



(51) International Patent Classification:

Not classified

(21) International Application Number:

PCT/US2018/038516

(22) International Filing Date:

20 June 2018 (20.06.2018)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/522,343 20 June 2017 (20.06.2017) US

(71) Applicant: ENTEGRIS, INC. [US/US]; 129 Concord Road, Billerica, Massachusetts 01821 (US).

(72) Inventors: BELANGER, Frank, V.; 134 Lake St, Webster, Massachusetts 01570 (US). TISON, Stuart; 1513 Westmont Drive, McKinney, Texas 75070 (US). GAUDREAU, John, Charles; 431 Evans Road, Chepachet, Rhode Island 02814 (US). SRIVASTAVA, Reena; 8 Independence Way Apt 314, Franklin, Massachusetts 02038 (US). SWEENEY, Joseph, D.; 9 Lance Lane, New Milford, Connecticut 06776 (US).

(74) Agent: AMICI, Robert, M.; Entegris, Inc., 129 Concord Road, Billerica, Massachusetts 01821 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,

SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: AIRBORNE MOLECULAR CONTAMINATION ACID REMOVAL FILTER USING FUNCTIONALIZED MATERIALS

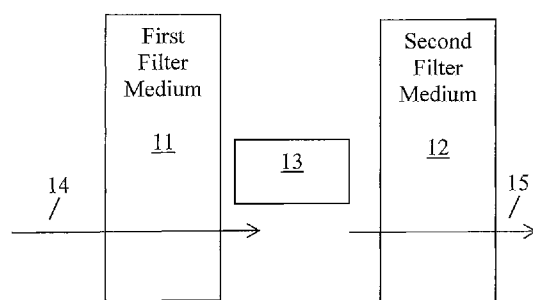


FIG. 1

(57) Abstract: An airborne molecular contamination filter is herein disclosed. The airborne molecular contamination filter comprises a first filter medium that removes first airborne contaminants from a first air stream, and a second filter medium downstream of the first filter medium removing second airborne contaminants from a second air stream output from the first filter medium. At least one of the first filter medium and the second filter medium comprises a functionalized substantially non-carbon filter medium that removes a weak acid from at least one of the first air stream and the second air stream.



AIRBORNE MOLECULAR CONTAMINATION ACID REMOVAL FILTER USING FUNCTIONALIZED MATERIALS

BACKGROUND

To filter contaminants from the air, gas phase filtration is commonly employed, typically
5 using activated carbon manufactured in various ways. Stacks of multiple filters deployed in series are required to try to achieve a very high removal efficiency for airborne molecular contaminants (AMCs).

For a variety of types of contaminants, chemical species in the gas stream can be converted to other, more harmful contaminants on the filter media of the AMC filter. For
10 example, nitrogen dioxide (NO₂) can be converted to HNO_x (where x is an integer), such as nitrous- or nitric- acid, in activated carbon filter media. The product of the conversion, such as a weak acid, can then be transmitted downstream of the AMC filter, which can potentially contribute to damage of optics or other components downstream of the gas filter, and/or require more frequent replacement of the AMC filter.

Therefore, conventionally, a sequence of filters is used to remove contaminants, and the
15 products of conversion reactions, as they pass through AMC filters. Potential drawbacks of conventional filters are that the pressure drop through the filters is high, and that the filter media require relatively frequent replacement in order to reduce exposure of downstream components to contaminants.

SUMMARY OF THE INVENTION

In accordance with a version of the invention, there is provided an airborne molecular contamination filter that can be used, potentially in addition to other uses, in weak acid applications. The airborne molecular contamination filter includes a filter medium that
25 comprises a functionalized substantially non-carbon filter medium that removes a weak acid from an air stream passing through the filter. The functionalized substantially non-carbon filter medium can, for example, comprise a functionalized non-woven fiber medium, such as at least one adsorbent and a polymer-based non-woven fiber medium. The functionalized non-woven fiber medium can, for example, comprise at least one of: a polyester non-woven fiber medium, a polypropylene non-woven fiber medium, a nylon non-woven fiber medium, and a fiberglass non-
30 woven fiber medium. In one example, the non-woven fiber medium can comprise a

functionalized polyester non-woven fiber medium and at least one adsorbent. The functionalized substantially non-carbon filter medium can comprise a coating from a potassium-containing solution. The functionalized substantially non-carbon filter medium is used with at least one other filter medium, for example (but not limited to) an activated carbon medium. A number of layers of the functionalized substantially non-carbon filter medium, a thickness per layer of the functionalized substantially non-carbon filter medium and a basis weight of adsorbent on the functionalized substantially non-carbon filter medium, can be configured to remove a desired quantity of the weak acid from the at least one of the first air stream and the second air stream. A sequence, in a series air flow, of two or more different types of filter medium in the filter can be configured to remove a desired quantity of airborne contaminants.

Other related versions of the invention are taught herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of an airborne molecular contamination filter in accordance with a version of the invention.

FIG. 2 is a schematic diagram illustrating contexts in which an AMC filter system in accordance with a version of the invention may be used.

FIG. 3 shows an asymmetrical stack of replaceable filters in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

A description of example embodiments of the invention follows.

In accordance with a version of the invention, there is provided an airborne molecular contamination filter that can be used, potentially in addition to other uses, in weak acid applications. Such an airborne molecular contamination filter can provide the advantage, for example, of improving performance and useable lifetime for filter media in weak acid applications.

FIG. 1 is a schematic block diagram of an airborne molecular contamination filter in accordance with a version of the invention. The filter 10 includes first filter medium 11 and a second filter medium 12. A first air stream 14 passes through the first medium 11, and a second air stream 15 passes through the second medium 12. One or more of the first filter medium 11 and the second filter medium 12 includes a functionalized substantially non-carbon filter medium, which may, for example, be a functionalized non-woven fiber. The non-woven fiber

may, for example, be functionalized by having been sprayed with, or dipped in, or transfer coated with, a potassium-containing solution, and may contain one or more binders. In one version, the potassium-containing solution is sprayed directly onto a non-woven fiber, such as a polyester non-woven fiber. In another version, the potassium-containing solution is applied to the non-woven fiber by transfer coating. For example, the transfer coating of a potassium-containing solution can be applied to one side of a non-woven layer only; or the same potassium-containing solution can be transfer coated onto both sides of a non-woven layer; or two different potassium-containing solutions can be applied to opposite side of the non-woven layer. The functionalized substantially non-carbon filter medium may further include one or more adsorbents. In accordance with a version of the invention, the functionalized non-woven fiber medium can comprise at least one adsorbent and a polymer-based non-woven fiber medium. The functionalized non-woven fiber medium can, for example, comprise at least one of: a polyester non-woven fiber medium, a polypropylene non-woven fiber medium, a nylon non-woven fiber medium, and a fiberglass non-woven fiber medium.

As used herein, “substantially non-carbon filter medium” can, for example, include less than about 10% by weight of carbon, or less than about 5% by weight of carbon, or less than about 2% by weight of carbon, or less than about 1% by weight of carbon, or less than about 0.1% by weight of carbon, or zero carbon (*i.e.*, only non-carbon materials).

In one version according to the invention, the functionalized substantially non-carbon filter medium is functionalized to remove a weak acid from the air stream passing through the filter. For example, in one version, the first filter medium 11 is an activated carbon filter medium. In some situations, gases such as NO₂ can be converted to a weak acid, such as HNO_x (where x is an integer), in the activated carbon filter medium itself. Therefore, in order to prevent the transmission of such weak acids through to downstream components (such as optics), a version according to the invention can use a functionalized substantially non-carbon filter medium to remove the weak acids. For example, the second filter medium 12 can include the functionalized substantially non-carbon filter medium to remove the weak acids.

Alternatively, in accordance with a version of the invention, a different order of the types of filter media can be used. For example, the first filter medium 11 can include the functionalized substantially non-carbon filter medium to remove weak acids, while the second filter medium contains another filter medium type, such as activated carbon. It will be appreciated that either the first filter medium, the second filter medium, or both can include a variety of different possible filter media other than the functionalized substantially non-carbon filter medium; and that additional filter media, such as more than two filter media (not shown in FIG. 1) can be used. For example, other possible filter media in the first, second and/or other

filter media, can include an activated carbon filter medium, an ion exchange filter medium and a mixed adsorbent filter medium. In any of the foregoing cases, the functionalized substantially non-carbon filter medium can be used to remove weak acids, while at least one other filter medium can be used to remove other airborne contaminants such as organics, acids and bases.

5 In addition, in accordance with a version of the invention, the functionalized substantially non-carbon filter medium can be arranged in layers with one or more other filter media. The number of layers of the functionalized substantially non-carbon filter medium, the thickness per layer of the functionalized substantially non-carbon filter medium and the basis weight of adsorbent on the functionalized substantially non-carbon filter medium, can be configured to
10 remove a desired quantity of the weak acid from the air stream. A sequence, in a series air flow, of two or more different types of filter medium in the filter can be configured to remove a desired quantity of airborne contaminants.

In accordance with a version of the invention, the weak acid that can be removed can be any type of weak acid, such as, for example, a nitrogen-containing acid having the chemical
15 formula HNO_x , where x is an integer greater than one, or a carboxylic acid, such as acetic acid.

In another version of the invention, the filter can be made of a stack of replaceable filters, where the first replaceable filter 11 of the stack comprises the first filter medium and the second replaceable filter 12 of the stack comprises the second filter medium. With reference to FIG. 1, the stack can include at least one interstack monitor 13 (which can be more than one for more
20 than two filters layers) between the filter stack layers, to measure the breakthrough of the airborne contaminants from one filter 11 to the next 12.

In accordance with a version of the invention, the functionalized substantially non-carbon filter medium can comprise any of a variety of different types of media, including a non-woven fiber, a monolithic filter medium, a granulated medium and a honeycomb filter medium.
25 Likewise, the first, second, third and other filter media used in the filter can comprise any of the foregoing different types of filter media.

In accordance with a version of the invention, a functionalized substantially non-carbon filter medium that removes a weak acid, for example a functionalized non-woven fiber medium, can be used in any permutation or combination of orders and arrangements of one or more filters
30 and/or filter media, such as but not limited to a plurality of filters and/or filter media, that are configured to remove the airborne molecular contamination. In particular, the functionalized substantially non-carbon filter medium can be used in the context of, or as a portion of (such as a filter medium and/or filter within) the SilverSet® chemical filter system, sold by Entegris, Inc., of Billerica, MA, U.S.A. For example, such a system can contain a combination of carbon and
35 polymeric chemical media that targets and removes molecular acids (such as HCl , H_2SO_4 and

HNO₃), acid forming species (such as SO₂), molecular bases (such as NH₃, NMP and amines) and condensable organic compounds. Symmetrical and asymmetrical filter arrangements can be used. In another example, any combination or permutation of one or more of physiosorptive and chemisorptive media configured for removal of the airborne molecular contamination can be used. In other examples, the functionalized substantially non-carbon filter medium can be used in the context or as a portion of (such as a filter medium and/or filter within) any of the filter systems and methods taught in the following, the entire teachings of which are hereby incorporated herein by reference: U.S. Patent No.'s 6,447,584; 6,610,128; 7,022,164; 6,740,147; 6,761,753; 7,014,693; 7,540,901; and 7,922,791.

In accordance with a version of the invention, a functionalized substantially non-carbon filter medium, for example a functionalized non-woven fiber medium, can be used in a system that also handles any one or more of a variety of other airborne molecular contaminants. For example, the system can prevent the conversion of Hexamethyldisiloxane (HMDSO) to the contaminant Trimethylsilanol (TMS). HMDSO is converted to TMS on acidic NH₃ filter media, typically employed to remove ammonia (NH₃). TMS is a low molecular weight/low boiling point Si-containing AMC, which quickly migrates through standard AMC filters. HMDSO is captured well on media containing activated carbon adsorbents. TMS, however, can contribute to permanent optics damage in 193 nm and 248 nm exposure tool optics.

In accordance with a version of the invention, a functionalized substantially non-carbon filter medium, for example a functionalized non-woven fiber medium, can also be used in a system that also prevents the conversion of PGMEA to the contaminant acetic acid. PGMEA is converted to acetic acid on acidic NH₃ filter media, which is usually employed to remove ammonia. Acetic acid can contribute to resist process variation and potential material corrosion in 193 nm and 248 nm microlithography exposure tools.

A version in accordance with the invention can, for example, be used in a filter system that also includes one or more of the following, either individually or in combinations of two or more thereof: acidic, NH₃-removing media such as sulfonic or carboxylic acid based media; HMDSO-removing media; airborne basic contaminant-removing media; airborne acidic contaminant-removing media; airborne organic contaminant removing media. In one version, the airborne organic contaminants removed by one or more filters or filter media include airborne organic contaminants such as, but not limited to, hexamethyldisiloxane (HMDSO), propylene glycol monomethyl ether acetate (PGMEA), and toluene, either individually or in combinations of two or more thereof. It should be understood that it is within and included in the scope of the invention to have two or more filters or filter media removing a plurality of airborne organic contaminants which may have various characteristics which differ or are similar

to each other. In one version according to the invention, the airborne basic contaminants removed by one or more filters or filter media in a filter system include bases such as but not limited to ammonia, organic primary, secondary or tertiary amine, etc. either individually or in combinations of two or more thereof.

5 In accordance with a version of the invention, a functionalized substantially non-carbon filter medium, for example a functionalized non-woven fiber medium, can also be used as one or more filters or filter media in a system in accordance with the teachings of FIG. 3. With reference to FIG. 3, an asymmetrical stack of replaceable filters 300 is described in accordance with an embodiment of the invention. The stack of replaceable filters 300 includes a first filter
10 310, second filter 320, and third filter 330. The first filter 310, in the first filter position, removes one or more airborne organic contaminants from an air stream that passes through the first filter 310. The second filter 320, in the second position, is downstream of the first filter, is physically and chemically exchangeable with the first filter and removes airborne organic contaminants from the air stream output from the first filter 310. The third filter 330, in the third position, is
15 downstream of the second filter 320, is not exchangeable with the first filter 310 or the second filter 320 and removes one or more airborne basic contaminants from the air stream output from the second filter 320. In an embodiment, an initial capacity of the first filter 310 and an initial capacity of the second filter 320 for removal of airborne organic contaminants are within +/- 25% as measured in part per billion-hours at a same gas flow rate and contaminant input
20 challenge) and the second filter 320 has a capacity for airborne organic contaminants sufficient to permit exchange with a depleted first filter in the stack of replaceable filters 300.

Each filter 310, 320, 330 has one or more media layers. In an embodiment, a filter 310, 320, 330 includes two media layers. In an embodiment, the first filter 310 includes two media layers 2, wherein both the media layers 2 remove one or more airborne contaminants that are
25 organics or acids. The second filter 320 also includes two media layers 2 wherein both the media layers 2 remove one or more airborne contaminants that are organics or acids. It should be appreciated that embodiments of first and second filters 310, 320 may include further media layers which are symmetrical to each other or differ from each. The third filter 330 has two media layers which differ from each. The two media layers for the third filter 330 are media
30 layer 1 to remove airborne contaminants that are organics or acids or bases and media layer 6 to remove airborne contaminants that are weak acids or bases. It should be appreciated that embodiments of the third filter 330 includes further media layers which differ from the media layers in the first and second filters 310, 320. It should also be appreciated that a filter stack may further include other filters and the plurality of filters may have various characteristics.

The stack of replaceable filters 300 are asymmetrical because although the first and second filters 310, 320 are similar or exchangeable based on the symmetry or similarity of the media layers, the third filter 320 differs from the first and second filter 310, 320, because the media layers of the third filter 330 differs from the media layers of the first and second filters 310, 320. Thus, the stack of replaceable filters 300 is asymmetrical because the third filter 320 differs from the first and second filters 310, 320.

In an embodiment, the airborne organic contaminants removed by first filter 310 and second filter 320 includes airborne organic contaminants such as, but not limited to, hexamethydisiloxane (HMDSO), propylene glycol monomethyl ether acetate (PGMEA), and toluene, either individually or in combinations of two or more thereof. It should be understood that it is within and included in the scope of the invention to have a first filter 310 and second filter 320 removing a plurality of airborne organic contaminants which may have various characteristics which differ or are similar to each other. In an embodiment, the airborne organic contaminants removed by first filter 310 and second filter 320 includes HMDSO. In another embodiment, the airborne organic contaminants removed by the first filter 310 and second filter 320 include PGMEA. In yet another embodiment, the airborne organic contaminants removed by first filter 310 and second filter 320 includes toluene. It should be appreciated that embodiments includes a first filter 310 and second filter 320 removing a plurality of airborne organic contaminants which may have various characteristics, which differ or are similar to each other. In an embodiment, the plurality of organic contaminants removed by first filter 310 and second filter 320 include HMDSO and PGMEA.

In another embodiment, the first filter 310 removes airborne organic contaminants and the second filter 320 removes less airborne organic contaminants compared to the first filter 320. In a particular embodiment, the first filter 310 has removed airborne organic contaminants such as but not limited to HMDSO or PGMEA that can be detected and the second filter 320 has removed less organic contaminants such as but not limited to HMDSO or PGMEA compared to the first filter as detected.

In an embodiment, the airborne basic contaminants removed by third filter 330 includes bases such as but not limited to ammonia, organic primary, secondary or tertiary amine, etc. either individually or in combinations of two or more thereof. It should be understood that it is within and included in the scope of the invention to have a third filter 330 removing a plurality of airborne basic contaminants which may have various characteristics. In a particular embodiment, the airborne basic contaminants removed by third filter 330 include bases such as ammonia.

In an embodiment, the stack of replaceable filters 300 further includes monitor mechanism to measure breakthrough of air borne contaminants through each of the filters in the stack, and an inlet stack monitor at the inlet of the stack. An embodiment include four monitor mechanisms to measure one or more AMC concentrations in the gas downstream of each filter:

5 a first interstack monitor 312 in the first interstack which is downstream of the first filter 310 and upstream of the second filter 320 to measure breakthrough of air borne contaminants from the first filter 310; a second interstack monitor 322 which is downstream of the second filter 320 and upstream of the third filter 320 to measure breakthrough of air borne contaminants from the second filter 320; an inlet stack monitor 302 at the inlet of the stack upstream of the first filter
10 and outlet stack monitor 332 at the outlet of the stack downstream of the third filter 330. In a particular embodiment, the monitor includes a sensor. See for example Patent application WO/2001/085308 which is incorporated by reference in its entirety.

An embodiment of the invention includes a gas cabinet housing comprising one or more replaceable filter stacks 300. A particular embodiment includes two parallel filter stacks 300
15 stacked on top of each other in front and 2 other filter stacks 300 behind. Each filter stack 300 has an outlet filter and two upstream filters, is exchangeable with the first right most filter. Although described with four filter stacks 300 in a gas cabinet, less or great number of filter stacks in a gas cabinet of varying size are within the scope of the invention.

In another version of the invention, the airborne molecular contamination filter 10
20 includes a filter cartridge including filter pleat pack media, where the pleat pack media comprise the functionalized substantially non-carbon filter medium. For example, the pleat pack can include a functionalized non-woven fiber medium, such as a polyester non-woven fiber medium, a polypropylene non-woven fiber medium, a nylon non-woven fiber medium, and a fiberglass non-woven fiber medium, any of which can be pleated. The pleat pack can include a pleat pack
25 separator. In one example, a functionalized non-woven fiber medium is co-pleated with a wire mesh, which can be positioned on both sides of the functionalized non-woven fiber medium. The pleat pack with the functionalized non-woven fiber medium can include one or more of: pleat separators, a wire mesh, corrugated aluminum, or another rigid structural material between the pleats of the pleat pack. The pleat pack may include one or more layers of scrim,
30 surrounding one or more layers of high loft. Both the scrim and the high loft may include non-woven materials, such as polyester or other non-woven fibers taught herein, and a binder. The high loft material may include an adsorbent, such as a carbon or ion exchange adsorbent, and may include mixed adsorbents. In other embodiments, the filter cartridge need not be pleated.

In accordance with a version of the invention, non-woven materials used in the filter pleat
35 pack can be any of a variety of different possible material types, fiber sizes and binding material.

For example, a polyester non-woven fiber medium, a polypropylene non-woven fiber medium, another polymer-based non-woven fiber medium, a nylon non-woven fiber medium, and a fiberglass non-woven fiber medium can be used. In one example, polyester fiber, of varying sizes, using ethyl-vinyl-chloride as a binder can be used. This polyester fiber can be randomly oriented or machine oriented, for example by being carded. Other types of fibers can be used, including bi-component fibers, such as bi-component fibers that include a polyethylene outer shell and a polyester core. Bi-component fibers can be used without binder.

In accordance with a version of the invention, adsorbents used in the filter pleat pack can, for example, be single granular material type, or mixes of different types of granular material types. For example, activated carbon mixed with ion exchange can be used. Activated carbon can be treated with a variety of different possible chemistries, each of which target different contaminants. An example of a mix ratio that can be used is 87% granular activated carbon with 13% ion exchange resin. Another mix ratio that can be used is 60% base treated granular activated carbon with 40% ion exchange.

In accordance with a version of the invention, the filter cartridge can include any of the materials taught in U.S. Patent No. 6,740,147 B2 of Kishkovich *et al.*, the entire teachings of which are hereby incorporated herein by reference; for example, in particular, the filter cartridge can include non-woven materials and adsorbents taught therein.

In accordance with a version of the invention, the filter cartridge is one that achieves superior outgas and particle discharge results for use in applications such as, for example, reduction of Airborne Molecular Contamination (AMC). For example, the filter cartridge system may be one that passes International Organization for Standardization (ISO) 14644-1 Cleanroom Standards at the Class 5, Class 4, Class 3, Class 2 or even Class 1, level for particle discharge. The entire teachings of the ISO 14644-1 Cleanroom Standards are hereby incorporated herein by reference, including particularly the particle discharge standards at the Class 1, Class 2, Class 3, Class 4 and Class 5 levels.

In addition, the filter cartridge may reduce total airborne molecular contaminant concentrations from about 10 to about 50 ppb upstream of the filter cartridge system to less than about 1 ppb to about 5 ppb downstream of the filter cartridge system. Further, the filter cartridge may achieve a removal efficiency of at least about 90% or greater at inlet contaminant concentrations of up to about 50 ppb, such as about 99.9% or greater for specified contaminants.

FIG. 2 is a schematic diagram illustrating contexts in which an AMC filter system in accordance with a version of the invention may be used. The filter system may be used in semiconductor manufacturing and cleanroom contexts; and may be used both in the plenum 21,

as a clean room ceiling chemical air filter 22, and as a tool-level AMC filter 23 on the fabrication level; and can be used for any tool (such as a baking tool, an etch tool, etc.).

While various compositions and methods are described, it is to be understood that this invention is not limited to the particular compositions, designs, methodologies or protocols described, as these may vary. It is also to be understood that the terminology used in the description is for the purpose of describing the particular versions or versions only, and is not intended to limit the scope of the present invention which will be limited only by the appended claims.

It must also be noted that as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural reference unless the context clearly dictates otherwise. Thus, for example, reference to a "filter medium" is a reference to one or more filter media and equivalents thereof known to those skilled in the art, and so forth. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Methods and materials similar or equivalent to those described herein can be used in the practice or testing of versions of the present invention. All publications mentioned herein are incorporated by reference in their entirety. Nothing herein is to be construed as an admission that the invention is not entitled to antedate such disclosure by virtue of prior invention. "Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not. All numeric values herein can be modified by the term "about," whether or not explicitly indicated. The term "about" generally refers to a range of numbers that one of skill in the art would consider equivalent to the recited value (i.e., having the same function or result). In some versions the term "about" refers to $\pm 10\%$ of the stated value, in other versions the term "about" refers to $\pm 2\%$ of the stated value. While compositions and methods are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions and methods can also "consist essentially of" or "consist of" the various components and steps, such terminology should be interpreted as defining essentially closed-member groups.

Although the invention has been shown and described with respect to one or more implementations, equivalent alterations and modifications will occur to others skilled in the art based upon a reading and understanding of this specification and the annexed drawings. The invention includes all such modifications and alterations and is limited only by the scope of the following claims. In addition, while a particular feature or aspect of the invention may have been disclosed with respect to only one of several implementations, such feature or aspect may be combined with one or more other features or aspects of the other implementations as may be

desired and advantageous for any given or particular application. Furthermore, to the extent that the terms "includes", "having", "has", "with", or variants thereof are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term "comprising." Also, the term "exemplary" is merely meant to mean an example, rather than the
5 best. It is also to be appreciated that features and/or elements depicted herein are illustrated with particular dimensions and/or orientations relative to one another for purposes of simplicity and ease of understanding, and that the actual dimensions and/or orientations may differ substantially from that illustrated herein.

Although the present invention has been described in considerable detail with reference
10 to certain versions thereof, other versions are possible. Therefore the spirit and scope of the appended claims should not be limited to the description and the versions contained within this specification.

The teachings of all patents, published applications and references cited herein are
15 incorporated by reference in their entirety.

CLAIMS

What is claimed is:

1. An airborne molecular contamination filter, the filter comprising:
a first filter medium that removes first airborne contaminants from a first air
5 stream that passes through the first filter medium;
a second filter medium downstream of the first filter medium, the second filter
medium removing second airborne contaminants from a second air stream output from
the first filter medium;
at least one of the first filter medium and the second filter medium comprising a
10 functionalized substantially non-carbon filter medium that removes a weak acid from at
least one of the first air stream and the second air stream.
2. The airborne molecular contamination filter of claim 1, wherein the functionalized
substantially non-carbon filter medium comprises a functionalized non-woven fiber
15 medium.
3. The airborne molecular contamination filter of claim 2, wherein the functionalized non-
woven fiber medium comprises at least one adsorbent and a polymer-based non-woven
fiber medium.
- 20 4. The airborne molecular contamination filter of claim 2, wherein the functionalized non-
woven fiber medium comprises at least one of: a polyester non-woven fiber medium, a
polypropylene non-woven fiber medium, a nylon non-woven fiber medium, and a
fiberglass non-woven fiber medium.
- 25 5. The airborne molecular contamination filter of claim 1, wherein the functionalized
substantially non-carbon filter medium comprises a coating from a potassium-containing
solution.
- 30 6. The airborne molecular contamination filter of claim 5, wherein the potassium-containing
solution comprises at least one of: a sprayed-on potassium-containing solution, a dipped
potassium-containing solution and a transfer coating potassium-containing solution.

7. The airborne molecular contamination filter of claim 1, wherein the first airborne contaminants comprise at least one of an organic, an acid and a base, and wherein the second filter medium comprises the functionalized substantially non-carbon filter medium that removes the weak acid.
- 5
8. The airborne molecular contamination filter of claim 7, wherein the first filter medium comprises at least one of an activated carbon filter medium and an ion exchange filter medium.
- 10
9. The airborne molecular contamination filter of claim 1, wherein the first filter medium comprises the functionalized substantially non-carbon filter medium that removes the weak acid, and wherein the second airborne contaminants comprise at least one of an organic, an acid and a base.
- 15
10. The airborne molecular contamination filter of claim 9, wherein the second filter medium comprises at least one of an activated carbon filter medium and an ion exchange filter medium.
- 20
11. The airborne molecular contamination filter of claim 1, wherein at least one of:
- (i) a number of layers of the functionalized substantially non-carbon filter medium,
- (ii) a thickness per layer of the functionalized substantially non-carbon filter medium and
- (iii) a basis weight of adsorbent on the functionalized substantially non-carbon
- 25
- filter medium,
- is configured to remove a desired quantity of the weak acid from the at least one of the first air stream and the second air stream.
- 30
12. The airborne molecular contamination filter of claim 1, wherein a sequence, in a series air flow, of the first filter medium, the second filter medium and at least one other filter medium, is configured to remove a desired quantity of at least the first airborne contaminants and the second airborne contaminants from at least the first air stream and the second air stream as they pass through the airborne molecular contamination filter.

13. The airborne molecular contamination filter of claim 1, wherein the weak acid comprises at least one of: a nitrogen-containing acid having the chemical formula HNO_x , where x is an integer greater than one; and a carboxylic acid.
- 5 14. The airborne molecular contamination filter of claim 1, comprising a stack of replaceable filters, a first replaceable filter of the stack comprising the first filter medium, and a second replaceable filter of the stack comprising the second filter medium.
- 10 15. The airborne molecular contamination filter of claim 14, further comprising at least one interstack monitor that is downstream of the first filter and upstream of the second filter to measure breakthrough of the first airborne contaminants from the first filter.
- 15 16. The airborne molecular contamination filter of claim 1, wherein the functionalized substantially non-carbon filter medium comprises at least one of: a non-woven fiber, a monolithic filter medium, a granulated medium and a honeycomb filter medium.
- 20 17. The airborne molecular contamination filter of claim 1, further comprising a filter cartridge including filter pleat pack media, the filter pleat pack media comprising the functionalized substantially non-carbon filter medium.
18. The airborne molecular contamination filter of claim 17, wherein the filter cartridge comprises a pleat separator.
- 25 19. The airborne molecular contamination filter of claim 1, wherein the airborne molecular contamination filter comprises mixed adsorbent media.

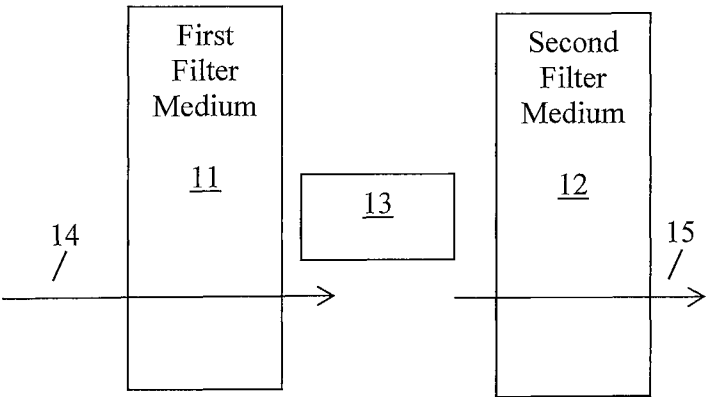


FIG. 1

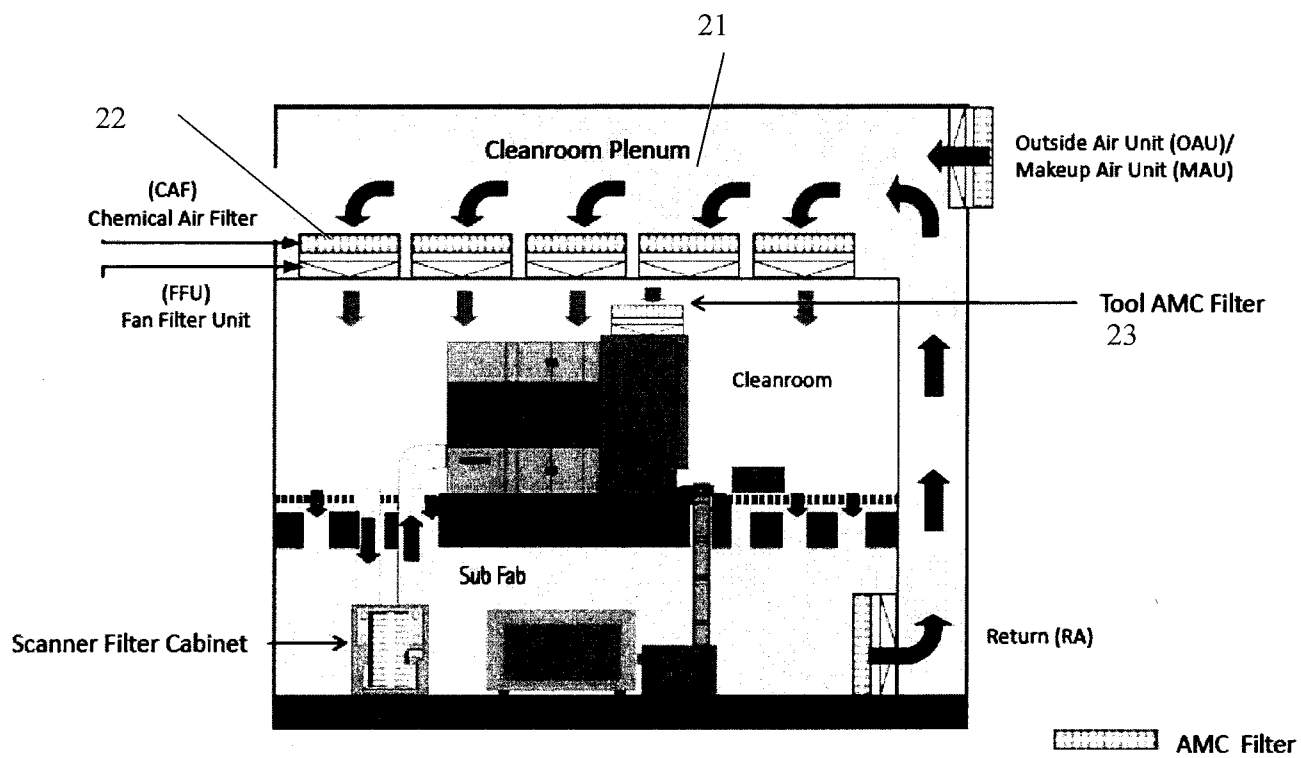


FIG. 2

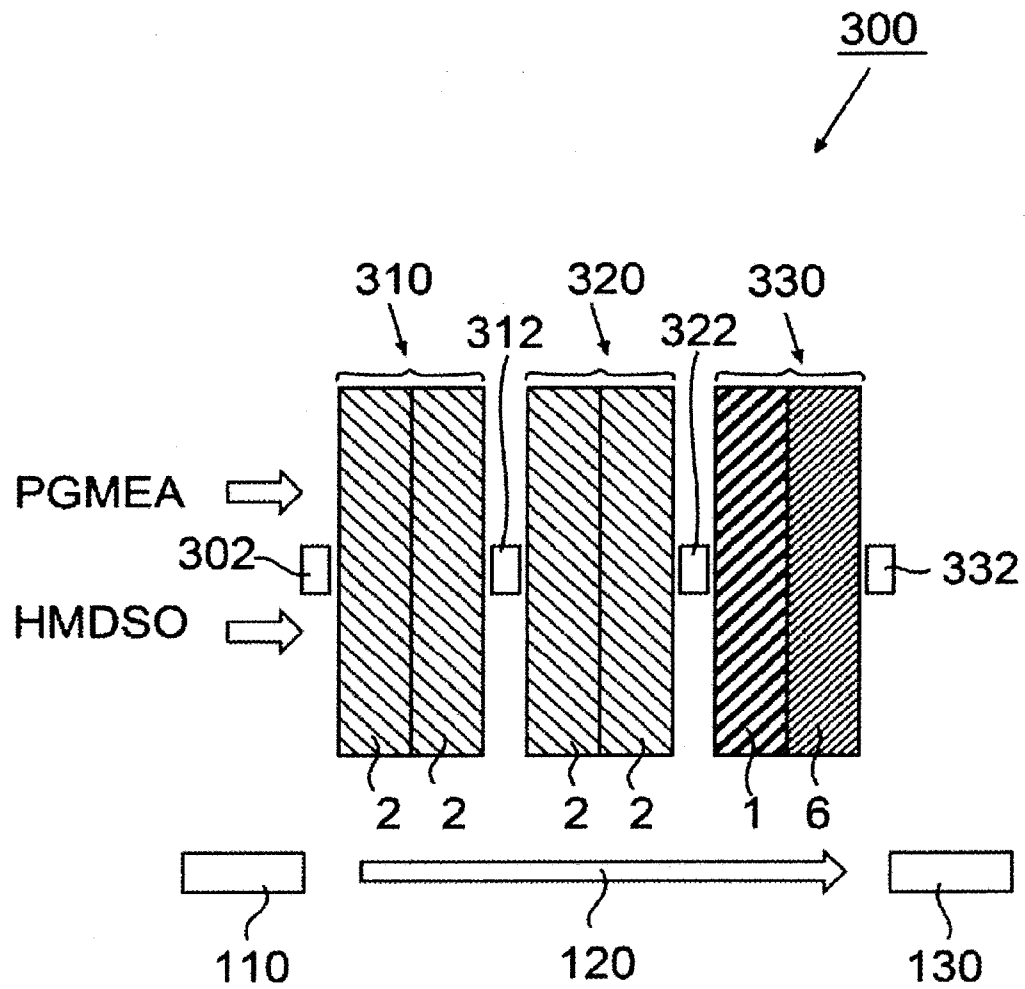


Figure 3