

METHODS OF PRODUCING FILTERS AND FILTER RODS COMPRISING POROUS MASSES AND ARTICLES RELATING THERETO

BACKGROUND

5 **[0001]** The present application relates to porous masses for use in filters for smoking devices, and articles and methods relating thereto.

[0002] The World Health Organization (WHO) has set forth recommendations for the reduction of certain components of tobacco smoke. See: WHO Technical Report Series No. 951, The Scientific Basis of Tobacco
10 Product Regulation, World Health Organization (2008). Therein, the WHO recommends that certain components, such as acetaldehyde, acrolein, benzene, benzoapyrene, 1,3-butadiene, and formaldehyde, among others, be reduced to a level below 125% of the median values of the data set. (Ibid., Table 3.10, page 112). In view of new international recommendations related to tobacco product
15 regulation, there is a need for new tobacco smoke filters and materials used to make tobacco smoke filters that are able to meet these regulations.

[0003] The use of carbon loaded tobacco smoke filters for removing tobacco smoke components has generally been limited to carbon-on-tow filters and carbon particulate contained within chambers of the filter. However, the
20 incorporation of such components into segmented filters have technical challenges like the production of high levels of dust that can contaminate other filter sections. Further, such components have limited technological flexibility for the incorporation of other active particles, the design of unique filter configurations, and the removal of high amounts of some smoke stream
25 components.

SUMMARY OF THE INVENTION

[0004] The present application relates to porous masses for use in filters for smoking devices, and articles and methods relating thereto.

30 **[0005]** In one embodiment of the present invention, a method comprises providing a porous mass rod that comprises a plurality of active particles and binder particles bound together at a plurality of contact points; providing a filter rod that does not have the same composition as the porous mass rod; cutting the porous mass rod and the filter rod into porous mass
35 sections and filter sections, respectively; forming a desired abutting

configuration that comprises a plurality of sections, the plurality of sections comprising at least some of the porous mass sections and at least some of the filter sections; securing the desired abutting configuration with a paper wrapper so as to yield a segmented filter rod length; and cutting the segmented filter rod length into segmented filter rods; wherein the steps of forming, securing, and cutting are performed so as to produce the segmented filter rods at a rate of about 25 m/min or greater.

[0006] In one embodiment of the present invention, a method comprises providing a porous mass rod that comprises a plurality of active particles and binder particles bound together at a plurality of contact points; providing a filter rod that does not have the same composition as the porous mass rod; cutting the porous mass rod and the filter rod into porous mass sections and filter sections, respectively; forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least some of the porous mass sections and at least some of the filter sections; securing the desired abutting configuration with an adhesive so as to yield a segmented filter rod length; and cutting the segmented filter rod length into segmented filter rods; wherein the steps of forming, securing, and cutting are performed so as to produce the segmented filter rods at a rate of about 25 m/min or greater.

[0007] In one embodiment of the present invention, a segmented filter rod may be produced by the process of: providing a plurality of porous mass sections that comprise a plurality of active particles and binder particles bound together at a plurality of contact points; providing a plurality of filter sections that does not have the same composition as the porous mass sections; forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least one of the porous mass sections and at least one of the filter sections; securing the desired abutting configuration with an adhesive so as to yield a segmented filter rod length; cutting the segmented filter rod length into segmented filter rods; cutting the segmented filter rods into segmented filters; wherein the steps of forming, securing, and cutting the segmented filter rod length are performed so as to produce the segmented filter rods at a rate of about 25 m/min or greater.

[0008] The features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the preferred embodiments that follows.

5 **BRIEF DESCRIPTION OF THE DRAWINGS**

[0009] The following figures are included to illustrate certain aspects of the present invention, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, as will occur to those skilled
10 in the art and having the benefit of this disclosure.

[0010] Figure 1 is a cross-sectional view of an embodiment of a cigarette including a filter section according to the present invention.

[0011] Figure 2 is a cross-sectional view of another embodiment of a cigarette including a filter section according to the present invention.

15 [0012] Figure 3 is a cross-sectional view of another embodiment of a cigarette including a filter section according to the present invention.

[0013] Figure 4 is a cross-sectional view of a smoking device including a filter section according to the present invention.

20 [0014] Figure 5 is a photomicrograph of a section of an embodiment of a porous mass of the present invention.

[0015] Figure 6 is a comparative document that shows the results of encapsulated pressure drop testing for carbon-on-tow filters having an average circumference of about 24.5 mm.

25 [0016] Figure 7 shows the results of encapsulated pressure drop testing for porous mass filters of the present invention (comprising polyethylene and carbon) having an average circumference of about 24.5 mm.

[0017] Figure 8 is a comparative document that shows the results of encapsulated pressure drop testing for carbon-on-tow filters having an average circumference of about 16.9 mm.

30 [0018] Figure 9 shows the results of encapsulated pressure drop testing for porous mass filters of the present invention (comprising polyethylene and carbon) having an average circumference of about 16.9 mm.

[0019] Figure 10 shows an illustrative diagram of the process of producing the filter rods according to at least some embodiments of the present
35 invention.

[0020] Figure 11 is a photograph of a plurality of filter rods produced using at least one method of the present invention.

[0021] Figure 12 shows an illustrative diagram of relating to at least some methods of the present invention for forming filters according to at least
5 some embodiments described herein.

DETAILED DESCRIPTION

[0022] The present application relates to porous masses for use in filters for smoking devices, and articles and methods relating thereto.

10 [0023] The present invention provides for, in some embodiments, filters and smoking devices having porous masses incorporated therein. The term "porous mass" as used herein refers to a mass comprising active particles and nonfibrous binder particles that form a structure bound by the binder particles with void spaces therein, whereby smoke can travel through the porous mass
15 and interact with the active particles. The porous masses described herein may advantageously reduce the concentration of at least some of the harmful components in a smoke stream, *e.g.*, a cigarette smoke stream. Further, the porous masses described herein may be configured to allow for use in standard cigarette manufacturing equipment, *e.g.*, filter combining machines to produce
20 segmented filter rods. The binding of the active particles to the binder particles may, in some embodiments, advantageously significantly reduce particulate contamination to other components of a filter.

[0024] The porous masses described herein further provide for a plurality of filter rod configurations and active particles so as to achieve
25 increased reduction of smoke stream components, while maintaining the draw characteristics consumers are familiar with.

[0025] It should be noted that when "about" is provided herein at the beginning of a numerical list, "about" modifies each number of the numerical list. It should be noted that in some numerical listings of ranges, some lower limits
30 listed may be greater than some upper limits listed. One skilled in the art will recognize that the selected subset will require the selection of an upper limit in excess of the selected lower limit.

I. POROUS MASSES

[0026] In some embodiments, the porous masses described herein
35 comprise active particles that are at least partially bonded together with binder

particles. For example, Figure 5, described in more detail in the Examples Section below, is a photomicrograph of an embodiment of the porous mass comprising active particles 50 (e.g., activated carbon particles) and binder particles 52. As shown, the binder particles and active particles are joined at a plurality of contact points 54. In some embodiments, the contact points 54 are randomly distributed throughout the porous mass, and the binder particles may retain their original physical shape (or substantially retain their original shape, e.g., no more than 10% variation (e.g., shrinkage) in shape from original). Although not wishing to be limited to any theory, it is believed that the contact points form when the binder particles are heated to their softening temperature, but not hot enough to reach a true melt. Further, in some embodiments, it is believed that the porous masses described herein are constructed so as to exhibit a minimal encapsulated pressure drop (described in more detail below) while maximizing the active particles' surface area, which enables incorporation in smoking devices because of the minimal impact on the draw characteristics of the filter.

[0027] Active particles suitable for use in conjunction with porous masses described herein may include any material adapted to enhance a smoke stream by removing, reducing, and/or adding components to the smoke stream.

The removal, reduction, or addition may be selective. By way of example, in the smoke stream from a cigarette, compounds such as those shown below in the following listing may be selectively removed or reduced. This table is available from the U.S. FDA as a Draft Proposed Initial List of Harmful/Potentially Harmful Constituents in Tobacco Products, including Tobacco Smoke. Examples of smoke stream components that may advantageously be reduced or removed may, in some embodiments, include, but are not limited to, acetaldehyde, acetamide, acetone, acrolein, acrylamide, acrylonitrile, aflatoxin B-1, 4-aminobiphenyl, 1-aminonaphthalene, 2-aminonaphthalene, ammonia, ammonium salts, anabasine, anatabine, 0-anisidine, arsenic, A- α -C, benz[a]anthracene, benz[b]fluoroanthene, benz[j]aceanthrylene, benz[k]fluoroanthene, benzene, benzo(b)furan, benzo[a]pyrene, benzo[c]phenanthrene, beryllium, 1,3-butadiene, butyraldehyde, cadmium, caffeic acid, carbon monoxide, catechol, chlorinated dioxins/furans, chromium, chrysene, cobalt, coumarin, a cresol, crotonaldehyde, cyclopenta[c,d]pyrene, dibenz(a,h)acridine, dibenz(a,j)acridine, dibenz[a,h]anthracene, dibenzo(c,g)carbazole, dibenzo[a,e]pyrene,

dibenzo[a,h]pyrene, dibenzo[a,i]pyrene, dibenzo[a,l]pyrene, 2,6-dimethylaniline, ethyl carbamate (urethane), ethylbenzene, ethylene oxide, eugenol, formaldehyde, furan, glu-P-1, glu-P-2, hydrazine, hydrogen cyanide, hydroquinone, indeno[1,2,3-cd]pyrene, IQ, isoprene, lead, MeA- α -C, mercury, methyl ethyl ketone, 5-methylchrysene, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK), 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL), naphthalene, nickel, nicotine, nitrate, nitric oxide, a nitrogen oxide, nitrite, nitrobenzene, nitromethane, 2-nitropropane, N-nitrosoanabasine (NAB), N-nitrosodiethanolamine (NDELA), N-nitrosodiethylamine, N-nitrosodimethylamine (NDMA), N-nitrosoethylmethylamine, N-nitrosomorpholine (NMOR), N-nitrosornicotine (NNN), N-nitrosopiperidine (NPIP), N-nitrosopyrrolidine (NPYR), N-nitrososarcosine (NSAR), phenol, PhIP, polonium-210 (radio-isotope), propionaldehyde, propylene oxide, pyridine, quinoline, resorcinol, selenium, styrene, tar, 2-toluidine, toluene, Trp-P-1, Trp-P-2, uranium-235 (radio-isotope), uranium-238 (radio-isotope), vinyl acetate, vinyl chloride, and any combination thereof.

[0028] In some embodiments, the active particles suitable for use in conjunction with porous masses described herein may comprise active carbon particles, for example, activated carbon (or activated charcoal or active coal). The activated carbon may, in some embodiments, be low activity (about 50% to about 75% CCl_4 adsorption), high activity (about 75% to about 95% CCl_4 adsorption), or a mixture thereof. In some embodiments, the active carbon particles may be nano-scaled carbon particles, *e.g.*, carbon nanotubes of any number of walls, carbon nanohorns, bamboo-like carbon nanostructures, fullerenes and fullerene aggregates, and graphene including few layer graphene and oxidized graphene.

[0029] Additional exemplary examples of active particles suitable for use in conjunction with porous masses described herein may include, but are not limited to, ion exchange resins, desiccants, silicates, molecular sieves, silica gels, activated alumina, zeolites, ion exchange resins (*e.g.*, a polymer with a backbone (*e.g.*, styrene-divinyl benzene (DVB) copolymer, acrylates, methacrylates, phenol formaldehyde condensates, and epichlorohydrin amine condensates) and a plurality of electrically charged functional groups attached to the polymer backbone), perlite, sepiolite, Fuller's Earth, magnesium silicate, metal oxides (*e.g.*, iron oxide and iron oxide nanoparticles like about 12 nm

Fe₃O₄), nanoparticles (e.g., metal nanoparticles like gold and silver; metal oxide nanoparticles like alumina; magnetic, paramagnetic, and superparamagnetic nanoparticles like gadolinium oxide, various crystal structures of iron oxide like hematite and magnetite, gado-nanotubes, and endofullerenes like Gd@C₆₀; and
5 core-shell and onionated nanoparticles like gold and silver nanoshells, onionated iron oxide, and other nanoparticles or microparticles with an outer shell of any of said materials), and any combination thereof. In some embodiments, combinations of any of the aforementioned active particles, including the active carbon particles, may be suitable.

10 **[0030]** It should be noted that nanoparticles, as used herein, include nanorods, nanospheres, nanorices, nanowires, nanostars (like nanotripods and nanotetrapods), hollow nanostructures, hybrid nanostructures that are two or more nanoparticles connected as one, and non-nano particles with nano-coatings or nano-thick walls. It should be further noted that nanoparticles include the
15 functionalized derivatives of nanoparticles including, but not limited to, nanoparticles that have been functionalized covalently and/or non-covalently, e.g., pi-stacking, physisorption, ionic association, van der Waals association, and the like. Suitable functional groups may include, but are not limited to, moieties comprising amines (1°, 2°, or 3°), amides, carboxylic acids, aldehydes, ketones,
20 ethers, esters, peroxides, silyls, organosilanes, hydrocarbons, aromatic hydrocarbons, and any combination thereof; polymers; chelating agents like ethylenediamine tetraacetate, diethylenetriaminepentaacetic acid, triglycollamic acid, and a structure comprising a pyrrole ring; and any combination thereof. Functional groups may, in some embodiments, enhance removal of smoke
25 components and/or enhance incorporation of nanoparticles into a porous mass.

[0031] In some embodiments, the active particles are a combination of various active particles. In some embodiments, the porous mass may comprise multiple active particles.

30 **[0032]** In some embodiments, the porous masses described herein may be effective at the reduction or removal of smoke stream components (e.g., those described herein). In some embodiments, a porous mass described herein may be used to reduce the delivery to the smoking device user of certain tobacco smoke components targeted by the WHO. For example, a porous mass where activated carbon is used as the active particles can be used to reduce the

delivery of certain tobacco smoke components to levels below the WHO recommendations. (See Table 13, below.)

[0033] In some embodiments, porous masses described herein that comprise activated carbon may reduce acetaldehydes in a smoke stream by about 3.0% to about 6.5%/mm length of porous mass; acrolein in a smoke stream by about 7.5% to about 12%/mm length of porous mass; benzene in a smoke stream by about 5.5% to about 8.0%/mm length of porous mass; benzo[a]pyrene in a smoke stream by about 9.0% to about 21.0%/mm length of porous mass; 1,3-butadiene in a smoke stream by about 1.5% to about 3.5%/mm length of porous mass; and formaldehyde in a smoke stream by about 9.0% to about 11.0%/mm length of porous mass.

[0034] In some embodiments, porous masses described herein that comprise ion exchange resins may reduce the delivery of certain tobacco smoke components to below the WHO recommendations. In some embodiments, porous masses described herein that comprise ion exchange resins may reduce acetaldehydes in a smoke stream by about 5.0% to about 7.0%/mm length of porous mass; acrolein in a smoke stream by about 4.0% to about 6.5%/mm length of porous mass; and formaldehyde in a smoke stream by about 9.0% to about 11.0%/mm length of porous mass.

[0035] In one embodiment, the active particles suitable for use in conjunction with porous masses described herein have particle sizes ranging from particles having at least one dimension of about less than one nanometer, e.g., graphene, to as large as a particle having a diameter in at least one dimension of about 5000 microns. The active particles may, in some embodiments, have a diameter in at least one dimension ranging from a lower limit of about 0.1 nanometers, 0.5 nanometers, 1 nanometer, 10 nanometers, 100 nanometers, 500 nanometers, 1 micron, 5 microns, 10 microns, 50 microns, 100 microns, 150 microns, 200 microns, or 250 microns to an upper limit of about 5000 microns, 2000 microns, 1000 microns, 900 microns, 700 microns, 500 microns, 400 microns, 300 microns, 250 microns, 200 microns, 150 microns, 100 microns, 50 microns, 10 microns, or 500 nanometers, and wherein the diameter in at least one dimension may range from any lower limit to any upper limit and encompass any subset therebetween. In some embodiments, the active particles may be a mixture of particle sizes.

[0036] The binder particles suitable for use in conjunction with porous masses described herein may be any suitable thermoplastic binder particles. In some embodiments, the binder particles suitable for use in conjunction with porous masses described herein may exhibit virtually very little flow at their melting temperature. This means a material that when heated to its melting temperature exhibits little to no polymer flow. Materials meeting these criteria include, but are not limited to, ultrahigh molecular weight polyethylene (UHMWPE), very high molecular weight polyethylene (VHMWPE), high molecular weight polyethylene (HMWPE), and combinations thereof. In one embodiment, the binder particles have a melt flow index (MFI, ASTM D1238) of less than or equal to about 3.5 g/10min at 190°C and 15 kg (or about 0-3.5 g/10min at 190°C and 15 kg). In another embodiment, the binder particles have an MFI of less than or equal to about 2.0 g/10min at 190°C and 15 kg (or about 0-2.0 g/10min at 190°C and 15 kg). Examples of low melt flow index binders may include, but are not limited to, UHMWPE with virtually no polymer flow, UHMWPE with an MFI of about 0-1.0 at 190°C and 15 kg, VHMWPE with an MFI of about 1.0-2.0 g/10min at 190°C and 15 kg, HMWPE with an MFI of about 2.0-3.5 g/10min at 190°C and 15 kg, and the like, and any combination thereof. In some embodiments, it may be preferable to use a mixture of binder particles having different molecular weights and/or different melt flow indexes.

[0037] In terms of molecular weight, UHMWPE encompasses polyethylene compositions with a weight-average molecular weight of at least about 3×10^6 g/mol. In some embodiments, the molecular weight of the UHMWPE may range from a lower limit of about 3×10^6 g/mol or 6×10^6 g/mol to an upper limit of about 30×10^6 g/mol, 20×10^6 g/mol, 10×10^6 g/mol, or 6×10^6 g/mol, and wherein the molecular weight may range from any lower limit to any upper limit and encompass any subset therebetween. In terms of molecular weight, VHMWPE encompasses polyethylene compositions with a weight average molecular weight of less than about 3×10^6 g/mol and more than about 1×10^6 g/mol. In some embodiments, the molecular weight of the very-high molecular weight polyethylene composition is between about 2×10^6 g/mol and less than about 3×10^6 g/mol. In terms of molecular weight, HMWPE encompasses polyethylene compositions with weight-average molecular weight of at least about 3×10^5 g/mol to about 1×10^6 g/mol. For purposes of the present

specification, the molecular weights referenced herein are determined in accordance with the Margolies equation ("Margolies molecular weight").

[0038] Examples of commercially available polyethylene products may include, but are not limited to, GUR® UHMWPE products (available from Ticona Polymers LLC, e.g., GUR® 2000 series (e.g., 2105, 2122, 2122-5, 2126), GUR 4000® series (e.g., 4120, 4130, 4150, 4170, 4012, 4122-5, 4022-6, 4050-3/4150-3), GUR 8000® series (e.g., 8110, 8020), GUR X® series (e.g., X143, X184, X168, X172, X192). Combinations of any of the aforementioned commercially available polyethylene products may be suitable, in some
10 embodiments.

[0039] In some embodiments, polyethylene suitable for use in conjunction with the binder described herein may have an intrinsic viscosity in the range of about 5 dl/g to about 30 dl/g and a degree of crystallinity of about 80% or more, e.g., as described in U.S. Patent Application Publication No.
15 2008/0090081, the entirety of which is incorporated herein by reference. In some embodiments, polyethylene suitable for use in conjunction with the binder described herein may have a molecular weight in the range of about 300,000 g/mol to about 2,000,000 g/mol as determined by ASTM-D 4020, an average particle size (D_{50}) between about 300 μm and about 1500 μm , and a bulk
20 density between about 0.25 g/ml and about 0.5 g/ml as described in U.S. Provisional Application No. 61/330,535 filed May 3, 2010.

[0040] The binder particles suitable for use in conjunction with porous masses described herein may be of any shape. Such shapes may include, but are not limited to, spherical, hyperion, asteroidal, chondular or interplanetary
25 dust-like, granulated, potato, popcorn, irregular, any hybrid thereof, and any combination thereof. In preferred embodiments, the binder particles suitable for use in the present invention are non-fibrous. In some embodiments, the binder particles are in the form of a powder, pellet, or particulate. In some embodiments, the binder particles are a combination of various binder particles
30 having different shapes.

[0041] In some embodiments, the binder particles suitable for use in conjunction with porous masses described herein have a diameter in at least one dimension ranging from a lower limit of about 0.1 nanometers, 0.5 nanometers, 1 nanometer, 10 nanometers, 100 nanometers, 500 nanometers, 1 micron, 5
35 microns, 10 microns, 50 microns, 100 microns, 150 microns, 200 microns, or

250 microns to an upper limit of about 5000 microns, 2000 microns, 1000 microns, 900 microns, 700 microns, 500 microns, 400 microns, 300 microns, 250 microns, 200 microns, 150 microns, 100 microns, 50 microns, 10 microns, and 500 nanometers, and wherein the diameter in at least one dimension may
5 range from any lower limit to any upper limit and encompass any subset therebetween. In some embodiments, the binder particles may be a mixture of particle sizes.

[0042] In some embodiments, the binder particles suitable for use in conjunction with porous masses described herein may have a bulk density in the
10 range of about 0.10 g/cm^3 to about 0.55 g/cm^3 . In another embodiment, the bulk density may be in the range of about 0.17 g/cm^3 to about 0.50 g/cm^3 . In yet another embodiment, the bulk density may be in the range of about 0.20 g/cm^3 to about 0.47 g/cm^3 .

[0043] In addition to the foregoing binder particles, in some
15 embodiments, other conventional thermoplastics may be used as binder particles for use in conjunction with porous masses described herein. Such thermoplastics may include, but are not limited to, polyolefins, polyesters, polyamides (or nylons), polyacrylics, polystyrenes, polyvinyls, polytetrafluoroethylene (PTFE), polyether ether ketone (PEEK), any copolymer thereof, any derivative thereof,
20 and any combination thereof. Non-fibrous plasticized cellulose derivatives may also be suitable for use as binder particles in the present invention. Examples of suitable polyolefins may include, but are not limited to, polyethylene, polypropylene, polybutylene, polymethylpentene, and the like, any copolymer thereof, any derivative thereof, and any combination thereof. Examples of
25 suitable polyethylenes may further include, but are not limited to, low-density polyethylene, linear low-density polyethylene, high-density polyethylene, and the like, any copolymer thereof, any derivative thereof, and any combination thereof. Examples of suitable polyesters may include, but are not limited to, polyethylene terephthalate, polybutylene terephthalate, polycyclohexylene
30 dimethylene terephthalate, polytrimethylene terephthalate, and the like, any copolymer thereof, any derivative thereof, and any combination thereof. Examples of suitable polyacrylics may include, but are not limited to, polymethyl methacrylate, and the like, any copolymer thereof, any derivative thereof, and any combination thereof. Examples of suitable polystyrenes may include, but are
35 not limited to, polystyrene, acrylonitrile-butadiene-styrene, styrene-acrylonitrile,

styrene-butadiene, styrene-maleic anhydride, and the like, any copolymer thereof, any derivative thereof, and any combination thereof. Examples of suitable polyvinyls may include, but are not limited to, ethylene vinyl acetate, ethylene vinyl alcohol, polyvinyl chloride, and the like, any copolymer thereof, any derivative thereof, and any combination thereof. Examples of suitable cellulose acetate butyrate, plasticized cellulose acetate, cellulose propionate, ethyl cellulose, and the like, any copolymer thereof, any derivative thereof, and any combination thereof. In some embodiments, a binder particle may comprise any copolymer, any derivative, and any combination of the exemplary binders described herein and the like.

[0044] Active particles and binder particles may be included in porous masses described herein in any weight ratio. In some embodiments, the weight ratio of active particles to binder particles may range from any lower limit of about 1:99, 10:90, 25:75, 40:60, or 50:50 to an upper limit of about 90:10, 75:25, 60:40, or 50:50, and wherein the weight ratio may range from any lower limit to any upper limit and encompass any subset therebetween.

[0045] In some embodiments, the porous masses described herein may be characterized by properties such as void volume, encapsulated pressure drop, and any combination thereof.

[0046] In some embodiments, porous masses described herein may have a void volume ranging from a lower limit of about 40%, 50%, or 60% to an upper limit of about 90%, 85%, 80%, or 75%, and wherein the void volume may range from any lower limit to any upper limit and encompass any subset therebetween.

[0047] To determine void volume, although not wishing to be limited by any particular theory, it is believed that testing indicates that the final density of the mixture was driven almost entirely by the active particle; thus the space occupied by the binder particles was not considered for this calculation. Thus, void volume, in this context, is calculated based on the space remaining after accounting for the active particles. To determine void volume, first the upper and lower diameters based on the mesh size were averaged for the active particles, and then the volume was calculated (assuming a spherical shape based on that averaged diameter) and using the density of the active material. Then, the percentage void volume is calculated as follows:

$$\text{Void Volume (\%)} = 1 - \frac{[(\text{porous mass volume, cm}^3) - (\text{weight of active particles, g}) / (\text{density of the active particles, g/cm}^3)] * 100}{\text{porous mass volume, cm}^3}$$

[0048] As used herein, the term “encapsulated pressure drop” refers to the static pressure difference between the two ends of a specimen when it is traversed by an air flow under steady conditions when the volume flow is 17.5 ml/sec at the output end when the specimen is completely encapsulated in a measuring device so that no air can pass through the wrapping. EPD has been measured herein under the CORESTA (“Cooperation Centre for Scientific Research Relative to Tobacco”) Recommended Method No. 41, dated June 2007.

In another embodiment, a porous mass of the present invention may have an EPD in the range of about 0.10 to about 10 mm of water per mm length of porous mass. In some embodiments, a porous mass of the present invention may have an EPD of about 2 to about 7 mm of water per mm length of porous mass (or no greater than 7 mm of water per mm length of porous mass).

[0049] In some embodiments, the porous masses described herein may have as an encapsulated pressure drop (EPD) ranging from a lower limit of about 0.10 mm of water per mm length of porous mass, 0.5 mm of water per mm length of porous mass, 1 mm of water per mm length of porous mass, or 5 mm of water per mm length of porous mass to an upper limit of about 25 mm of water per mm length of porous mass, 15 mm of water per mm length of porous mass, 10 mm of water per mm length of porous mass, or 5 mm of water per mm length of porous mass, and wherein the EPD may range from any lower limit to any upper limit and encompass any subset therebetween.

[0050] In some embodiments, the porous mass of the present invention may have an active particle loading of at least about 1 mg/mm, 2 mg/mm, 3 mg/mm, 4 mg/mm, 5 mg/mm, 6 mg/mm, 7 mg/mm, 8 mg/mm, 9 mg/mm, 10 mg/mm, 11 mg/mm, 12 mg/mm, 13 mg/mm, 14 mg/mm, 15 mg/mm, 16 mg/mm, 17 mg/mm, 18 mg/mm, 19 mg/mm, 20 mg/mm, 21 mg/mm, 22 mg/mm, 23 mg/mm, 24 mg/mm, or 25 mg/mm in combination with an EPD of less than about 20 mm of water or less per mm of porous mass, 19 mm of water or less per mm of porous mass, 18 mm of water or less per mm of porous mass, 17 mm of water or less per mm of porous mass, 16 mm of water or less per mm of porous mass, 15 mm of water or less per mm of porous mass, 14 mm of

water or less per mm of porous mass, 13 mm of water or less per mm of porous mass, 12 mm of water or less per mm of porous mass, 11 mm of water or less per mm of porous mass, 10 mm of water or less per mm of porous mass, 9 mm of water or less per mm of porous mass, 8 mm of water or less per mm of porous mass, 7 mm of water or less per mm of porous mass, 6 mm of water or less per mm of porous mass, 5 mm of water or less per mm of porous mass, 4 mm of water or less per mm of porous mass, 3 mm of water or less per mm of porous mass, 2 mm of water or less per mm of porous mass, or 1 mm of water or less per mm of porous mass.

[0051] By way of nonlimiting example, in some embodiments, the porous mass may have an active particle loading of at least about 1 mg/mm and an EPD of about 20 mm of water or less per mm of porous mass. In other embodiments, the porous mass may have an active particle loading of at least about 1 mg/mm and an EPD of about 20 mm of water or less per mm of porous mass, wherein the active particle is not carbon. In other embodiments, the porous mass may have an active particle comprising carbon with a loading of at least 6 mg/mm in combination with an EPD of 10 mm of water or less per mm of porous mass.

[0052] In some embodiments, matrix materials and/or porous masses may comprise active particles, binder particles, and additives. In some embodiments, the matrix material or porous masses may comprise additives in an amount ranging from a lower limit of about 0.001 wt%, 0.01 wt%, 0.05 wt%, 0.1 wt%, 1 wt%, 5 wt%, or 10 wt% of the matrix material or porous masses to an upper limit of about 25 wt%, 15 wt%, 10 wt%, 5 wt%, or 1 wt% of the matrix material or porous masses, and wherein the amount of additives can range from any lower limit to any upper limit and encompass any subset therebetween. It should be noted that porous masses as referenced herein include porous mass lengths, porous masses, and porous mass sections (wrapped or otherwise).

[0053] Suitable additives may include, but are not limited to, active compounds, ionic resins, zeolites, nanoparticles, ceramic particles, glass beads, softening agents, plasticizers, pigments, dyes, flavorants, aromas, controlled release vesicles, adhesives, tackifiers, surface modification agents, vitamins, peroxides, biocides, antifungals, antimicrobials, antistatic agents, flame retardants, degradation agents, microcapsules, and any combination thereof.

[0054] Suitable active compounds may be compounds and/or molecules suitable for removing components from a smoke stream including, but not limited to, malic acid, potassium carbonate, citric acid, tartaric acid, lactic acid, ascorbic acid, polyethyleneimine, cyclodextrin, sodium hydroxide, sulphamic acid, sodium sulphamate, polyvinyl acetate, carboxylated acrylate, and any combination thereof. It should be noted that an active particle may also be considered an active compound, and vice versa. By way of nonlimiting example, fullerenes and some carbon nanotubes may be considered to be a particulate and a molecule.

[0055] Suitable ionic resins may include, but are not limited to, polymers with a backbone of styrene-divinyl benzene (DVB) copolymer, acrylates, methacrylates, phenol formaldehyde condensates, epichlorohydrin amine condensates, and the like, and any combination thereof; a plurality of electrically charged functional groups attached to the polymer backbone; and any combination thereof.

[0056] Zeolites may include crystalline aluminosilicates having pores, *e.g.*, channels, or cavities of uniform, molecular-sized dimensions. Zeolites may include natural and synthetic materials. Suitable zeolites may include, but are not limited to, zeolite BETA ($\text{Na}_7(\text{Al}_7\text{Si}_{57}\text{O}_{128})$ tetragonal), zeolite ZSM-5 ($\text{Na}_n(\text{Al}_n\text{Si}_{96-n}\text{O}_{192}) 16 \text{ H}_2\text{O}$, with $n < 27$), zeolite A, zeolite X, zeolite Y, zeolite K-G, zeolite ZK-5, zeolite ZK-4, mesoporous silicates, SBA-15, MCM-41, MCM48 modified by 3-aminopropylsilyl groups, alumino-phosphates, mesoporous aluminosilicates, other related porous materials (*e.g.*, such as mixed oxide gels), or any combination thereof.

[0057] Suitable nanoparticles may include, but are not limited to, nano-scaled carbon particles like carbon nanotubes of any number of walls, carbon nanohorns, bamboo-like carbon nanostructures, fullerenes and fullerene aggregates, and graphene including few layer graphene and oxidized graphene; metal nanoparticles like gold and silver; metal oxide nanoparticles like alumina, silica, and titania; magnetic, paramagnetic, and superparamagnetic nanoparticles like gadolinium oxide, various crystal structures of iron oxide like hematite and magnetite, about 12 nm Fe_3O_4 , gado-nanotubes, and endofullerenes like $\text{Gd}@\text{C}_{60}$; and core-shell and onionated nanoparticles like gold and silver nanoshells, onionated iron oxide, and other nanoparticles or microparticles with an outer shell of any of said materials) and any combination

of the foregoing (including activated carbon). It should be noted that nanoparticles may include nanorods, nanospheres, nanorices, nanowires, nanostars (like nanotripods and nanotetrapods), hollow nanostructures, hybrid nanostructures that are two or more nanoparticles connected as one, and non-nano particles with nano-coatings or nano-thick walls. It should be further noted that nanoparticles may include the functionalized derivatives of nanoparticles including, but not limited to, nanoparticles that have been functionalized covalently and/or non-covalently, e.g., pi-stacking, physisorption, ionic association, van der Waals association, and the like. Suitable functional groups may include, but are not limited to, moieties comprising amines (1°, 2°, or 3°), amides, carboxylic acids, aldehydes, ketones, ethers, esters, peroxides, silyls, organosilanes, hydrocarbons, aromatic hydrocarbons, and any combination thereof; polymers; chelating agents like ethylenediamine tetraacetate, diethylenetriaminepentaacetic acid, triglycollamic acid, and a structure comprising a pyrrole ring; and any combination thereof. Functional groups may enhance removal of smoke components and/or enhance incorporation of nanoparticles into a porous mass.

[0058] Suitable ceramic particles may include, but are not limited to, oxides (e.g., silica, titania, alumina, beryllia, ceria, and zirconia), nonoxides (e.g., carbides, borides, nitrides, and silicides), composites thereof, or any combination thereof. Ceramic particles may be crystalline, non-crystalline, or semi-crystalline.

[0059] As used herein, pigments refer to compounds and/or particles that impart color and are incorporated throughout the matrix material and/or a component thereof. Suitable pigments may include, but are not limited to, titanium dioxide, silicon dioxide, tartrazine, E102, phthalocyanine blue, phthalocyanine green, quinacridones, perylene tetracarboxylic acid di-imides, dioxazines, perinones disazo pigments, anthraquinone pigments, carbon black, titanium dioxide, metal powders, iron oxide, ultramarine, or any combination thereof.

[0060] As used herein, dyes refer to compounds and/or particles that impart color and are a surface treatment. Suitable dyes may include, but are not limited to, CARTASOL[®] dyes (cationic dyes, available from Clariant Services) in liquid and/or granular form (e.g., CARTASOL[®] Brilliant Yellow K-6G liquid, CARTASOL[®] Yellow K-4GL liquid, CARTASOL[®] Yellow K-GL liquid, CARTASOL[®]

Orange K-3GL liquid, CARTASOL® Scarlet K-2GL liquid, CARTASOL® Red K-3BN liquid, CARTASOL® Blue K-5R liquid, CARTASOL® Blue K-RL liquid, CARTASOL® Turquoise K-RL liquid/granules, CARTASOL® Brown K-BL liquid), FASTUSOL® dyes (an auxochrome, available from BASF) (e.g., Yellow 3GL, Fastusol C Blue 74L).

[0061] Suitable flavorants may be any flavorant suitable for use in smoking device filters including those that impart a taste and/or a flavor to the smoke stream. Suitable flavorants may include, but are not limited to, organic material (or naturally flavored particles), carriers for natural flavors, carriers for artificial flavors, and any combination thereof. Organic materials (or naturally flavored particles) include, but are not limited to, tobacco, cloves (e.g., ground cloves and clove flowers), cocoa, and the like. Natural and artificial flavors may include, but are not limited to, menthol, cloves, cherry, chocolate, cardamom, orange, mint, mango, vanilla, cinnamon, tobacco, and the like. Such flavors may be provided by menthol, anethole (licorice), anisole, limonene (citrus), eugenol (clove), and the like, or any combination thereof. In some embodiments, more than one flavorant may be used including any combination of the flavorants provided herein. These flavorants may be placed in the tobacco column or in a section of a filter. The amount to include will depend on the desired level of flavor in the smoke taking into account all filter sections, the length of the smoking device, the type of smoking device, the diameter of the smoking device, as well as other factors known to those of skill in the art.

[0062] Suitable aromas may include, but are not limited to, spices, spice extracts, herb extracts, essential oils, smelling salts, volatile organic compounds, volatile small molecules, methyl formate, methyl acetate, methyl butyrate, ethyl acetate, ethyl butyrate, isoamyl acetate, pentyl butyrate, pentyl pentanoate, octyl acetate, myrcene, geraniol, nerol, citral, citronellal, citronellol, linalool, nerolidol, limonene, camphor, terpineol, alpha-ionone, thujone, benzaldehyde, eugenol, cinnamaldehyde, ethyl maltol, vanilla, anisole, anethole, estragole, thymol, furaneol, methanol, rosemary, lavender, citrus, freesia, apricot blossoms, greens, peach, jasmine, rosewood, pine, thyme, oakmoss, musk, vetiver, myrrh, blackcurrant, bergamot, grapefruit, acacia, passiflora, sandalwood, mandarin, neroli, violet leaves, gardenia, red fruits, ylang-ylang, acacia farnesiana, mimosa, tonka bean, woods, ambergris, daffodil, hyacinth, narcissus, black currant bud, iris, raspberry, lily of the valley, cedarwood, neroli,

bergamot, strawberry, carnation, oregano, honey, civet, heliotrope, caramel, coumarin, patchouli, dewberry, helonial, hyacinth, cardamom, coriander, pimento berry, labdanum, cassie, aldehydes, orchid, amber, benzoin, orris, tuberose, palmarosa, cinnamon, nutmeg, moss, styrax, pineapple, bergamot, 5 foxglove, tulip, wisteria, clematis, ambergris, gums, resins, peach, plum, castoreum, geranium, rose violet, jonquil, spicy carnation, galbanum, hyacinth, petitgrain, hyacinth, honeysuckle, pepper, raspberry, benzoin, mango, coconut, hesperides, castoreum, osmanthus, mousse de chene, nectarine, mint, anise, cinnamon, orris, apricot, plumeria, marigold, rose otto, narcissus, tolu balsam, 10 frankincense, amber, orange blossom, bourbon vetiver, opopanax, white musk, papaya, sugar candy, jackfruit, honeydew, lotus blossom, muguet, mulberry, absinthe, ginger, juniper berries, spicebush, peony, violet, lemon, lime, hibiscus, white rum, basil, lavender, balsamics, fo-ti-tieng, osmanthus, karo karunde, white orchid, calla lilies, white rose, rhubrum lily, tagetes, ambergris, ivy, grass, 15 seringa, spearmint, clary sage, cottonwood, grapes, brimbelle, lotus, cyclamen, orchid, glycine, tiare flower, ginger lily, green osmanthus, passion flower, blue rose, bay rum, cassie, African tagetes, Anatolian rose, Auvergne narcissus, British broom, British broom chocolate, Bulgarian rose, Chinese patchouli, Chinese gardenia, Calabrian mandarin, Comoros Island tuberose, Ceylonese cardamom, Caribbean passion fruit, Damascena rose, Georgia peach, white 20 Madonna lily, Egyptian jasmine, Egyptian marigold, Ethiopian civet, Farnesian cassie, Florentine iris, French jasmine, French jonquil, French hyacinth, Guinea oranges, Guyana wacapua, Grasse petitgrain, Grasse rose, Grasse tuberose, Haitian vetiver, Hawaiian pineapple, Israeli basil, Indian sandalwood, Indian 25 Ocean vanilla, Italian bergamot, Italian iris, Jamaican pepper, May rose, Madagascar ylang-ylang, Madagascar vanilla, Moroccan jasmine, Moroccan rose, Moroccan oakmoss, Moroccan orange blossom, Mysore sandalwood, Oriental rose, Russian leather, Russian coriander, Sicilian mandarin, South African marigold, South American tonka bean, Singapore patchouli, Spanish orange blossom, Sicilian lime, Reunion Island vetiver, Turkish rose, Thai benzoin, 30 Tunisian orange blossom, Yugoslavian oakmoss, Virginian cedarwood, Utah yarrow, West Indian rosewood, and the like, and any combination thereof.

[0063] Suitable tackifiers may include, but are not limited to, methylcellulose, ethylcellulose, hydroxyethylcellulose, carboxy methylcellulose, 35 carboxy ethylcellulose, water-soluble cellulose acetate, amides, diamines,

polyesters, polycarbonates, silyl-modified polyamide compounds, polycarbamates, urethanes, natural resins, shellacs, acrylic acid polymers, 2-ethylhexylacrylate, acrylic acid ester polymers, acrylic acid derivative polymers, acrylic acid homopolymers, an acrylic acid ester homopolymers, poly(methyl acrylate), poly(butyl acrylate), poly(2-ethylhexyl acrylate), acrylic acid ester co-polymers, methacrylic acid derivative polymers, methacrylic acid homopolymers, methacrylic acid ester homopolymers, poly(methyl methacrylate), poly(butyl methacrylate), poly(2-ethylhexyl methacrylate), acrylamido-methyl-propane sulfonate polymers, acrylamido-methyl-propane sulfonate derivative polymers, acrylamido-methyl-propane sulfonate co-polymers, acrylic acid/acrylamido-methyl-propane sulfonate co-polymers, benzyl coco di-(hydroxyethyl) quaternary amines, p-T-amyl-phenols condensed with formaldehyde, dialkyl amino alkyl (meth)acrylates, acrylamides, N-(dialkyl amino alkyl) acrylamide, methacrylamides, hydroxy alkyl (meth)acrylates, methacrylic acids, acrylic acids, hydroxyethyl acrylates, and the like, any derivative thereof, or any combination thereof.

[0064] Suitable vitamins may include, but are not limited to, vitamin A, vitamin B1, vitamin B2, vitamin C, vitamin D, vitamin E, or any combination thereof.

[0065] Suitable antimicrobials may include, but are not limited to, antimicrobial metal ions, chlorhexidine, chlorhexidine salt, triclosan, polymyxin, tetracycline, amino glycoside (e.g., gentamicin), rifampicin, bacitracin, erythromycin, neomycin, chloramphenicol, miconazole, quinolone, penicillin, nonoxynol 9, fusidic acid, cephalosporin, mupirocin, metronidazole, secropin, protegrin, bacteriolcin, defensin, nitrofurazone, mafenide, acyclovir, vancomycin, clindamycin, lincomycin, sulfonamide, norfloxacin, pefloxacin, nalidixic acid, oxalic acid, enoxacin acid, ciprofloxacin, polyhexamethylene biguanide (PHMB), PHMB derivatives (e.g., biodegradable biguanides like polyethylene hexamethylene biguanide (PEHMB)), chlorhexidine gluconate, chlorhexidine hydrochloride, ethylenediaminetetraacetic acid (EDTA), EDTA derivatives (e.g., disodium EDTA or tetrasodium EDTA), the like, and any combination thereof.

[0066] Antistatic agents may comprise any suitable anionic, cationic, amphoteric or nonionic antistatic agent. Anionic antistatic agents may generally include, but are not limited to, alkali sulfates, alkali phosphates, phosphate esters of alcohols, phosphate esters of ethoxylated alcohols, or any combination

thereof. Examples may include, but are not limited to, alkali neutralized phosphate ester (e.g., TRYFAC® 5559 or TRYFRAC® 5576, available from Henkel Corporation, Mauldin, SC). Cationic antistatic agents may generally include, but are not limited to, quaternary ammonium salts and imidazolines which possess a positive charge. Examples of nonionics include the poly(oxyalkylene) derivatives, e.g., ethoxylated fatty acids like EMEREST® 2650 (an ethoxylated fatty acid, available from Henkel Corporation, Mauldin, SC), ethoxylated fatty alcohols like TRYCOL® 5964 (an ethoxylated lauryl alcohol, available from Henkel Corporation, Mauldin, SC), ethoxylated fatty amines like TRYMEEN® 6606 (an ethoxylated tallow amine, available from Henkel Corporation, Mauldin, SC), alkanolamides like EMID® 6545 (an oleic diethanolamine, available from Henkel Corporation, Mauldin, SC), or any combination thereof. Anionic and cationic materials tend to be more effective antistatic agents.

[0067] As used herein, "microcapsules" refer to porous microparticles (spherical or otherwise) having exterior surface pores and having diameters of less than about 1 micron to about 1000 microns. In some embodiments, microcapsules may comprise any of the additives described herein (singularly or in combination) provided the additives are suitably sized to fit within the inner contents and maintain operability of the microcapsule. Suitable microcapsules for use in conjunction with the present invention may be those formed by any suitable technique, which may include, but is not limited to, those described in U.S. Patent Nos. 5,064,949 entitled "Cellulose Ester Microparticles and Processes for Making the Same," and 5,047,180 entitled "Process for Making Cellulose Ester Microparticles," the relevant disclosures of which are incorporated herein by reference. Suitable microcapsules for use in conjunction with the present invention may be formed of any suitable materials, which may include, but are not limited to, gelatins, celluloses, modified celluloses, methylcellulose, hydroxypropylmethyl cellulose, chlorophyllin, polyvinylalcohol, polyvinyl pyrrolidone, and the like, or any combination thereof.

[0068] The length of a porous mass described herein may, in some embodiments, range from a lower limit of about 2 mm, 3 mm, 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, or 30 mm to an upper limit of about 150 mm, 100 mm, 50 mm, 25 mm, 15 mm, or 10 mm, and wherein the length may range from any lower limit to any upper limit and encompass any subset therebetween.

[0069] The porous mass may have any physical shape, e.g., in some embodiments, helical, triangular, discus, square, rectangular, cylindrical, and any hybrid thereof. In some embodiments, the porous mass may be machined for, *inter alia*, to be lighter in weight, if desired, for example, by drilling out a portion of the porous mass. In one embodiment, the porous mass may have a specific shape adapted to fit within the cigarette holder or pipe to allow for smoke passage through the filter to the consumer. When discussing the shape of a porous mass herein, the shape may be referred to in terms of diameter or circumference (wherein the circumference is the perimeter of a circle) of the cross-section of the cylinder. However, the term "circumference" refers generally to the perimeter of any shaped cross-section, unless otherwise specified, including a circular and polyagonal cross-sections.

[0070] The circumference of a porous mass described herein may range from a lower limit of about 5 mm, 6 mm, 7 mm, 8 mm, 9 mm, 10 mm, 11 mm, 12 mm, 13 mm, 14 mm, 15 mm, 16 mm, 17 mm, 18 mm, 19 mm, 20 mm, 21 mm, 22 mm, 23 mm, 24 mm, 25 mm, or 26 mm to an upper limit of about 60 mm, 50 mm, 40 mm, 30 mm, 20 mm, 29 mm, 28 mm, 27 mm, 26 mm, 25 mm, 24 mm, 23 mm, 22 mm, 21 mm, 20 mm, 19 mm, 18 mm, 17 mm, or 16 mm, wherein the circumference may range from any lower limit to any upper limit and encompass any subset therebetween.

[0071] In some embodiments, a porous mass may have at least one paper disposed thereabout. Unless otherwise specified, embodiments described herein that pertain to porous masses also pertain to wrapped porous masses. Examples of papers that may be disposed about porous masses described herein may include, but are not limited to, papers (e.g., wood-based papers, papers containing flax, flax papers, cotton paper, papers produced from other natural or synthetic fibers, functionalized papers, special marking papers, colorized papers), plastics (e.g., fluorinated polymers like polytetrafluoroethylene, silicone), films, coated papers, coated plastics, coated films, and the like, and any combination thereof. In some embodiments, the papers may be high porosity, corrugated, and/or have a high surface strength. In some embodiments, papers may be substantially non-porosity less, e.g., than about 10 CORESTA units.

[0072] Porous masses described herein may be produced by any suitable method and with any suitable apparatus and/or system including, but

not limited to, the methods, systems, and apparatuses described in co-pending application PCT/US11/56388 filed October 14, 2011, the entirety of which is incorporated herein by reference. For example, porous masses may be produced utilizing mold cavities in continuous, batch, or hybrid processes.

5 **II. ARTICLES COMPRISING POROUS MASSES**

[0073] The porous mass described hereinafter may be used as a filter or a filter segment, including use in conjunction with smoking device filters. As used herein, the term "smoking device" refers to an article capable of maintaining a smokable substance and a filter in fluid communication and when
10 in operation allows for a user to draw on the smoking device causing the smoke from the smokable passes through the filter and to the user (*e.g.*, a human). The term smoking device encompasses, but is not limited to, cigarettes, cigarette holders, cigars, cigar holders, pipes, water pipes, hookahs, electronic smoking devices, roll-your-own cigarettes or cigars, and the like, and any hybrid
15 thereof.

[0074] In some embodiments, a smoking device may comprise a housing capable of maintaining a smokeable substance in fluid communication with the filter. Suitable housings may include, but are not limited to, a cigarette, a cigarette holder, a cigar, a cigar holder, a pipe, a water pipe, a hookah, an
20 electronic smoking device, a roll-your-own cigarette, a roll-your-own cigar, a paper, and the like, any hybrid thereof, and any combination thereof.

[0075] Referring to the nonlimiting example illustrated in Figure 1, smoking device 10 includes filter 14 and a smokable substance illustrated as tobacco column 12. Filter 14 may comprise at least two sections, first section 16
25 and second section 18. For example, the first section 16 may comprise conventional filter material (discussed in greater detail herein) and the second section 18 comprises a porous mass (discussed in greater detail herein).

[0076] Referring now to the nonlimiting example illustrated in Figure 2, smoking device 20 has filter 22 and a smokable substance illustrated as tobacco
30 column 12. Filter 22 illustrates a multi-segmented with three sections, sometimes referred to as a dual offset filter, that include in order filter section 24, porous mass 26, and filter section 24. Filter section 24 may include, in some embodiments, any of the filter section materials and/or attributes described herein.

[0077] Referring now to the nonlimiting example illustrated in Figure 3, smoking device 30 has filter 32 and a smokable substance illustrated as tobacco column 12. Filter 32 is multi-segmented with sections 34,36,37,38, where section 34 is the mouth and a smoking device 30. In some embodiments, section 34 may comprise conventional filter materials so as to provide a normal mouth-feel to a user, and sections 36,37,38 may independently comprise any filter material and/or attributes described herein, such that at least one of sections 36,37,38 is a porous mass described herein.

[0078] Referring now to the nonlimiting example illustrated in Figure 4, a smoking device illustrated as pipe 40 has a burning bowl 42, a mouth piece 44, and a channel 46 interconnecting burning bowl 42 and mouth piece 44. Channel 46 includes a cavity 47 adapted for receipt of a filter 48. Filter 48 may, in some embodiments, be a porous mass or a multi-segmented filter, *e.g.*, as illustrated in filter 14 of Figure 1, filter 22 of Figure 2, or filter 32 of Figure 3. The size of filter 48 may vary based on the dimensions of cavity 47. In some embodiments, filter 48 may be removable, replaceable, disposable, recyclable, and/or degradable.

[0079] In some embodiments, filters that comprise porous masses described herein may have any number of sections, *e.g.*, 2, 3, 4, 5, 6, or more sections, and the sections may be placed in any suitable configuration and independently comprise materials and attributes as described.

[0080] Materials suitable for use in filters and/or filter sections that are not porous masses may include, but are not limited to, cellulose acetate, cellulose esters, polypropylene, polyethylene, polyolefin tow, polypropylene tow, polyethylene terephthalate, polybutylene terephthalate, random oriented acetate, papers, corrugated papers, concentric filters (*e.g.*, a peripheral filter of fibrous tow and a core of a web material), carbon-on-tow (sometimes referred to as a "Dalmatian filter"), silica, magnesium silicate, zeolites (*e.g.*, BETA, SBA-15, MCM-41, and MCM-48 modified by 3-aminopropylsilyl groups), molecular sieves, salts, catalysts, sodium chloride, nylon, flavorants, tobacco, capsules, cellulose, cellulosic derivatives, cellulose ester microspheres, catalytic converters, iodine pentoxide, coarse powders, carbon particles, carbon fibers, fibers, glass beads, nanoparticles, void chambers (*e.g.*, formed by rigid elements, such as paper or plastic), baffled void chambers, and any combination thereof. Further, filters

and/or filter sections that that are not porous masses may include additives described herein.

[0081] In some embodiments, a filter comprising a porous mass described herein may comprise a cavity between two filter sections, *e.g.*,
5 between two porous mass sections, between two sections not being porous masses, or between a porous mass section and another section. The cavity may be filled with active particles and/or additives described herein, *e.g.*, granulated carbon, flavorants, and the like. The cavity may contain a capsule, *e.g.*, a polymeric capsule, that itself contains active particles and/or additives described
10 herein. In some embodiments, the cavity may include tobacco as an additional flavorant. One should note that if the cavity is insufficiently filled with a chosen substance, in some embodiments, this may create a lack of interaction between the components of the mainstream smoke and the substance in the cavity and in the other filter section(s).

[0082] In some embodiments, a filter comprising a porous mass described herein may be characterized by EPD. In some embodiments, a filter comprising a porous mass described herein may have an EPD of less than about 20 mm of water or less per mm of porous mass, 19 mm of water or less per mm of porous mass, 18 mm of water or less per mm of porous mass, 17 mm of
20 water or less per mm of porous mass, 16 mm of water or less per mm of porous mass, 15 mm of water or less per mm of porous mass, 14 mm of water or less per mm of porous mass, 13 mm of water or less per mm of porous mass, 12 mm of water or less per mm of porous mass, 11 mm of water or less per mm of porous mass, 10 mm of water or less per mm of porous mass, 9 mm of water or
25 less per mm of porous mass, 8 mm of water or less per mm of porous mass, 7 mm of water or less per mm of porous mass, 6 mm of water or less per mm of porous mass, 5 mm of water or less per mm of porous mass, 4 mm of water or less per mm of porous mass, 3 mm of water or less per mm of porous mass, 2 mm of water or less per mm of porous mass, or 1 mm of water or less per mm
30 of porous mass.

[0083] In some embodiments, the filter may be substantially degradable over time (*e.g.*, over about 2 to about 5 years), either naturally or in the presence of a catalyst, that in some embodiments, may be present in a filter section itself.

[0084] As illustrated in Figures 1-3, in some embodiments, a filter section comprising a porous mass and at least one other filter section may be co-axial, juxtaposed, abutting, and have equivalent cross-sectional areas (or substantially equivalent cross-sectional areas). However, it is understood that the porous mass and the conventional materials need not be joined in such a fashion, and that there may be other possible configurations. Moreover, while it is envisioned that porous masses will be, most often, used in a combined or multi-segmented filter configuration, *e.g.*, as shown in Figures 1-3., in some embodiments, the filter may consist essentially of a porous mass of the present invention, as discussed above with regard to Figure 4.

[0085] As described above, filters comprising porous masses described herein may be utilized in conjunction with a smoking device. In some embodiments, the filter may abut the smokeable substance of the smoking device, *e.g.*, a cigarette or a cigar. In some embodiments, the filter may be in fluid communication but not abutting the smokeable substance, *e.g.*, a hookah, a pipe, a cigar holder, a cigarette holder, or a cigarette or cigar with a cavity disposed between the filter and the smokeable substance.

[0086] In some embodiments, a smokeable substance may be in the form of a tobacco column. As used herein, the term "tobacco column" refers to the blend of tobacco, and optionally other ingredients and flavorants that may be combined to produce a tobacco-based smokeable article, such as a cigarette or cigar. In some embodiments, the tobacco column may comprise ingredients selected from the group consisting of: tobacco, sugar (such as sucrose, brown sugar, invert sugar, or high fructose corn syrup), propylene glycol, glycerol, cocoa, cocoa products, carob beans, carob bean extracts, and any combination thereof. In still other embodiments, the tobacco column may further comprise flavorants, menthol, licorice extract, diammonium phosphate, ammonium hydroxide, and any combination thereof. Examples of suitable types of tobacco that may be used in the tobacco columns may include, but are not limited to, bright leaf tobacco, burley tobacco, Oriental tobacco (also known as Turkish tobacco), Cavendish tobacco, corajo tobacco, criollo tobacco, Perique tobacco, shade tobacco, white burley tobacco, and any combination thereof. The tobacco may be grown in the United States, or may be grown in a jurisdiction outside the United States.

III. METHODS OF FORMING FILTERS AND SMOKING DEVICES

[0087] In some embodiments, filter sections may be combined or joined so as to form a filter or a filter rod. As used herein the term "filter rod" refers to a length of filter that is suitable for being cut into two or more filters. By way of nonlimiting example, the filter rods that comprise a porous mass described
5 herein may, in some embodiments, have lengths ranging from about 80 mm to about 150 mm and may be cut into filters having lengths about 5 to about 35 mm in length during a smoking device tipping operation (the addition of a tobacco column to a filter).

[0088] Tipping operations may involve combining or joining a filter or
10 filter rod described herein with a tobacco column. During tipping operations, the filter rods that comprise a porous mass described herein may, in some embodiments, be first cut into filters or cut into filters during the tipping process. Further, in some embodiments, tipping methods may further involve combining or joining additional sections that comprise paper and/or charcoal to the filter,
15 filter rods, or tobacco column.

[0089] In the production of filters, filter rods, and/or smoking devices, some embodiments may involve wrapping a paper about the various components thereof so as to maintain the components in the desired configuration and/or contact. For example, producing filter and/or filter rods may
20 involve wrapping paper about a series of abutting filter sections. In some embodiments, porous masses wrapped with a paper wrapping may have an additional wrapping disposed thereabout to maintain contact between the porous mass and another section of the filter. Suitable papers for producing filters, filter rods, and/or smoking devices may include any paper described herein in
25 relation to wrapping porous masses. In some embodiments, the papers may comprise additives, sizing, and/or printing agents.

[0090] In the production of filters, filter rods, and/or smoking devices, some embodiments may involve adhering adjacent components thereof (e.g., a porous mass to an adjacent filter section, tobacco column, and the like, or any
30 combination thereof). Preferable adhesives may include those that do not impart flavor or aroma under ambient conditions and/or under burning conditions. In some embodiments, wrapping and adhering may be utilized in the production of filters, filter rods, and/or smoking devices.

[0091] Some embodiments of the present invention may involve
35 providing a porous mass rod that comprise a plurality of active particles and

binder particles bound together at a plurality of contact points; providing a filter rod that does not have the same composition as the porous mass rod; cutting the porous mass rod and the filter rod into porous mass sections and filter sections, respectively; forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least some of the porous mass sections and at least some of the filter sections; securing the desired abutting configuration with a paper wrapper and/or an adhesive so as to yield a segmented filter rod length; cutting the segmented filter rod length into segmented filter rods; and wherein the method is performed so as to produce the segmented filter rods at a rate of about 600 m/min or less. Some embodiments may further involve forming a smoking device with at least a portion of the segmented filter rod.

[0092] As used herein, the term "abutting configuration" refers to a configuration where two filter sections (or the like) are axially aligned so as to touch one end of the first section to one end of the second section. One skilled in the art would understand that this abutting configuration can be continuous (*i.e.*, not never-ending, rather very long) with a large number of sections or short in length with at least two to many sections.

[0093] It should be noted that in some method embodiments described herein, the term "segmented" is used for clarity to modify various articles and should be viewed to be encompassed by various embodiments described herein with reference to articles (*e.g.*, filters and filter rods) comprising porous masses.

[0094] Some embodiments of the present invention may involve providing a plurality of porous mass sections that comprise a plurality of active particles and binder particles bound together at a plurality of contact points; providing a plurality of filter sections that does not have the same composition as the porous mass sections; forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least one of the porous mass sections and at least one of the filter sections; securing the desired abutting configuration with a paper wrapper and/or adhesive so as to produce a segmented filter or a segmented filter rod length; and wherein the method is performed so as to produce the segmented filter or the segmented filter rod at a rate of about 600 m/min or less. Some embodiments may further

involve forming a smoking device with the segmented filter or at least a portion of the segmented filter rod.

[0095] In some embodiments, the foregoing method of the present invention may be adapted to accommodate three or more filter sections. For example, a desired configuration of a filter rod length may be a first porous mass section, a first filter section, and a second filter section in series a first porous mass section, a first second filter section, a first first filter section, a second second filter section, a second porous mass section, a third second filter section, a second first filter section, and a fourth second filter section in series. Such a configuration may be at least one embodiment useful for producing filters that comprise three sections, as illustrated in Figure 12, which illustrates a filter rod length being cut into a filter rod that is then cut two additional times so as to yield a filter section comprising three sections.

[0096] In some embodiments, a capsule may be included so as to be nested between two abutting sections. As used herein, the term "nested" or "nesting" refers to being inside and not directly exposed to the exterior of the article produced. Accordingly, nesting between two abutting sections allows for the adjacent sections to be touching, *i.e.*, abutting. In some embodiments, a capsule may be in a portion

[0097] In some embodiments, filters described herein may be produced using known instrumentation, *e.g.*, greater than about 25 m/min in automated instruments and lower for hand production instruments. While the rate of production may be limited by the instrument capabilities only, in some embodiments, filter sections described herein may be combined to form a filter rod at a rate ranging from a lower limit of about 25 m/min or less, 50 m/min or less, or 100 m/min or less to an upper limit of about 600 m/min or less, about 400 m/min or less, about 300 m/min or less, or about 250 m/min or less.

[0098] In some embodiments, porous masses utilized in the production of filter and/or filter rods described herein may be wrapped with a paper. The paper may, in some embodiments, reduce damage and particulate production due to the mechanical manipulation of the porous masses. Paper suitable for use in conjunction with protecting porous masses during manipulation may include, but are not limited to, wood-based papers, papers containing flax, flax papers, cotton paper, functionalized papers (*e.g.*, those that are functionalized so as to reduce tar and/or carbon monoxide), special marking papers, colorized papers,

and any combination thereof. In some embodiments, the papers may be high porosity, corrugated, and/or have a high surface strength. In some embodiments, papers may be substantially non-porosity less, *e.g.*, than about 10 CORESTA units.

5 **[0099]** In some embodiments, the filters and/or filter rods comprising porous masses described herein may be directly transported to a manufacturing line whereby they will be combined with tobacco columns to form smoking devices. An example of such a method includes a process for producing a smoking device comprising: providing a filter rod comprising at least one filter
10 section comprising a porous mass described herein that comprises an active particle and a binder particle; providing a tobacco column; cutting the filter rod transverse to its longitudinal axis through the center of the rod to form at least two filters having at least one filter section, each filter section comprising a porous mass that comprises an active particle and a binder particle; and joining
15 at least one of the filters to the tobacco column along the longitudinal axis of the filter and the longitudinal axis of the tobacco column to form at least one smoking device.

[00100] In other embodiments, the device filters and/or filter rods comprising porous masses may be placed in a suitable container for storage until
20 further use. Suitable storage containers include those commonly used in the smoking device filter art including, but not limited to, crates, boxes, drums, bags, cartons, and the like.

[00101] In some embodiments, filters and/or smoking devices comprising porous masses as described herein may be incorporated into packs of
25 the filters and/or smoking devices. The pack may be a hinge-lid pack, a slide-and-shell pack, a hard cup pack, a soft cup pack, or any other suitable pack container. In some embodiments, the packs may have an outer wrapping, such as a polypropylene wrapper, and optionally a tear tab. In some embodiments, the filters and/or smoking devices may be sealed as a bundle inside a pack. A
30 bundle may contain a number of filters and/or smoking devices, for example, 20 or more. However, a bundle may include a single filter and/or smoking device, in some embodiments, such for individual sale or for preserving flavors.

[00102] In some embodiments, a carton of packs that includes at least one pack filters and/or smoking devices comprising porous masses as described
35 herein. In some embodiments, the carton (*e.g.*, a container) has the physical

integrity to contain the weight from the packs of cigarettes. This may be accomplished through thicker cardstock being used to form the carton or stronger adhesives being used to bind elements of the carton.

[00103] Because it is expected that a consumer will smoke a smoking device that includes a porous mass as described herein, the present invention also provides methods of smoking the smoking devices described herein. For example, in one embodiment, the present invention provides a method of smoking a smoking device comprising: heating or lighting a smoking device to form smoke, the smoking device comprising at least one filter that comprises a porous mass described herein; and drawing the smoke through the smoking device, wherein the filter reduces the presence of at least one component in the smoke as compared to a filter without the porous mass.

[00104] In some embodiments, a filter and/or a filter rod may comprise or consist essentially of a porous mass (having a desired shape, length, circumference, void space, and encapsulated pressure drop as described herein including combinations thereof) that comprises active particles, binder particles, and optionally further comprises additives according to any combination of compositions, sizes, shapes, and/or concentrations of the active particles, binder particles, and additives as described herein. In some embodiments, a filter and/or a filter rod, according to any of the foregoing embodiments, may further comprise a desired number and composition of additional filter segments (including additional porous masses) and may have a desired shape, length, circumference, encapsulated pressure drop, and combination thereof. In some embodiments, a filter and/or a filter rod, according to any of the foregoing embodiments, may comprise a porous mass that comprises an active particle and a binder particle, the filter having at least one of the following or any combination thereof:

(a) the active particle comprising an element selected from the group consisting of: a nano-scaled carbon particle, a carbon nanotube having at least one wall, a carbon nanohorn, a bamboo-like carbon nanostructure, a fullerene, a fullerene aggregate, graphene, a few layer graphene, oxidized graphene, an iron oxide nanoparticle, a nanoparticle, a metal nanoparticle, a gold nanoparticle, a silver nanoparticle, a metal oxide nanoparticle, an alumina nanoparticle, a magnetic nanoparticle, a paramagnetic nanoparticle, a superparamagnetic nanoparticle, a gadolinium oxide nanoparticle, a hematite nanoparticle, a

magnetite nanoparticle, a gado-nanotube, an endofullerene, Gd@C60, a core-shell nanoparticle, an onionated nanoparticle, a nanoshell, an onionated iron oxide nanoparticle, and any combination thereof;

5 (b) the porous mass having a void volume in the range of about 40% to about 90%;

(c) the active particle comprising carbon, and the porous mass having a carbon loading of at least about 6 mg/mm, and an EPD of about 20 mm of water or less per mm of porous mass; and

10 (d) the porous mass having an active particle loading of at least about 1 mg/mm and an EPD of 20 mm of water or less per mm of porous mass.

[00105] In some embodiments, a filter and/or a filter rod, according to any of the foregoing embodiments, may be included in and/or used in conjunction with forming a smoking device described herein, in any configuration and by any methods described herein.

15 **[00106]** To facilitate a better understanding of the present invention, the following examples of preferred or representative embodiments are given. In no way should the following examples be read to limit, or to define, the scope of the invention.

20 **EXAMPLES**

[00107] In the following example, the effectiveness of a porous mass in removing certain components of the cigarette smoke is illustrated. The porous mass was made from 25 weight % GUR 2105 from Ticona, LLC, and 75 weight % PICA RC 259 (95% active carbon) from PICA USA, Inc. of Columbus, OH. The porous mass has a % void volume of 72% and an encapsulated pressure drop (EPD) of 2.2 mm of water/mm of porous mass length. The porous mass has a circumference of about 24.5 mm. The PICA RC 259 carbon had an average particle size of 569 microns (μ). The porous mass was made by mixing the resin (GUR 2105) and carbon (PICA RC 259) and then filling a mold with the mixture
25 without pressure on the heated mixture (free sintering). Then, the mold was heated to 200°C for 40 minutes. Thereafter, the porous mass was removed from the mold and allowed to cool. A defined-length section of the porous mass was combined with a sufficient amount of cellulose acetate tow to yield a filter with a total encapsulated pressure drop of 70 mm of water. All smoke assays were
30 performed according to tobacco industry standards. All cigarettes were smoked
35

using the Canadian intense protocol (*i.e.*, T-115, "Determination of "Tar," Nicotine and Carbon Monoxide in Mainstream Tobacco Smoke," Health Canada, 1999) and a Cerulean 450 smoking machine.

5

Table 1

Carbonyls µg/cigarette	Control	5 mm porous mass 20 mm Tow	%	10 mm porous mass 15 mm Tow	%	15 mm porous mass 13 mm Tow	%
formaldehyde	10.4	5.1	-51	0.0	-100	0.0	-100
acetaldehyde	295.3	211.2	-28	186.8	-37	188.5	-36
acetone	601.0	287.7	-52	104.7	-83	95.4	-84
propionaldehyde	100.2	42.4	-58	16.0	-84	14.9	-85
crotonaldehyde	101.7	29.4	-71	0.0	-100	0.0	-100
butyraldehyde	114.8	43.3	-62	0.0	-100	0.0	-100
methyl ethyl ketone	178.8	64.2	-64	20.8	-88	21.5	-88
acrolein	101.8	45.3	-56	13.6	-87	14.8	-85

Table 2

Other compounds	Control	5 mm porous mass 20 mm Tow	%	10 mm porous mass 15 mm Tow	%	15 mm porous mass 13 mm Tow	%
benzene (µg/cig)	79.0	54.0	-32	22.0	-72	20.0	-75
1,3 butadiene (µg/cig)	220.0	192.0	-13	162.0	-26	98.0	-55
benzo[a]Pyrene (ng/cig)	5.0	0.0	-100	0.0	-100	0.0	-100

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Table 3

Tar, nicotine, etc	Control	5 mm porous mass 20 mm Tow	Control	10 mm porous mass 15 mm Tow	Control	15 mm porous mass 13 mm Tow
tar (mg/cig)	39.0	37.1	35.8	34.4	33.7	34.9
nicotine (mg/cig)	2.8	2.8	2.5	2.6	2.6	2.7
water (mg/cig)	17.7	17.0	14.0	13.3	14.7	11.2
CO (mg/cig)	34.4	35.4	32.6	32.1	31.4	31.2

[00108] In the following example, the effectiveness of a porous mass in removing certain components of the cigarette smoke is illustrated. The porous mass was made from 30 weight % GUR X192 from Ticona, of Dallas, TX and 70 weight % PICA 30x70 (60% active carbon) from PICA USA, Inc. of Columbus, OH. The porous mass has a % void volume of 75% and an encapsulated pressure drop (EPD) of 3.3 mm of water/mm of porous mass length. The porous mass has a circumference of about 24.5 mm. The PICA 30x70 carbon had an average particle size of 405 microns (μ). The porous mass was made by mixing the resin (GUR X192) and carbon (PICA 30x70) and then filling a mold with the mixture without pressure on the heated mixture (free sintering). Then, the mold was heated to 220°C for 60 minutes. Thereafter, the porous mass was removed from the mold and allowed to cool. A defined-length section of the porous mass was combined with a sufficient amount of cellulose acetate tow to yield a filter with a total encapsulated pressure drop of 70 mm of water. All smoke assays were performed according to tobacco industry standards. All cigarettes were smoked using the Canadian intense protocol (*i.e.*, T-115, "Determination of Tar," Nicotine and Carbon Monoxide in Mainstream Tobacco Smoke," Health Canada, 1999) and a Cerulean 450 smoking machine.

Table 4

Carbonyls μg/cigarette	Control	5 mm porous mass 20 mm Tow	%	10 mm porous mass 15 mm Tow	%	15 mm porous mass 13 mm Tow	%
formaldehyde	7.9	5.3	-32	0.0	-100	0.0	-100
acetaldehyde	477.7	478.0	-0	413.5	-13	337.8	-29
acetone	557.4	433.4	-22	214.0	-62	121.2	-78
propionaldehyde	118.5	72.5	-39	31.6	-73	17.4	-85
crotonaldehyde	83.0	38.5	-54	14.5	-83	10.7	-87
butyraldehyde	86.8	39.7	-54	10.7	-88	5.9	-93
methyl ethyl ketone	195.7	100.8	-49	37.1	-81	19.2	-90
acrolein	84.0	55.5	-34	22.5	-73	13.3	-84

Table 5

Other compounds	Control	5 mm porous mass 20 mm Tow	%	10 mm porous mass 15 mm Tow	%	15 mm porous mass 13 mm Tow	%
benzene (µg/cig)	118.7	82.7	-30	40.1	-66	23.5	-80
1,3 butadiene (µg/cig)	257.3	259.1	1	204.4	-21	148.7	-42
benzo[a]Pyrene (ng/cig)	6.4	3.0	-53	0.0	-100	0.0	-100

Table 6

Tar, nicotine, etc	Control	5 mm porous mass 20 mm Tow	10 mm porous mass 15 mm Tow	15 mm porous mass 13 mm Tow
tar (mg/cig)	41.5	41.5	41.2	38.4
nicotine (mg/cig)	2.8	2.8	2.9	2.8
water (mg/cig)	16.7	17.0	17.7	12.6
CO (mg/cig)	30.8	33.2	35.5	31.6

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[00109] In the following example, the effectiveness of a porous ion exchange resin mass in removing certain components of the cigarette smoke is illustrated. The porous mass was made from 20 weight % GUR 2105 from Ticona LLC and 80 weight % of an amine based resin (AMBERLITE IRA96RF from Rohm & Haas of Philadelphia, PA). A 10 mm section of the porous mass was combined with a sufficient amount of cellulose acetate tow (12 mm) to yield a filter with a total encapsulated pressure drop of 70 mm of water. All smoke assays were performed according to tobacco industry standards. All cigarettes were smoked using the Canadian intense protocol (*i.e.*, T-115, "Determination of "Tar," Nicotine and Carbon Monoxide in Mainstream Tobacco Smoke," Health Canada, 1999) and a Cerulean 450 smoking machine.

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Table 7

Carbonyls µg/cigarette	Control	Ion Exchange Resin	% change
formaldehyde	8.0	ND	-100
acetaldehyde	491.0	192.0	-61
acetone	519.0	589.0	14
acrolein	65.0	28.0	-56
propionaldehyde	114.0	72.0	-37
crotonaldehyde	83.0	45.0	-45
methyl ethyl ketone	179.0	184.0	3
butyraldehyde	54.0	61.0	13

[00110] In the following example, the effectiveness of a porous desiccant

5 mass in removing water from the cigarette smoke is illustrated. The porous mass was made from 20 weight % GUR 2105 from Ticona, of Dallas, TX and 80 weight % of desiccant (calcium sulfate, DRIERITE from W. A. Hammond DRIERITE Co. Ltd. of Xenia, OH). A 10 mm section of the porous mass was
 10 combined with a sufficient amount of cellulose acetate tow (15 mm) to yield a filter with a total pressure drop of 70 mm of water. All smoke assays were performed according to tobacco industry standards. All cigarettes were smoked using the Canadian intense protocol (*i.e.*, T-115, "Determination of "Tar," Nicotine and Carbon Monoxide in Mainstream Tobacco Smoke," Health Canada, 1999) and a Cerulean 450 smoking machine.

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Table 8

mg/cigarette	Control	Desiccant Conditioned	% Change	Desiccant Unconditioned	% Change
Cambridge particular matter	62.0	55.6	-10.3	54.0	-12.8
water deliveries	15.0	12.8	-15.1	11.2	-25.6
nicotine deliveries	2.7	2.9	8.0	2.9	8.0
tar deliveries	44.2	39.9	-9.7	40.0	-9.7
carbon monoxide	35.0	35.9	2.5	35.0	0.1
tar/nicotine ratio	16.5	13.8	-16.4	13.8	-16.4

[00111] In the following example, a carbon-on-tow filter element is compared to the inventive porous mass. In this comparison, equal total carbon loadings are compared. In other words, the amount of carbon in each element is the same; the length of the element is allowed to change so that equal amounts of carbon were obtained. The reported change in smoke component is made in relation to conventional cellulose acetate filter (the % change is in relation to a conventional cellulose acetate filter). All filter tips consisted of the carbon element and cellulose acetate tow. All filter tips were tipped with a sufficient length of cellulose acetate filter tow to obtain a targeted filter pressure drop of 70 mm of water. The total filter length was 20 mm (carbon element and tow element). The carbon was 30x70, 60% active PICA carbon. All cigarettes were smoked using the Canadian intense protocol (*i.e.*, T-115, "Determination of Tar," Nicotine and Carbon Monoxide in Mainstream Tobacco Smoke," Health Canada, 1999).

Table 9

Carbonyls	Total Carbon Loading = 39 mg		Total Carbon loading = 56 mg	
	Carbon-on-tow(10 mm) % change	porous mass (2 mm) % change	Carbon-on-tow (10 mm) % change	porous mass (3 mm) % change
formaldehyde	-24.6	-13.7	-32.3	-27.6
acetaldehyde	-4.5	-3.4	-6.3	-12.5
acetone	-19.7	-33.1	-27.3	-49.2
propionaldehyde	-32.0	-42.2	-38.6	-55.7
crotonaldehyde	-64.5	-57.3	-71.0	-68.0
butyraldehyde	7.9	-34.4	-8.2	-54.4
methyl ethyl ketone	-35.4	-48.3	-45.6	-63.2
acrolein	-22.5	-40.3	-31.3	-52.6

[00112] In the following example, a porous mass made with a highly active carbon (95% CCl₄ absorption) is compared with a porous mass made with a lower active carbon (60% CCl₄ absorption). The combined filters were made using a 10 mm section of the porous mass plus a sufficient length of cellulose acetate to reach a targeted combined encapsulated pressure drop of 69-70 mm of water. These filters were attached to a commercial tobacco column and smoked on a Cerulean SM 450 smoking machine using the Canadian intense

smoking protocol, T-115, "Determination of "Tar," Nicotine and Carbon Monoxide in Mainstream Tobacco Smoke," Health Canada, 1999. The high active carbon was PICA RC 259, particle size 20x50, 95% activity (CCl₄ adsorption). The low active carbon was PICA PCA, particle size 30x70, 60% activity (CCl₄ adsorption).

- 5 The carbon loading of each porous mass element was 18.2 mg/mm, low active carbon, and 16.7 mg/mm, high active carbon. The data is reported in relation to a conventional cellulose acetate filter.

Table 10

Carbonyls	60% active carbon (% change)	95% active carbon (% change)
formaldehyde	-100.0	-100.0
acetaldehyde	-65.8	-37.0
acetone	-89.9	-83.0
propionaldehyde	-91.0	-84.0
crotonaldehyde	-100.0	-100.0
butyraldehyde	-100.0	-100.0
methyl ethyl ketone	-100.0	-88.0
acrolein	-90.7	-87.0

10

Table 11

Other compounds	60% active carbon (% change)	95% active carbon (% change)
benzene	2.6	-72.0
1,3 butadiene	-3.2	-26.0
benzo[a]pyrene	-100.0	-100.0

- 15 **[00113]** In the following example, the effect of particle size on encapsulated pressure drop (EPD) is illustrated. Porous masses with carbons of various particle sizes were molded into rods (length=39 mm and circumference=24.5 mm) by adding the mixture of carbon and resin (GUR 2105) into a mold and heating (free sintering) the mixture at 200°C for 40 minutes.
- 20 Thereafter, the porous mass was removed from the mold and allowed to cool to room temperature. The EPD's were determined for 10 porous masses and averaged.

Table 12

Carbon	Carbon:GUR Weight Ratio	Average Particle Size (μ)	Average EPD (mm of water/mm of porous mass length)
RC 259	75:25	569.0	2.2
PICA	80:20	402.5	3.5
NC506	75:25	177.5	25.0

[00114] In the following example, porous masses, as set forth in Tables 1-3, are used to demonstrate that filters made with such porous masses can be used to manufacture cigarettes that meet World Health Organization (WHO) standards for cigarettes. WHO standards may be found in WHO Technical Report Series No. 951, *The Scientific Basis of Tobacco Product Regulation*, World Health Organization (2008), Table 3.10, page 112. The results reported below, show that the porous mass can be used to reduce the listed components from tobacco smoke to a level below that recommended by the WHO.

Table 13

(μg)	Median¹	Upper limit (125% of median)	Highest delivery brand¹	% red.² 5 mm	% red.² 10 mm	Amt. deliv. 5 mm	Amt. deliv. 10 mm
1,3-butadiene	53.3	66.7	75.5	13	26	65.7	55.9
acetaldehyde	687.6	859.5	997.2	28	37	718.0	628.2
acrolein	66.5	83.2	99.5	56	87	43.8	12.9
benzene	38.0	47.5	51.1	32	72	34.7	14.3
benzo[a]pyrene	9.1	11.4	13.8	100	100	0.0	0.0
formaldehyde	37.7	47.1	90.5	51	100	44.4	0.0

¹ Information based on data in Counts, ME, et al., (2004) *Mainstream smoke toxicant yields and predicting relationships from a worldwide market sample of cigarette brands: ISO smoking conditions*, Regulatory Toxicology and Pharmacology, 39:111-134, and Counts ME, et al., (2005) *Smoke composition and predicting relationships for international commercial cigarettes smoked with three machine-smoking conditions*, Regulatory Toxicology and Pharmacology, 41:185-227.

² % reductions obtained from Tables 1-3 above.

[00115] In the following example, porous mass where ion exchange resins are used as the active particles, as set forth in Table 4, are used to demonstrate that filters made with such porous masses can be used to manufacture cigarettes that meet World Health Organization (WHO) standards

for cigarettes. WHO standards may be found in WHO Technical Report Series No. 951, *The Scientific Basis of Tobacco Product Regulation*, World Health Organization (2008), Table 3.10, page 112. The results reported below, show that the porous mass can be used to reduce the certain components from tobacco smoke to a level below that recommended by the WHO.

Table 14

(μg)	Median ¹	Upper limit (125% of median)	Highest delivery brand ¹	% reduction ² 10 mm	Amount delivered 10 mm
acetaldehyde	687.6	859.5	997.2	61	388.9
acrolein	66.5	83.2	99.5	56	43.8
formaldehyde	37.7	47.1	90.5	100	0.0

¹ Information based on data in Counts, ME, et al., (2004) *Mainstream smoke toxicant yields and predicting relationships from a worldwide market sample of cigarette brands: ISO smoking conditions*, Regulatory Toxicology and Pharmacology, 39:111-134, and Counts ME, et al., (2005) *Smoke composition and predicting relationships for international commercial cigarettes smoked with three machine-smoking conditions*, Regulatory Toxicology and Pharmacology, 41:185-227.

² % reductions obtained from Table 4 above.

[00116] In the following example, the encapsulated pressure drop was measured for a filter. The porous masses were formed by mixing the binder particles (ultra high molecular weight polyethylene) and active particles (carbon) at a desired weight ratio in a tumbled jar until well mixed. A mold formed of stainless steel tube having a length of 120 mm, an inside diameter of 7.747 mm, and a circumference of 24.34 mm. The circumference of each of the molds was lined with a standard, non-porous filter plug wrap. With a fitting on the bottom to close off the bottom of the mold, the mixture was then placed into the paper-lined molds to reach to the top of the mold. The mold is tamped (bounced) ten times off of a rubber stopper and then topped off to again reach the top of the paper within the mold and bounced three times. The top of the mold is then sealed and placed in an oven and heated, without the addition of pressure, to a temperature of 220°C for 25 to 45 minutes, depending on the mold design, the molecular weight of the binder particles, and the heat transfer. The encapsulated pressure drop was measured in mm of water. Those components of the mixtures and test results are listed below in Tables 15 - 20 below. The

polyethylene binder particles used are from Ticona Polymers LLC, a division of Celanese Corporation of Dallas, TX under the following tradenames, the molecular weights are in parentheses: GUR® 2126 (approximately 4×10^6 g/mol), GUR® 4050-3 (approximately $8-9 \times 10^6$ g/mol), GUR® 2105 (approximately 0.47×10^6 g/mol), GUR® X192 (approximately 0.60×10^6 g/mol), GUR® 4012 (approximately 1.5×10^6 g/mol), and GUR® 4022-6 (approximately 4×10^6 g/mol).

Table 15
Comparative Examples

<i>Carbon Loading for Comparative Examples (30x70 Pica Carbon)</i> Carbon:Binder Particle Weight Ratio	Comparative Example 1 (GUR® 2126) Average mg Carbon/mm	Comparative Example 2 (GUR® 4050-3) Average mg Carbon/mm	Comparative Example 3 (1:1 Blend: GUR® 2126: GUR® 4050-3) Average mg Carbon/mm
50/50	11.10	20.65	12.66
60/40	13.90	20.40	15.41
70/30	17.15	19.89	18.30
80/20	20.52	16.61	20.66
90/10	21.01	13.99	21.11

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Table 16
Comparative Examples

<i>Encapsulated Pressure Drop for Comparative Examples (30x70 Pica Carbon)</i> Carbon:Binder Particle Weight Ratio	Comparative Example 1 (GUR® 2126) Average mm of water/mm	Comparative Example 2 (GUR® 4050-3) Average mm of water/mm	Comparative Example 3 (1:1 Blend: GUR® 2126: GUR® 4050-3) Average mm of water/mm
50/50	20.0	11.9	20.1
60/40	20.0	19.8	20.0
70/30	20.0	20.0	20.0
80/20	19.9	19.8	20.3
90/10	16.0	20.0	15.2

Table 17
Porous masses described herein

<i>Carbon Loading</i> (30x70 Pica Carbon) Carbon:Binder Particle Weight Ratio	Binder Particle 1 (GUR® 2105) Average mg Carbon/mm	Binder Particle 2 (GUR® X192) Average mg Carbon/mm	Binder Particle 3 (GUR® 4012) Average mg Carbon/mm	Binder Particle 4 (GUR® 4022-6) Average mg Carbon/mm
50/50	NA*	NA	11.66	10.51
60/40	10.61	11.16	13.35	12.66
65/35	11.70	12.23	NA	NA
70/30	12.70	13.22	15.01	14.55
75/25	13.81	14.30	NA	NA
80/20	14.75	15.34	16.20	16.57

* Where NA is noted, rods were not made for these cells.

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Table 18
Porous masses described herein

<i>Encapsulated Pressure Drop</i> (30x70 Pica Carbon) Carbon:Binder Particle Weight Ratio	Binder Particle 1 (GUR® 2105) Average mm of water/mm	Binder Particle 2 (GUR®X192) Average mm of water/mm	Binder Particle 3 (GUR® 4012) Average mm of water/mm	Binder Particle 4 (GUR® 4022-6) Average mm of water/mm
50/50	NA*	NA	18.48	7.87
60/40	0.94	2.32	15.71	8.00
65/35	1.48	2.40	NA	NA
70/30	1.59	2.52	11.43	6.22
75/25	1.88	2.74	NA	NA
80/20	2.64	3.25	7.81	5.41

* Where NA is noted, rods were not made for these cells.

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Table 19
Porous Masses Described Herein

Pica Carbon Mesh	Carbon Weight %	Binder Particle Blend ¹ Weight %	Average Carbon mg/mm	Average EPD mm of water/mm of porous mass
80x325	50	50	9.14	2.0
80x325	60	40	12.24	6.4
80x325	70	30	14.05	11.4
80x325	80	20	17.02	19.3

¹ The binder blend was a 1:1 weight mixture of GUR® 2105 and GUR® X192.

Table 20
Additional Comparative Examples

Commercial cigarette filters (Cellulose acetate)	Length (mm)	Average of 20 filters EPD mm of water/mm	EPD/mm of porous mass length
Marlboro	21	70	3.3
Winston	27	79	2.9

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[00117] The data shown in Figures 6 through 9 were generated from additional EPD testing of porous masses described herein based on carbon loading and comparative samples. The porous masses were formed by mixing the binder particles, specifically ultra high molecular weight polyethylene chosen from GUR® 2105, GUR® X192, GUR® 4012, and GUR® 8020), and active particles (carbon) at a desired weight ratio in a tumbler jar until well mixed. A mold formed of stainless steel tube having a length of about 120 mm, an inside diameter of about 7.747 mm, and a circumference of about 24.5 mm (theoretical) or about 17.4 (theoretical). The circumference of each of the molds was lined with a standard, non-porous filter plug wrap. With a fitting on the bottom to close off the bottom of the mold, the mixture was then placed into the paper-lined molds to reach to the top of the mold. The mold is tapped (bounced) ten times off of a rubber stopper and then topped off to again reach the top of the paper within the mold and bounced three times. The top of the mold is then sealed and placed in an oven and heated, without the addition of pressure, to a temperature of 220°C for 25 to 45 minutes, depending on the mold design, the molecular weight, and the heat transfer. The length of the filter is then cut down to 100 mm. The circumference of the filters tested is reported. These were substantially circular in shape. The encapsulated pressure drop was measured in mm of water according to the CORESTA procedure.

[00118] Figure 6 is a comparative document that shows the results of encapsulated pressure drop testing for carbon-on-tow filters having an average circumference of about 24.5 mm.

[00119] Figure 7 shows the results of encapsulated pressure drop testing for porous mass filters of the present invention (comprising polyethylene and carbon) having an average circumference of about 24.5 mm.

[00120] Figure 8 is a comparative document that shows the results of encapsulated pressure drop testing for carbon-on-tow filters having an average circumference of about 16.9 mm.

5 [00121] Figure 9 shows the results of encapsulated pressure drop testing for porous mass filters of the present invention (comprising polyethylene and carbon) having an average circumference of about 16.9 mm.

[00122] In the following example, porous mass segments were combined with cellulose acetate filter segments to yield a segmented filter rod that could then be used to produce segmented filters and, optionally, cigarettes comprising segmented filters. The porous mass rods and cellulose acetate filter rods utilized
10 in this example had dimensions of about 23.75 mm (+/- 0.15 mm) circumference and about 120 mm length. Referring now to Figure 10, a diagram of the process of producing the segmented filters in this example, cellulose acetate filter rods 1010 1012 were cut into 8 sections (about 15 mm each) to
15 yield cellulose acetate segments 1014 and porous mass rods 1012 into 10 segments (about 12 mm each) to yield porous mass segments 1016. The segments 1014, 1016 were then aligned end-on-end in an alternating configuration, push together, and wrapped with paper that was glued at the same line so as to yield a segmented filter length 1018. The segmented filter
20 length 1018 was then cut in about the middle of every fourth cellulose acetate segment 1014 so as to yield segmented filter rod 1020 having portions of a cellulose acetate segment 1014 disposed on each end. One skilled in the art with the benefit of this disclosure will understand that other sizes and configurations of cellulose acetate segments and porous mass segments may be used to yield
25 the segmented filter lengths and can then be cut at any point to yield a desired segmented filter rod, *e.g.*, segmented filter rod 1020'.

[00123] In this example, the segmented filter rod 1020 described above and shown in Figure 11 was produced using a SOLARIS® instrument (a filter combining machine, available from International Tobacco Machine group) with
30 minor modifications to accommodate the weight and mechanical strength of the porous masses. Combining speeds of up to 400 m/min were achieved. It was observed that the cutting into segments, paper wrapping, and gluing steps proceeded without issue. Further it was observed that the amount of dust produced by the mechanical manipulation of the porous masses was less than is
35 typically produced with Dalmatian filter rods are used in place of porous mass

filter rods in the combiner. Further, upon visual inspection of the segmented filter rods produced the cellulose acetate segments were minimally, if at all, contaminated with dust produced from the mechanical manipulation of the porous masses.

5 **[00124]** Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein.

10 Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope and spirit of the present invention. The invention illustratively disclosed

15 herein suitably may be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps.

20 All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately

25 a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it

30 introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

CLAIMS

The invention claimed is:

1. A method comprising:
 - providing a porous mass rod that comprises a plurality of active particles and binder particles bound together at a plurality of contact points;
 - providing a filter rod that does not have the same composition as the porous mass rod;
 - cutting the porous mass rod and the filter rod into porous mass sections and filter sections, respectively;
 - forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least some of the porous mass sections and at least some of the filter sections;
 - securing the desired abutting configuration with a paper wrapper so as to yield a segmented filter rod length; and
 - cutting the segmented filter rod length into segmented filter rods;
 - wherein the steps of forming, securing, and cutting are performed so as to produce the segmented filter rods at a rate of about 25 m/min or greater.
2. A method comprising:
 - providing a porous mass rod that comprises a plurality of active particles and binder particles bound together at a plurality of contact points;
 - providing a filter rod that does not have the same composition as the porous mass rod;
 - cutting the porous mass rod and the filter rod into porous mass sections and filter sections, respectively;
 - forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least some of the porous mass sections and at least some of the filter sections;
 - securing the desired abutting configuration with an adhesive so as to yield a segmented filter rod length; and
 - cutting the segmented filter rod length into segmented filter rods;
 - wherein the steps of forming, securing, and cutting are performed so as to produce the segmented filter rods at a rate of about 25 m/min or greater.
3. A segmented filter rod produced by the process of:

providing a plurality of porous mass sections that comprise a plurality of active particles and binder particles bound together at a plurality of contact points;

providing a plurality of filter sections that does not have the same composition as the porous mass sections;

forming a desired abutting configuration that comprises a plurality of sections, the plurality of sections comprising at least one of the porous mass sections and at least one of the filter sections;

securing the desired abutting configuration with an adhesive so as to yield a segmented filter rod length;

cutting the segmented filter rod length into segmented filter rods;

cutting the segmented filter rods into segmented filter;

wherein the steps of forming, securing, and cutting the segmented filter rod length are performed so as to produce the segmented filter rods at a rate of about 25 m/min or greater.