation 236, and the left central panel 232 and the left lower panel 234 are separated by a second line of demarcation 238. The first and second lines of demarcation of each of the right

and left portions 202, 204 of the mask body 210 can include any suitable bond line, weld line, seam, etc. Further, the first and second lines of demarcation for each of the right and left portions 202, 204 of the mask body 210 can be formed using any suitable technique or combination of techniques.

For example, panels 220 and 222 can be defined by welded bond line 226, which extends over at least part of the region between panels 220 and 222. In similar fashion, panels 222 and 224 can be defined by welded bond line 228, panels 230 and 232 can be defined by welded bond line 236, and panels 232 and 234 can be defined by welded bond line 238. One or more of panels 220, 222, 224, 230, 232, and 234 may be provided as separate components. Further, respirator 200 may be folded in half (e.g., for storage in a package prior to use or in a wearer's pocket) along the centerline 201 that, in this embodiment, corresponds to the second seal region 245.

The mask body 212 can also include functional material (not shown) disposed in one or both of a filter region 240 of the right portion 202 and filter region 242 of the left portion 204. The functional material can include any suitable functional material, e.g., the same material described regarding functional material 80 of respirator 10.

The functional material can be disposed in one or both of the filter region 240 of the right portion 202 and the filter region 240 of the left portion 204. In one or more embodiments, the functional material is not disposed in at least a portion of the perimeter seal region 250. Further, in one or more embodiments, the functional material is also not disposed in at least a portion of one or both of the first seal region 243 and the second seal region 245. And in one or more embodiments, the functional material can also not be disposed in one or more of the lines of demarcation 220, 224, 236, and 238 of the left and right portions 202, 204. In one or more embodiments, the functional material is disposed in no greater than 50% of a total area of the perimeter seal region 250. In one or more embodiments, the functional material is disposed in no greater than 10% of a total area of the perimeter seal region 250. Further, in one or more embodiments, the functional material is disposed in no greater than 5% of a total area of the perimeter seal region 250. And in one or more embodiments, the functional materials disposed in no greater than 1% of the total area of the perimeter seal region 250. Similarly, the functional material is disposed in no greater than 50% of a total area of one or both of the first seal region 243 and second seal region 245. In one or more embodiments, the functional material is disposed in no greater than 10% of a total area of one or both of the first seal region 243 and second seal region 245. Further, in one or more embodiments, the functional material is disposed in no greater than 5% of the total area of one or both of the first seal region 243 and second seal region 245. And in one or more embodiments, the functional material is disposed in no greater than 1% of the total area of one or both of the first seal region 243 and second seal region 245. Similarly,

the functional material can be disposed in no greater than any predetermined area of the total area of the lines of demarcation 226, 228, 236, and 238 of the right and left portions 202, 204.

The various embodiments of respirators described herein can be manufactured using any suitable technique or combination of techniques. *See*, e.g., U.S. Patent No. 6,148, 817 to Bryant et al.; U.S. Patent No. 6,722,366 to Bostock et al.; U.S. Patent No. 6,394,090 to Chen et al., and U.S. Patent Publication No. 2008/0011303 to Angadjivand et al. For example, FIG. 9 is a schematic perspective view of one embodiment of a manufacturing process 300. In one or more embodiments, the process can be continuous, i.e., the respirator can be manufactured along a manufacturing line without the need to remove the respirator from the line prior to the completion of the process. The respirator can be formed from a single piece (which single piece can have multiple layers), although multiple pieces can be attached to one another using any suitable technique or combination of techniques, such as a batch process (e.g., by plunge welding) or a continuous process (e.g., rotary welding). Although the process is described in reference to the respirator 10 as illustrated in FIGS. 1-6, the process can be utilized to manufacture any filtering face-piece respirator.

The first (inner) cover web 60 can be provided using any suitable technique or combination techniques. At adhesive printing station 304, one or more layers of adhesive can be disposed on the first cover web 60 using any suitable technique or combination of techniques, e.g., one or more printing processes (e.g., screen, gravure, spray). In one or more embodiments, one or more of the adhesive layers can be continuous. In one or more embodiments, the adhesive applied at adhesive printing station 304 can be a patterned adhesive layer or layers. In one or more embodiments in which the machinery is configured differently than as shown in FIG. 9, adhesive can also be disposed (e.g., printed) on one or both of the second cover web 70 and the filter media 80 at adhesive printing station 304.

One or more layers of active particles can be selectively disposed on or in the adhesive layer at coating station 306 to provide functional material 90 on the first cover web 60. Any suitable technique or combination of techniques can be utilized to dispose active particles on the adhesive layer at station 306, e.g., water-fall, curtain, etc., such that at least a portion of the active particles is attached to the adhesive layer. In one or more embodiments, a portion of the active particles that is not attached to the adhesive layer can be removed using any suitable technique or combination of techniques.

Filter media 80 can be disposed on the first cover web 60 such that the functional material 90 is between the first cover web and the filter media. One or more optional layers can also be disposed on the filter media 80, on the first cover web 60, or between the filter media and the first cover web, e.g., a stiffening layer 390. The second (outer) cover web 70 can be disposed

on the filter media 80. At folding station 308, the various layers are folded together to form one or more mask body blanks 310, each having an upper, central, and lower panels 14, 16, 18. A cutting station (not shown) can be utilized to separate the mask body blanks 310 to form one or more mask bodies. The three panels may be joined prior to, or as part of, the cutting step.

5 FIG. 10 is a flowchart of another embodiment of a method 400 of forming a filtering face-piece respirator that includes a mask body. Although the method 400 will be described in regard to the respirator 10 of FIGS. 1-6, the method can be utilized to form any suitable filtering face-piece respirator. The method 400 includes forming filter media 80 using any suitable technique or combination of techniques at 402. Functional material 90 is selectively disposed in
10 the filter region 40 of the mask body 12 at 404. The functional material 90 can be disposed either between the first cover web 60 and the second cover web 70 of the mask body 12, or on one or both of the outer surfaces 64, 74 of the first cover web and second cover web.

 The filter media 80 can be disposed between the first cover web 60 and the second cover web 70 at 406. Further, at 408, at least one of the first cover web 60, the filter media 80, and the
15 second cover web 70 can be attached together to form the perimeter seal region 50 that defines at least a portion of the perimeter 30 of the mask body 12. In one or more embodiments, the functional material 90 is not disposed in at least a portion of the perimeter seal region 50 as is further described herein.

 FIG. 11 is a schematic flow chart of another embodiment of a method 500 of forming a
20 mask body of a filtering face-piece respirator. Although the method 500 will be described in regard to the filtering face-piece respirator 10 of FIGS. 1-6, the method can be utilized to form any suitable filtering face-piece respirator. The method 500 includes forming the upper panel 14, the central panel 16, and the lower panel 18 of the mask body 12 using any suitable technique or combination of techniques at 502. Each of the upper, central, and lower panels 14, 16, 18 can be
25 formed by forming filter media 80 at 504. At 506, functional material 90 can be selectively disposed in the filter region 40 of each of the upper, central, and lower panels 14, 16, 18 between the first cover web 60 and the second cover web 70, on the outer surfaces 64, 74 of at least one of the first cover web and the second cover web or between the first and second cover webs and one or both of the outer surfaces of the first and second cover webs.

30 At 508, the filter media 80 can be selectively disposed between the first cover web 60 and the second cover web 70. Further, at 510, the upper panel 14 can be attached to the central panel 16 along the first seal region 24 using any suitable technique or combination of techniques. The lower panel 18 can be attached to the central panel 16 along the second seal region 26 using any suitable technique or combination of techniques. Further, at least two of the first cover web
35 60, the filter media 80, and the second cover web 70 of the upper, central, and lower panels 14,

16, 18 can be attached together along the perimeter 30 of the mask body 12 to form the perimeter seal region 50 using any suitable technique or combination of techniques. In one or more embodiments, the functional material 90 is not disposed in at least a portion of at least one of the perimeter seal region 50, the first seal region 24, and the second seal region 26.

5

Examples

The following examples are intended to illustrate exemplary embodiments within the scope of this disclosure. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the disclosure are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

15

Examples 1 and 2

A filtering face piece respirator mask was prepared as follows:

A pressure sensitive adhesive mixture was produced by combining a material commercially available under the trade designation "Acronal A220 na" from BASF, Germany with 0.4 wt % of another material commercially available under the trade designation "Ultrez 10" from Lubrizol, Wickliffe, Ohio using a jar roller. A nonwoven web composed of polypropylene blown melt fibers (BMF) was provided, similar to those described in US5496507. A seamless, electroformed rotary screen (such as those commercially available from Lebanon Valley Engravers, Pennsylvania) was provided with a mesh size of 40 threads per inch, and an emulsion coating that defines the desired pattern for printing, corresponding to the desired filter region within the mask. The adhesive mixture was pressed through the rotary screen onto the nonwoven substrate in a continuous fashion, and the printed nonwoven web was passed through a drying oven set to approximately 49°C for approximately 18 seconds to dry the adhesive. This resulted in a dried weight of roughly 10 grams per square meter (gsm) of adhesive within the printed areas, and no adhesive in the unprinted areas. A 2 mil thick liner, such as those commercially available under the trade designation "Primeliner 7320 silicone coated liner, with part # PK-2395-1325" from Loparex, Hammond, WI, was laminated against the adhesive pattern after drying to prevent the nonwoven web from sticking to itself during winding.

25

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Sections of nonwoven web corresponding to one respirator mask were then cut from this roll of printed nonwoven web. Activated carbon particles, such as those commercially available under the trade designation “GW-H activated carbon particles” from Kuraray Chemicals, Osaka, Japan, with a mesh size of 32 x 60 (0.545 x 0.25 mm) were scattered uniformly and in excess on top of the printed nonwoven web by hand, such that the carbon is able to bond to the pressure sensitive adhesive wherever it is printed. Excess unbonded carbon is removed by inverting the web and gently shaking it, allowing any carbon that is not bonded to the adhesive to fall off and be recycled. Using this approach the carbon add was found to be approximately 135 gsm in the printed area, with only a negligible amount of residual carbon in the unprinted area, and resulting in a BMF layer with patterned carbon.

This patterned carbon sheet was then covered with a 40 gsm coverweb, such as those commercially available under the trade designation “Daltex polyethylene spunbond coverweb” from Don & Low, Angus, France. An additional layer of BMF nonwoven web without any carbon was placed beneath the patterned carbon sheet, and a second polypropylene cover web (approximately 20 gsm) was placed beneath this second layer of BMF. This resulting stack of four webs (lower cover web, lower layer of BMF, BMF layer with patterned carbon, and upper coverweb) were ultrasonically welded along the perimeter of the printed pattern, creating a perimeter sealing zone with a minimal amount of carbon.

The resulting four layers as prepared above were assembled into a respirator as described in Example 2 of patent EP1994961A1.

Samples were tested for nuisance organic vapor service life according to the following test method: a respirator was mounted in a closed chamber, with an air stream containing 50 ppm of n-hexane entering the chamber at an inlet at approximately 20 LPM airflow, 50% relative humidity ($\pm 3\%$) and 35° C ($\pm 2^\circ$ C). The n-hexane concentration was added to the airstream using an infusion syringe pump, such as those commercially available under the trade designation “Harvard Apparatus PHD 2000” from Harvard Apparatus, Holliston, Massachusetts, and a syringe, such as those commercially available under the trade designation “Hamilton gas tight 1005 syringe” from Hamilton Company, Reno, NV, along with a metal plate at room temperature to create n-hexane vapor. The concentration of n-hexane on the opposite side of the respirator sample was monitored using a gas chromatograph, such as those commercially available under the trade designation “8610C” from SRI Instruments, Torrance, CA, equipped with a flame ionization detector (FID). The time required for the concentration of n-hexane measured by the GC to reach 10 ppm is reported in Table 1 as the organic vapor (OV) service life, in minutes.

Particulate and penetration were determined using a filter tester, such as those commercially available under the trade designation “TSI 8130” from TSI, Inc, St. Paul, MN, filter tester, which determines the amount of particulate that passes through the filtering face piece when sealed into a test fixture per EN149:2001 test standard. The air flow rate was set to 95 LPM and the NaCl concentration to 2%. Results are recorded in Table 1 as Initial Pressure Drop and Initial NaCl Penetration.

Referring to Table 1, Examples 1 and 2 consist of the following construction: lower cover web, first BMF layer, second BMF layer which includes printed adhesive and carbon, upper cover web. In Example 1, the carbon and printed adhesive on the BMF layer are oriented towards the upper cover web, whereas in Example 2 the carbon and printed adhesive on the BMF layer are oriented towards the first BMF layer. In the control, the same general construction is used, but there is no carbon present.

Table 1

	Description	Initial Pressure Drop at 95 LPM (mmH ₂ O)	Initial NaCl Penetration (percent)	OV Service Life (mins)
Example 1	2 layer filter media with patterned carbon between BMF and top cover web	14.6	0.12%	63
Example 2	2 layer filter media with patterned carbon between two BMF layers	15.0	0.30%	60
Control	2 layer filter media	14.0	0.06%	0

Examples 3 to 9

A pressure sensitive adhesive mixture was produced by combining Acronal A220 na with 0.4 wt% Ultrez 10 using a jar roller. A nonwoven web composed of polypropylene blown melt fibers (BMF) was provided, similar to those described in U.S. Pat. No. 5496507. A seamless, electroformed rotary screen (such as those commercially available from Lebanon Valley Engravers, Pennsylvania) was provided with a mesh size of 40 threads per inch, and an emulsion coating that defines the desired pattern for printing, in this case being circles with a diameter of 11.4 cm. The adhesive mixture was pressed through the rotary screen onto the nonwoven substrate in a continuous fashion, and the printed nonwoven web was passed through a drying oven set to approximately 49°C for approximately 18 seconds to dry the adhesive. This resulted in a dried weight of roughly 10 grams per square meter (gsm) of adhesive within the printed areas, and no adhesive in the unprinted areas. A 2 mil thick 7320 silicone coated liner was

laminated against the adhesive pattern after drying to prevent the nonwoven web from sticking to itself during winding.

Sections of nonwoven web corresponding to one respirator mask were then cut from this roll of printed nonwoven web. GW-H activated carbon particles with varying mesh sizes (see Table 2) were scattered uniformly and in excess on top of the printed nonwoven web by hand, such that the carbon is able to bond to the pressure sensitive adhesive wherever it is printed. Excess unbonded carbon is removed by inverting the web and gently shaking it, allowing any carbon that is not bonded to the adhesive to fall off and be recycled. In some cases multiple mesh sizes of carbon were added successively, i.e. in Example 5 a 12 x 20 mesh carbon was scattered by hand onto the sample, then inverted and shaken to remove excess carbon. A 20 x 50 mesh carbon was then scattered onto the same sample, inverted and shaken to remove excess carbon. A 40 x 200 mesh carbon was then scattered onto the same sample, inverted and shaken to remove excess carbon. In Table 2, columns 2 through 5 list the amount of carbon bonded to the sample at a given mesh size, and column 6 lists the total amount of carbon added to the sample.

Table 2 also presents OV service life data, obtained using the following test method: a respirator was mounted in a closed chamber, with an air stream containing 50 ppm of n-hexane entering the chamber at an inlet at approximately 20 LPM airflow, 50% relative humidity ($\pm 3\%$) and 35°C ($\pm 2^\circ\text{C}$). The n-hexane concentration was added to the airstream using a Harvard Apparatus PHD 2000 infusion syringe pump and a Hamilton gas tight 1005 syringe, along with a metal plate at room temperature to create n-hexane vapor. The concentration of n-hexane on the opposite side of the respirator sample was monitored using an 8610C gas chromatograph equipped with an FID. The time required for the concentration of n-hexane measured by the GC to reach 5 ppm is reported in Table 1 as the organic vapor (OV) service life, in minutes.

Finally, Table 2 presents the pressure drop over the sample, obtained by measuring the pressure in an enclosed chamber upstream and downstream of a given sample, with air flowing normal to the sample at 85 L/min.

Table 2

	12x20 gsm	20x50 gsm	32x60 gsm	40x200 gsm	Total Carbon Mass (g)	5 ppm service life (mins)	Pressure Drop at 85 LPM (mmH ₂ O)
Example 3	431.4	-	-	-	431.4	0.0	10.5
Example 4	451.4	88.4	-	-	539.8	36.0	11.6
Example 5	446.2	97.9	-	21.0	565.1	43.0	12.4
Example 6	-	170.5	-	-	170.5	15.3	10.6

Example 7	-	168.4	-	91.5	259.9	21.3	13.9
Example 8	-	-	134.7	-	134.7	17.0	12.0
Example 9	-	-	134.7	89.8	224.5	22.8	13.4

Examples 10 to 14

To determine how the added adhesive weight impacts the amount of activated carbon bonded to the nonwoven web, the following test method was used: a material commercially available under the trade designation “Accuspray 16570” from 3M, St. Paul, MN was used to spray Acronal A220 na onto a nonwoven web composed of polypropylene blown melt fibers (BMF), similar to those described in U.S. Pat. No. 5496507. The amount of adhesive applied was varied in each Example. 32 x 60 mesh GW-H activated carbon particles was scattered uniformly and in excess on top of the printed nonwoven web by hand, such that the carbon was able to bond to the pressure sensitive adhesive wherever it was printed. Excess unbonded carbon was removed by inverting the web and gently shaking it, allowing any carbon that was not bonded to the adhesive to fall off and be recycled. Table 3 lists the weight of adhesive and carbon applied to the sample. In addition, Table 3 presents the pressure drop across the carbon loaded sample, obtained by measuring the pressure in an enclosed chamber upstream and downstream of a given sample, with air flowing normal to the sample at 85 L/min. Finally, particulate penetration was determined using a TSI 8130 filter tester, which determines the amount of particulate that passes through the filtering face piece when sealed into a test fixture per EN149:2001 test standard. The air flow rate was set to 95 LPM and the NaCl concentration to 2%. Results are recorded in Table 1 as Initial Pressure Drop and Initial NaCl Penetration.

These results are presented in Table 3

Table 3

	Adhesive gsm	Carbon gsm	Pressure Drop at 85 LPM (mmH ₂ O)	Particulate Penetration (percent)
Example 10	2.3	115.3	8.7	1.47%
Example 11	10.3	137.6	9.5	1.49%
Example 12	26.0	142.5	9.1	1.79%
Example 13	45.0	140.4	11.0	1.81%
Example 14	66.2	132.6	12.3	1.37%

All references and publications cited herein are expressly incorporated herein by reference in their entirety into this disclosure, except to the extent they may directly contradict this disclosure. Illustrative embodiments of this disclosure are discussed and reference has been

made to possible variations within the scope of this disclosure. These and other variations and modifications in the disclosure will be apparent to those skilled in the art without departing from the scope of the disclosure, and it should be understood that this disclosure is not limited to the illustrative embodiments set forth herein. Accordingly, the disclosure is to be limited only by

5 the claims provided below.

What is claimed is:

1. A filtering face-piece respirator comprising a mask body, wherein the mask body comprises:

5 a first cover web comprising an inner surface and an outer surface;
a second cover web comprising an inner surface and an outer surface;
filter media disposed between the first cover web and the second cover web;
a perimeter seal region that defines at least a portion of a perimeter of the mask body,
wherein at least two of the first cover web, second cover web, and filter media are connected
10 together in the perimeter seal region;
functional material disposed between the first cover web and the second cover web,
wherein the functional material comprises active particles; and
wherein the functional material is not disposed in at least a portion of the perimeter seal
region.

15 2. The respirator of claim 1, wherein the active particles are functionally disposed on at least one of the first cover web, second cover web, filter media, or an air permeable substrate.

3. The respirator of claim 1, further comprising a harness attached to the mask body.

20 4. The respirator of claim 1 or 2, wherein the mask body further comprises one or more interior seal regions disposed between panels defined within the perimeter seal region, wherein a panel is an area of the mask body separated at least in part from another area of the mask body by a line of demarcation.

25 5. The respirator of claim 4, wherein the functional material is not disposed in at least a portion of the interior seal regions.

30 6. The respirator of claim 1 or 2, wherein the mask body further comprises an upper panel, a lower panel, and a central panel disposed between the upper and lower panels, wherein the central panel is attached to the upper panel and the lower panel by first and second seal regions respectively.

35 7. The respirator of claim 4, wherein the functional material is not disposed in at least a portion of the first and second seal regions.

8. The respirator of any one of claims 1-4, wherein the functional material is disposed in no greater than 50% of a total area of the perimeter seal region and interior seal regions.

5 9. The respirator of any one of claims claim 1-4 wherein the functional material is disposed in no greater than 5% of a total area of the perimeter seal region and interior seal regions.

10. The respirator of any one of claims 1-4, wherein the functional material is disposed in no greater than 1% of a total area of the perimeter seal region and interior seal regions.

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11. The respirator of any one of claims 1-10, wherein the active particles of the functional material comprise carbon particles.

12. The respirator of any one of claims 1-11, wherein the functional material comprises a patterned functional material.

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13. The respirator of any one of claims 1-12, wherein the filter media comprises a filtration layer, wherein at least a portion of the functional material is disposed on the filtration layer.

14. The respirator of any one of claims 1-13, wherein the filtration layer comprises a blown microfiber web layer.

20

15. The respirator of any one of claims 1-14, wherein at least a portion of the functional material is disposed between the first cover web and the second cover web.

25

16. The respirator of any one of claims 1-15, wherein at least a portion of the functional material is disposed on at least one of the outer surface of the first cover web and the outer surface of the second cover web.

17. The respirator of claim 1, wherein the mask body is molded into a cup-shaped configuration.

30

18. A method of forming a filtering face-piece respirator that comprises a mask body, the method comprising:

forming filter media;

selectively disposing functional material in a filter region of the mask body either

5 between a first cover web and a second cover web of the mask body or on an outer surface of at least one of the first cover web and second cover web, wherein the functional material comprises active particles disposed on an adhesive layer;

disposing the filter media between the first cover web and the second cover web; and

10 attaching at least two of the first cover web, the filter media, and the second cover web together to form a perimeter seal region that defines at least a portion of a perimeter of the mask body, wherein the functional material is not disposed in at least a portion of the perimeter seal region.

19. The method of claim 18, wherein selectively disposing functional material comprises:

15 selectively disposing an adhesive layer in the filter region of the mask body on at least one of an inner surface of the first cover web, an inner surface of the second cover web, the filter media, an outer surface of the first cover web, and an outer surface of the second cover web; and

disposing the active particles on the adhesive layer such that at least a portion of the active particles is attached to the adhesive layer.

20. The method of claim 19, wherein selectively disposing functional material further comprises removing a portion of the active particles that is not attached to the adhesive layer.

21. A method of forming a mask body of a filtering face-piece respirator, the method comprising:

25 forming an upper panel, a central panel, and a lower panel, wherein forming each of the upper, central, and lower panels comprises:

forming filter media;

30 selectively disposing functional material in a filter region of each of the upper panel, central panel, and lower panel either between a first cover web and a second cover web or on an outer surface of at least one of the first cover web and the second cover web, wherein the functional material comprises active particles disposed on an adhesive layer;

disposing the filter media between the first cover web and the second cover web;

35 attaching the upper panel to the central panel to form a first seal region;

attaching the lower panel to the central panel to form a second seal region; and
attaching at least two of the first cover web, the filter media, and the second cover web of
the upper, central, and lower panels together along a perimeter of the mask body to form a
perimeter seal region;

5 wherein the functional material is not disposed in at least a portion of the first and second
seal regions and the perimeter seal region.

22. The method of claim 21, wherein selectively disposing functional material comprises:
selectively disposing the adhesive layer in the filter region of each of the upper panel,
10 central panel, and lower panel on at least one of an inner surface of the first cover web, an inner
surface of the second cover web, the filter media, the outer surface of the first cover web, and the
outer surface of the second cover web; and

disposing the active particles on the adhesive layer such that at least a portion of the
active particles is attached to the adhesive layer.

15

23. The method of claim 22, wherein selectively disposing functional material further
comprises removing a portion of the active particles that is not attached to the adhesive layer.

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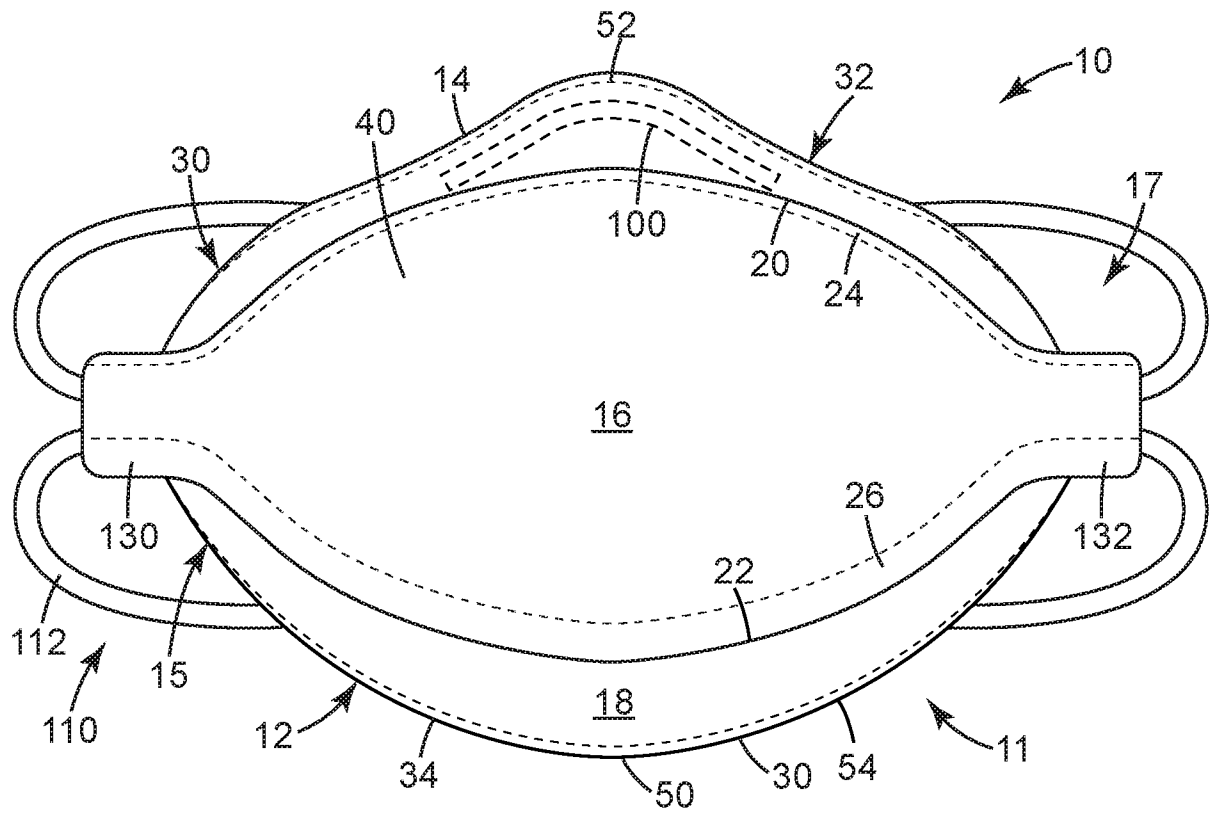


Fig. 1

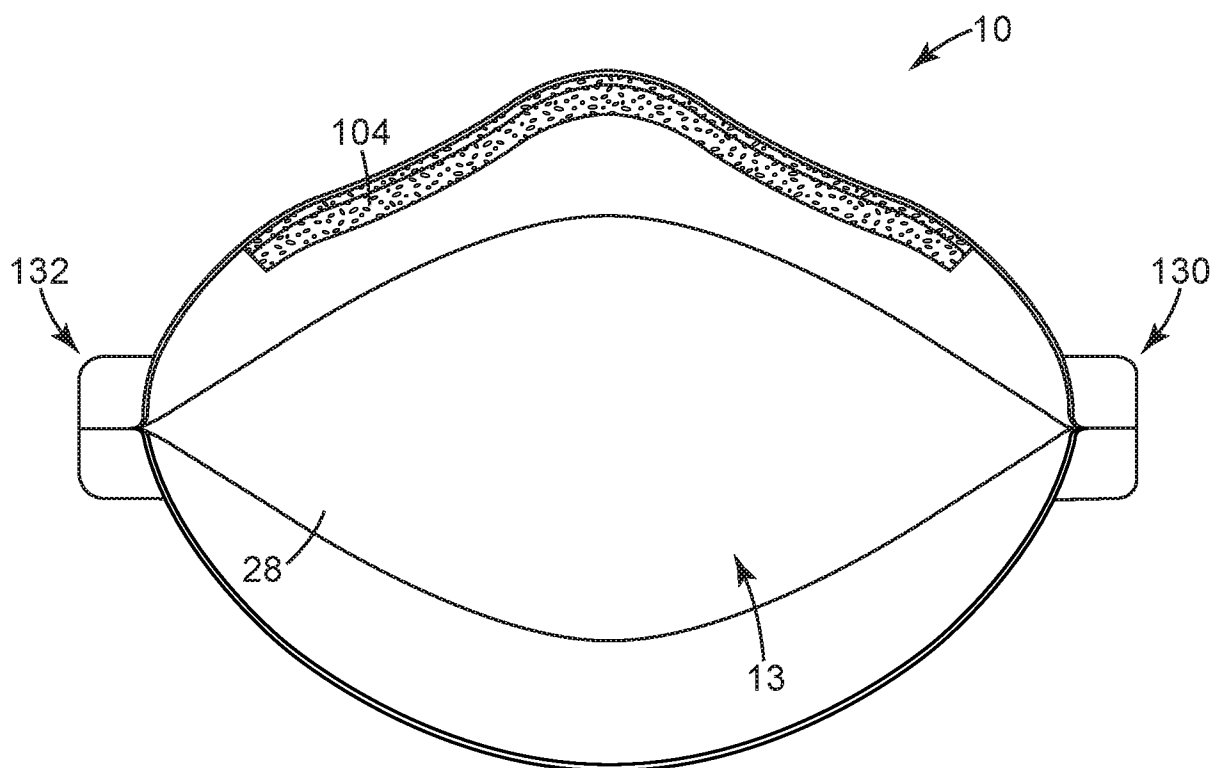


Fig. 2

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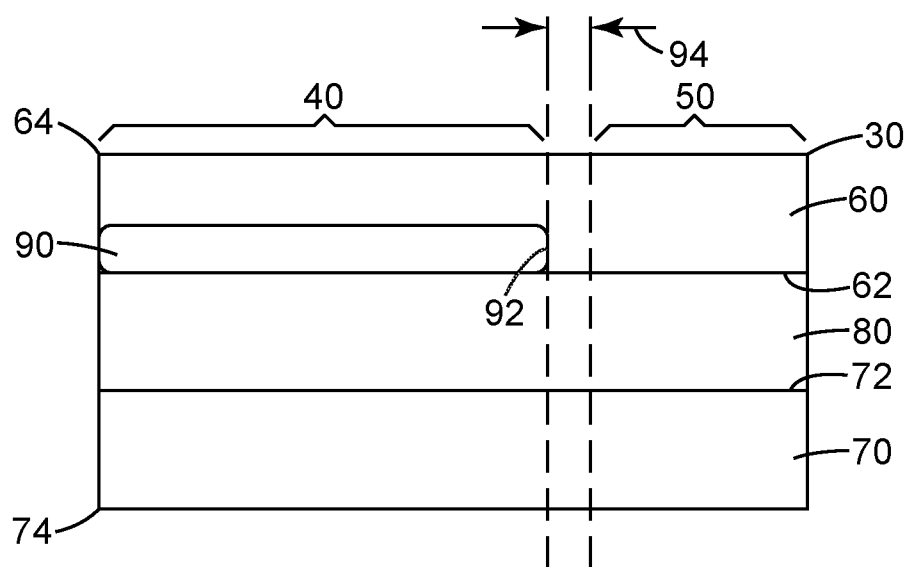


Fig. 3

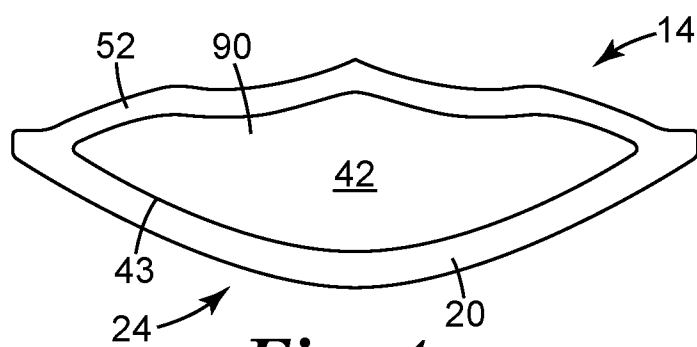


Fig. 4

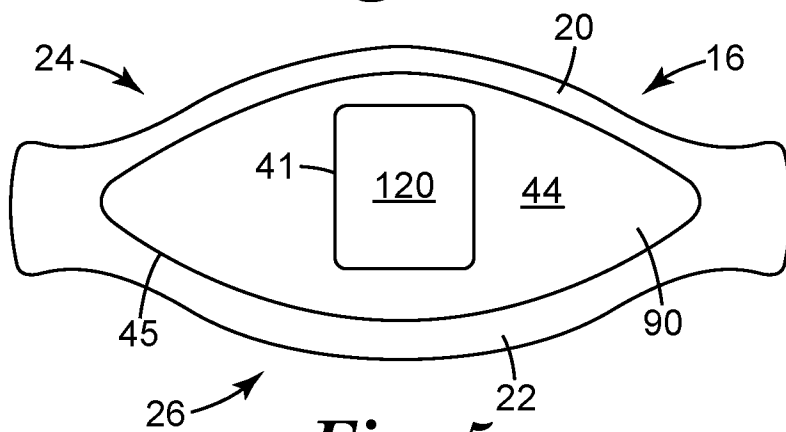


Fig. 5

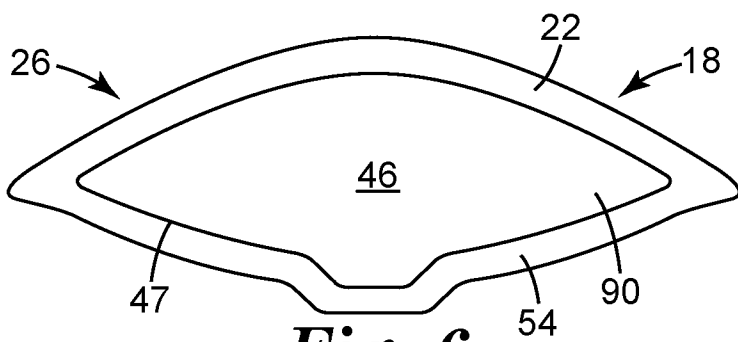


Fig. 6

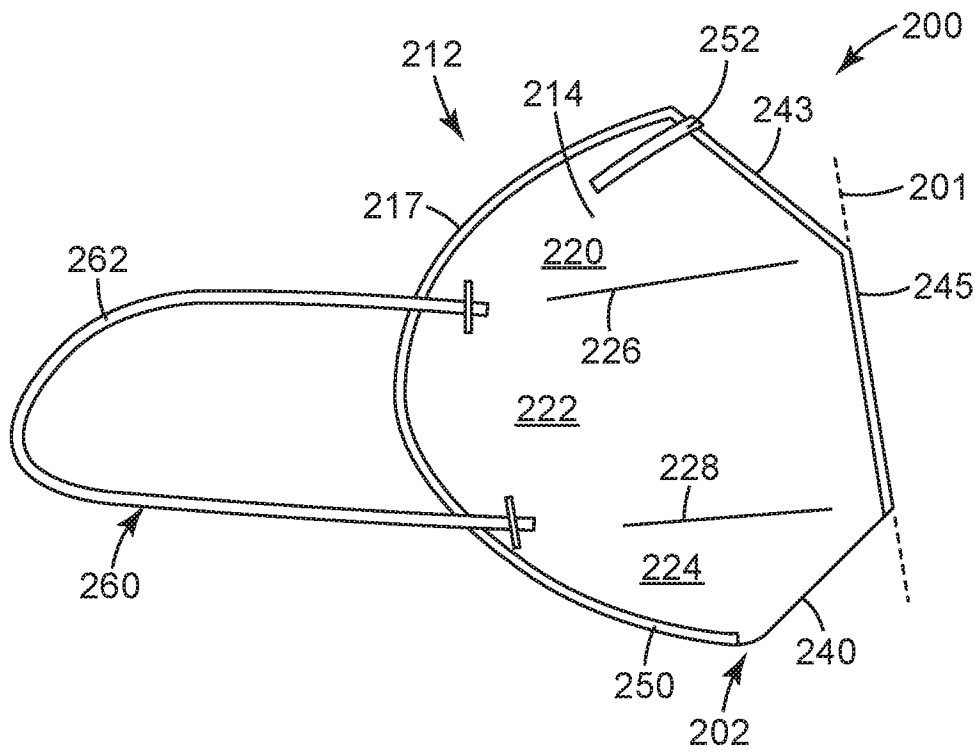


Fig. 7

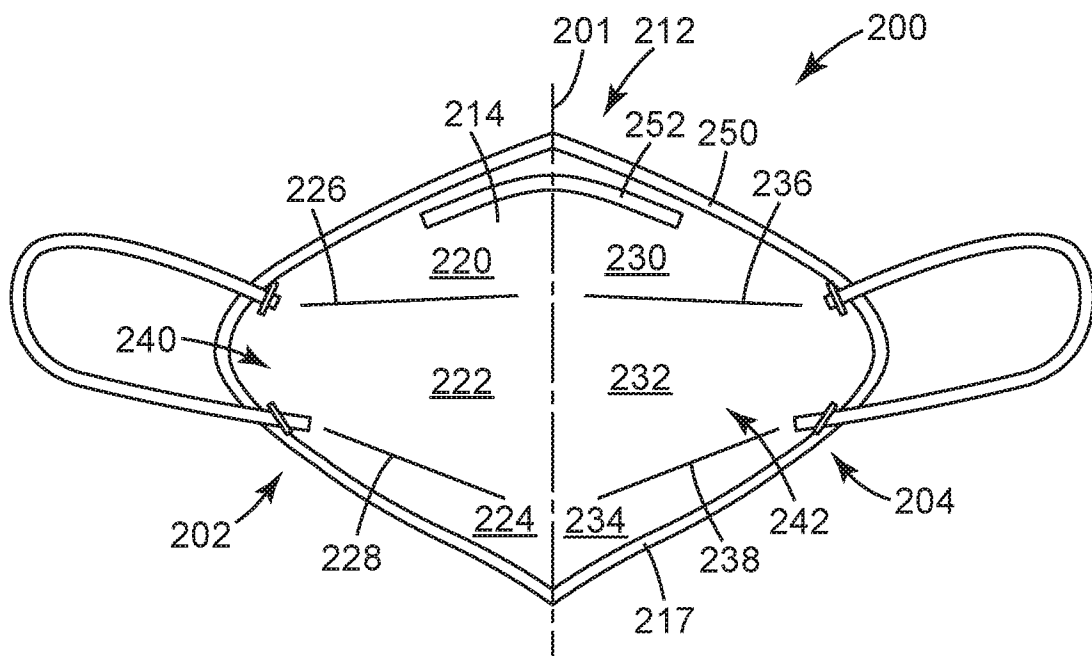
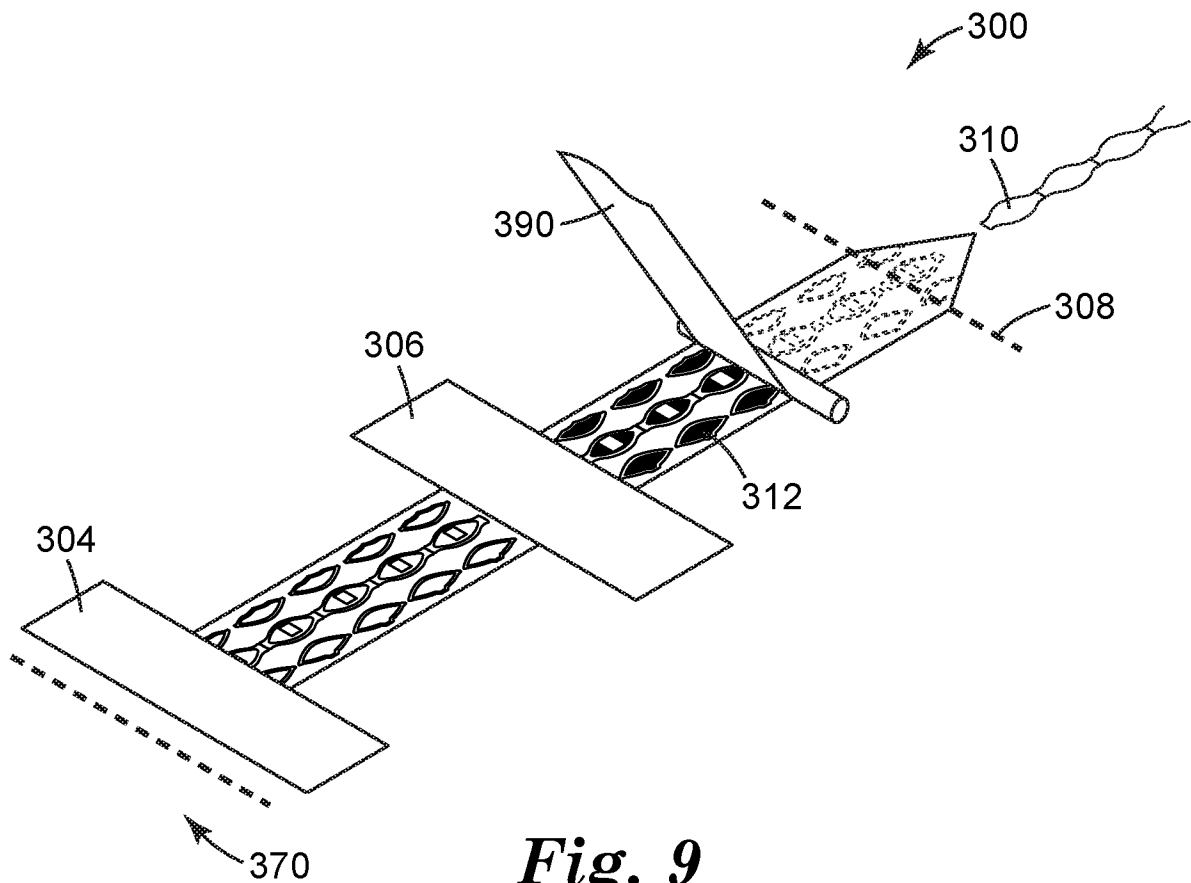
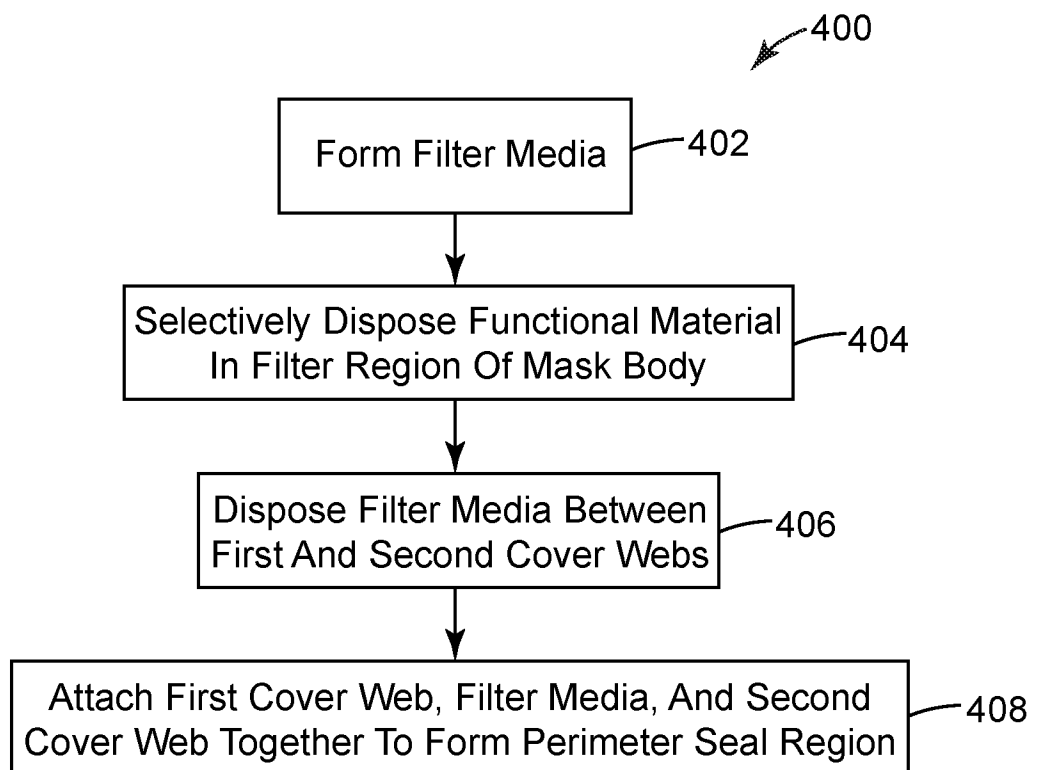
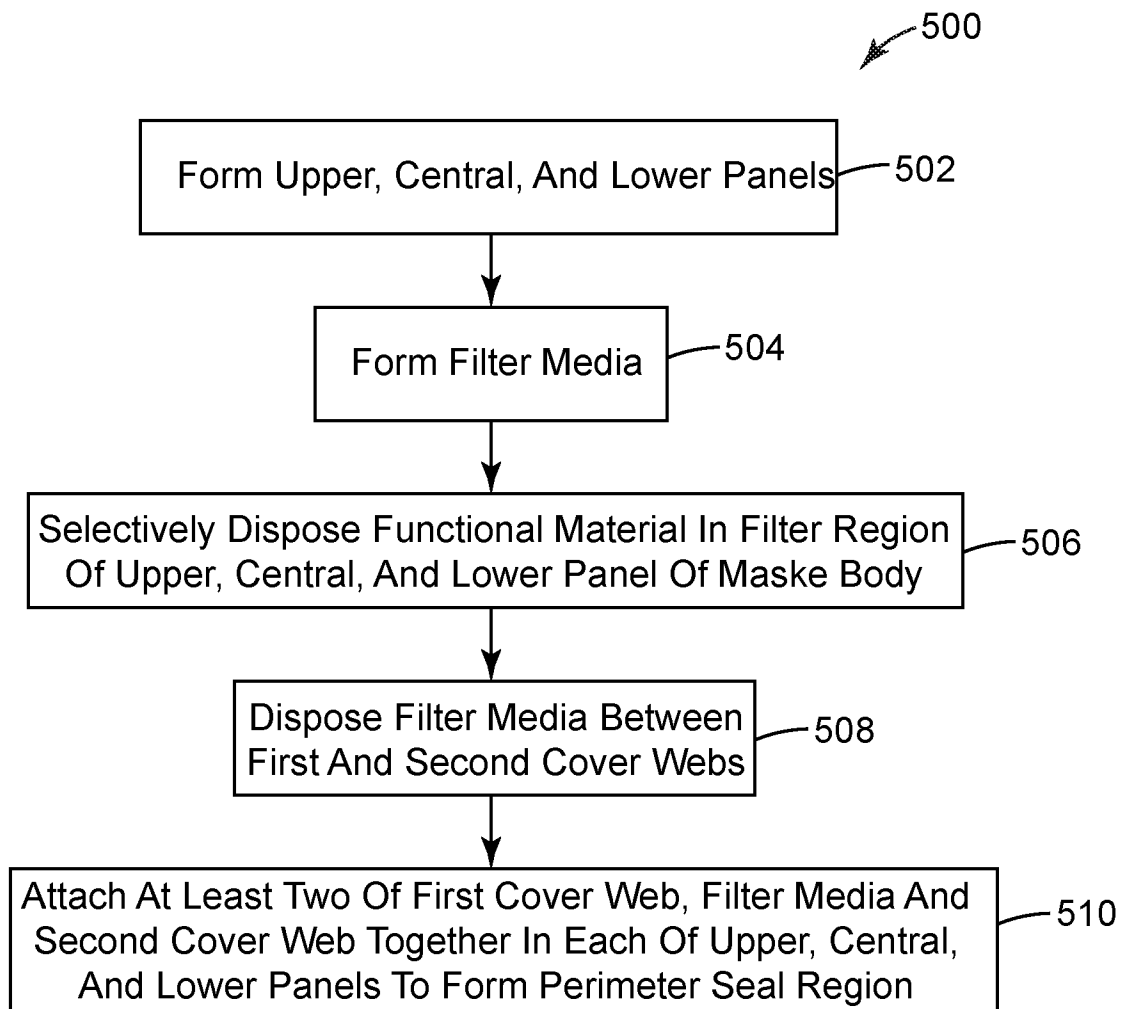


Fig. 8

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**Fig. 9****Fig. 10**

***Fig. 11***

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/056586

A. CLASSIFICATION OF SUBJECT MATTER INV. A62B23/02 A41D13/11 A62B18/02 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) A62B A41D		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
L	WO 2016/127296 A1 (3M INNOVATIVE PROPERTIES CO [US]; ZHOU XIAOPING [CN]) 18 August 2016 (2016-08-18) figures 1-4 page 8, lines 1-9 page 9, lines 10-19 page 10, lines 13-20 page 6, line 21 - page 20, line 34 -----	1-23
X	US 2012/017911 A1 (CHOI DONG-IL [KR] ET AL) 26 January 2012 (2012-01-26) figures 1-3 paragraphs [0040] - [0063] -----	1-23
X	US 2015/173436 A1 (TSUEI ALEXANDER C [US]) 25 June 2015 (2015-06-25) paragraphs [0013] - [0058]; figures 1-3 ----- -/--	1-23
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search 19 December 2016		Date of mailing of the international search report 02/01/2017
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Horrix, Doerte

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