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(54) **SMOKING ARTICLES COMPRISING MAGNETIC FILTER ELEMENTS**

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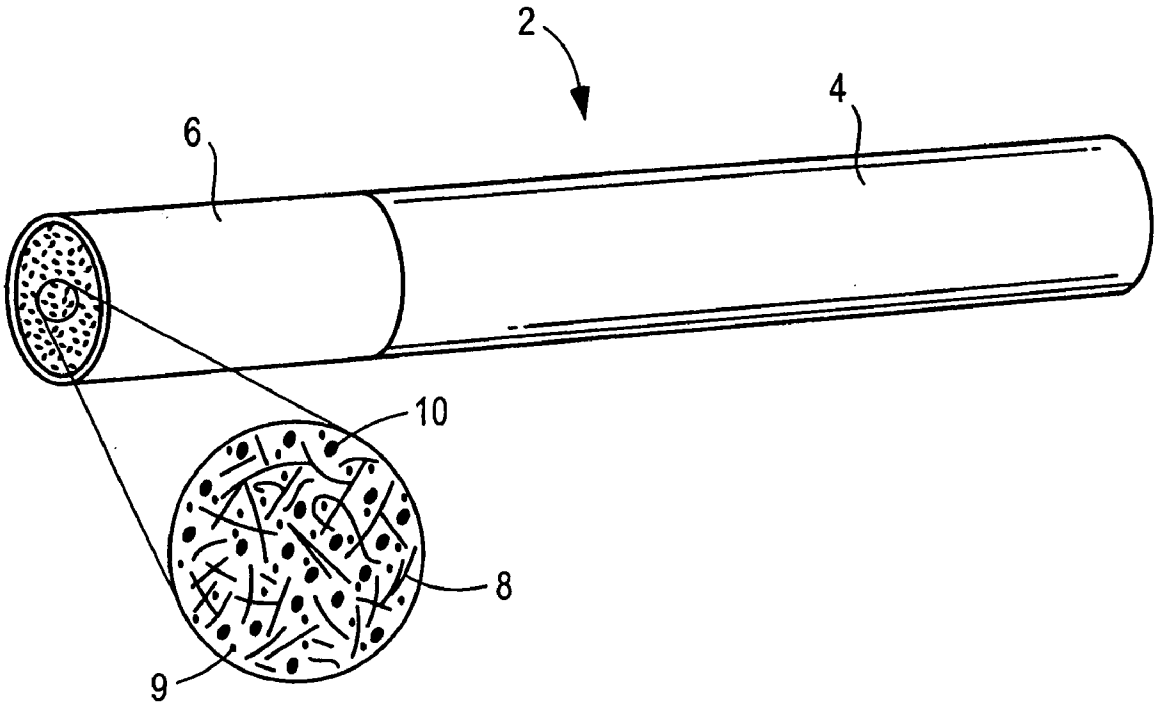
(57) **ABSTRACT**

Disclosed is a filter element adapted to be incorporated into a filter cigarette. The filter element comprises filter material, particles of a magnetized adsorbent, and at least one magnetic substrate. During smoking of a cigarette comprising the filter element, the at least one magnetic substrate can filter (i.e., magnetically attract and trap) the magnetized adsorbent particles or fragments thereof within the filter element.



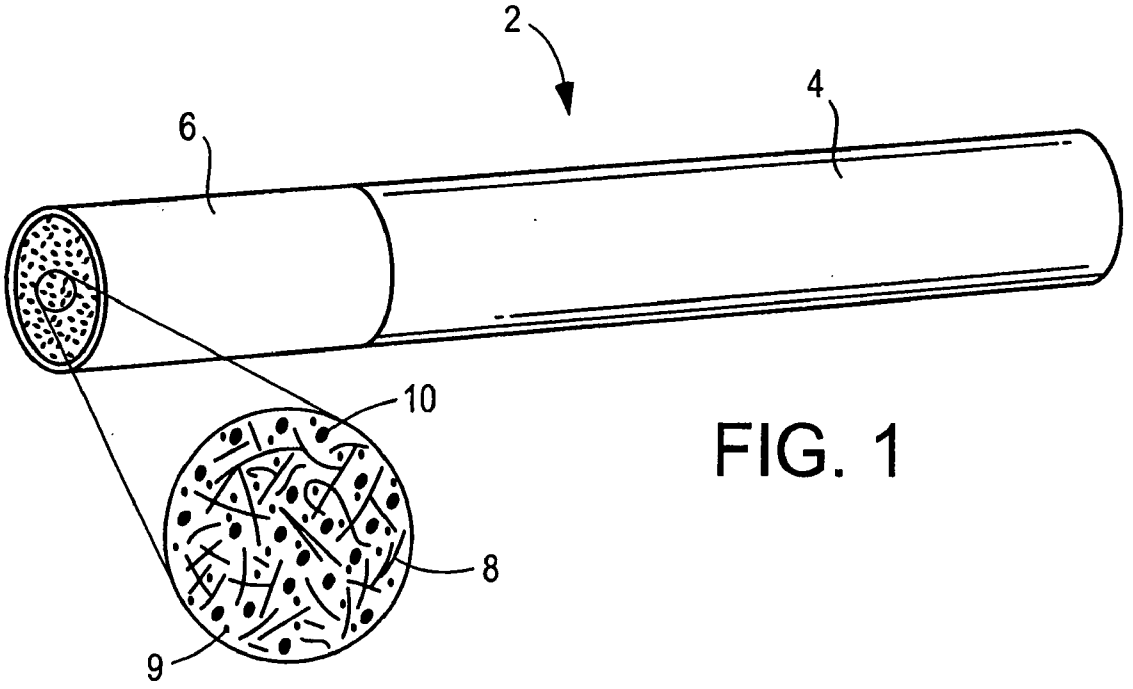


FIG. 1

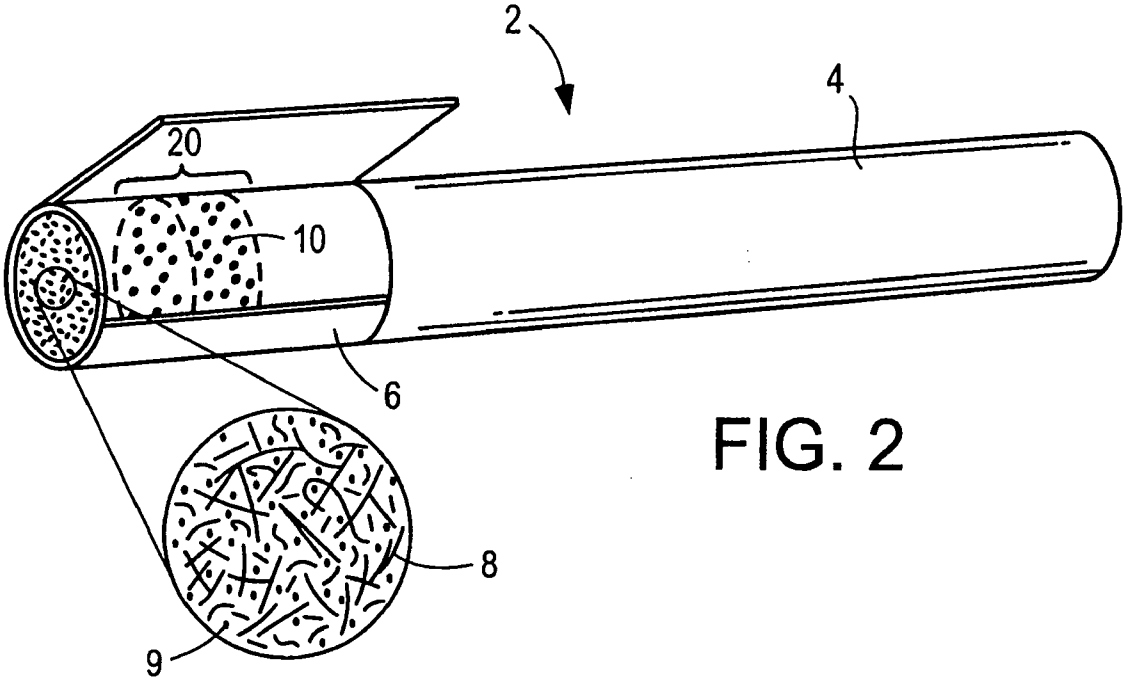


FIG. 2

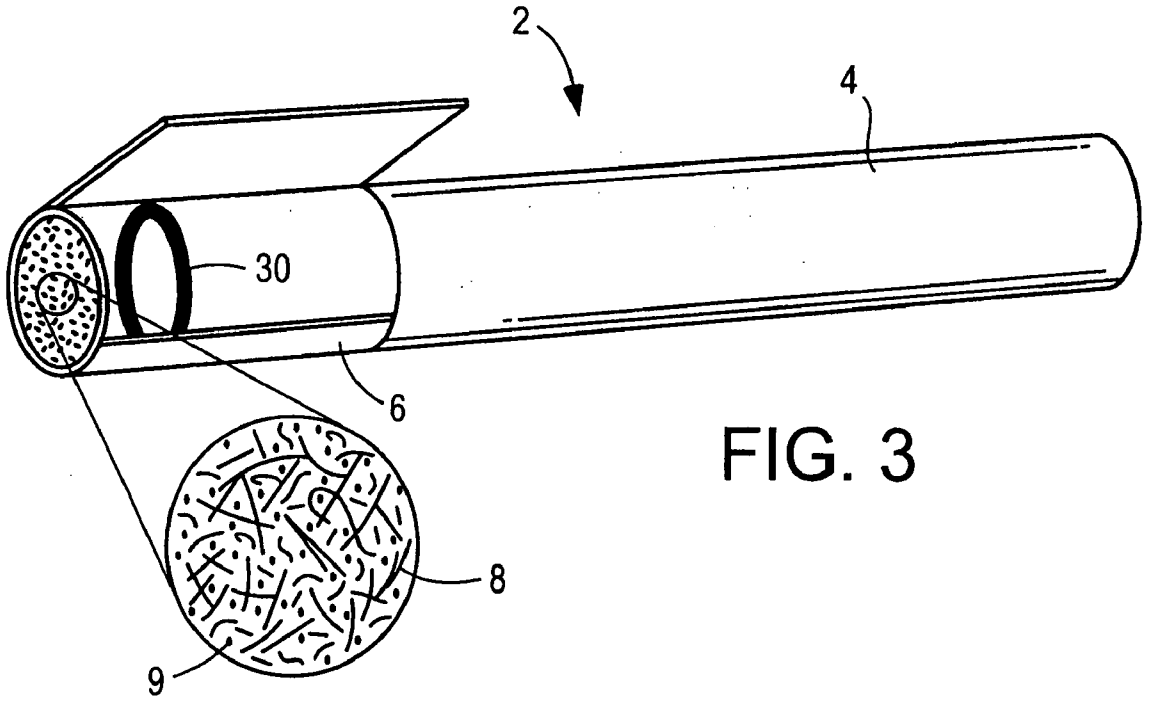


FIG. 3

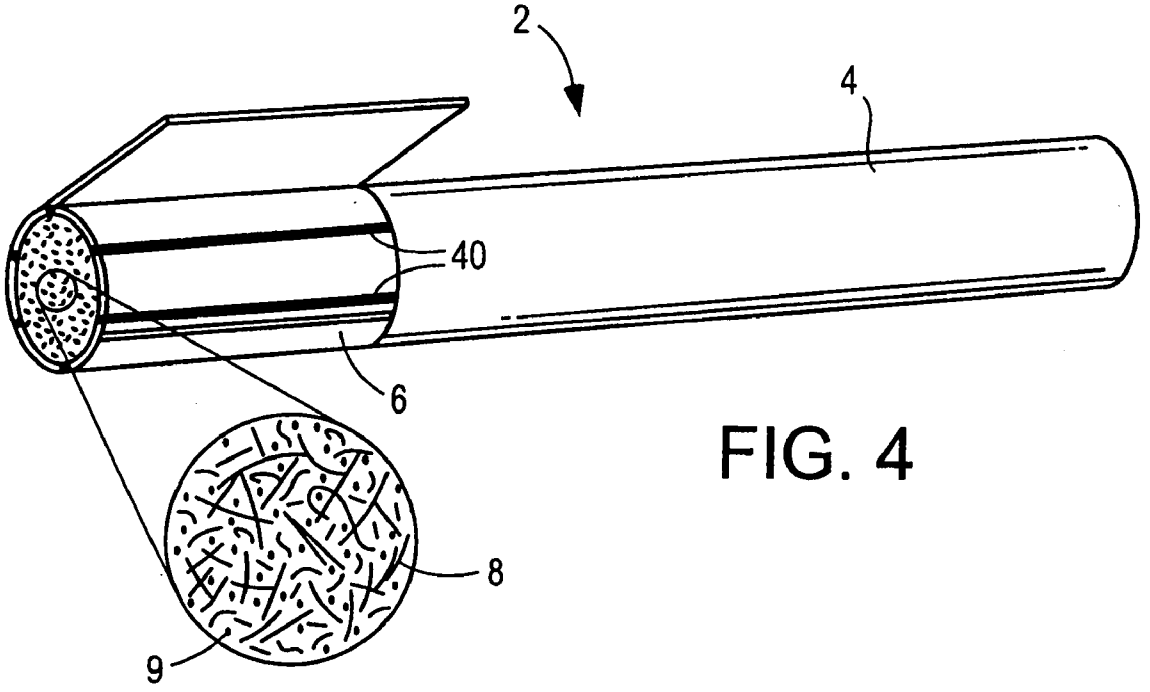


FIG. 4

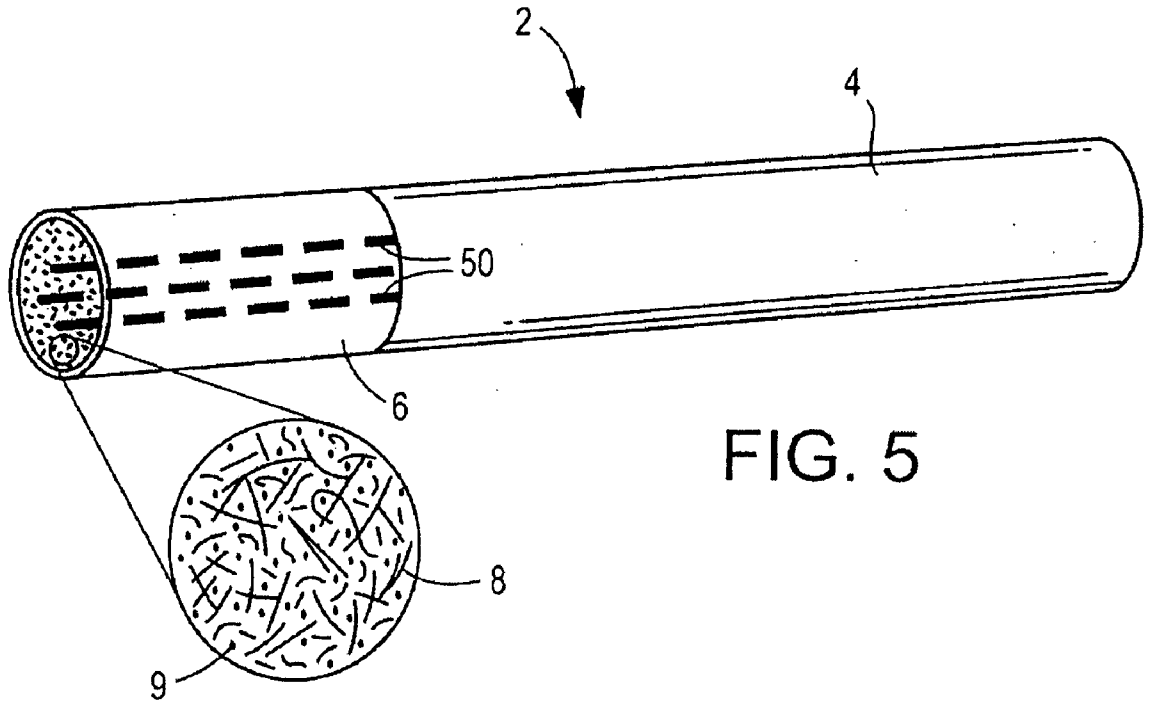


FIG. 5

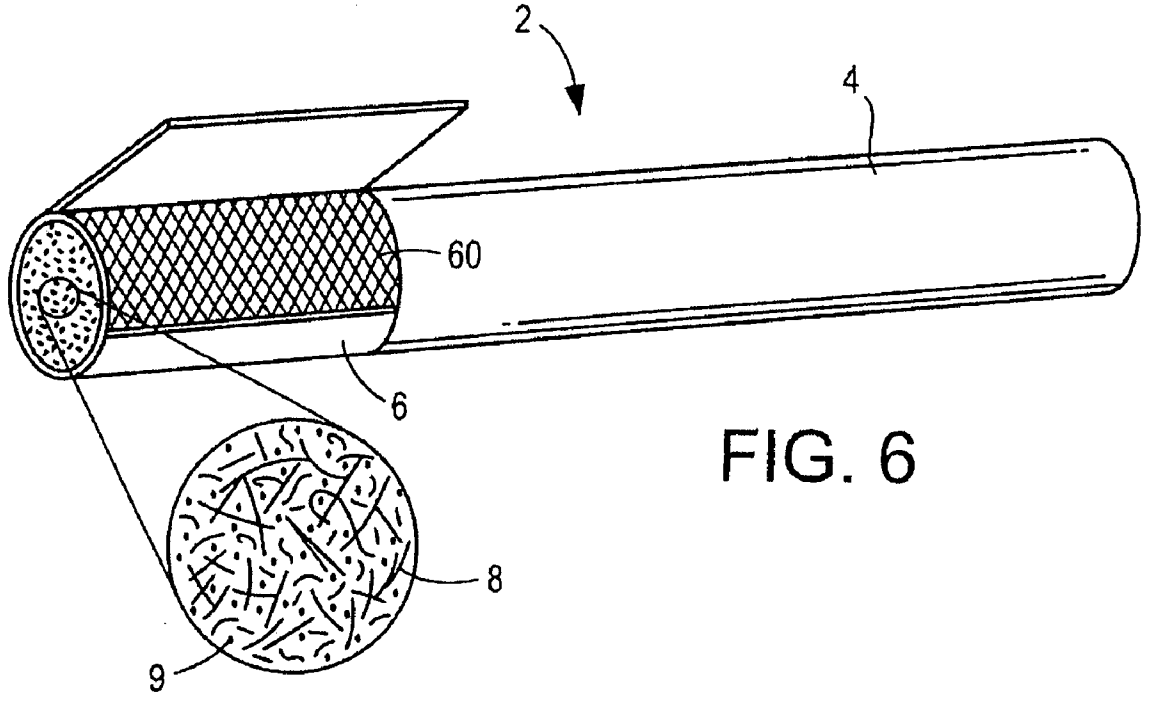


FIG. 6

SMOKING ARTICLES COMPRISING MAGNETIC FILTER ELEMENTS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority under 35 U.S.C. §119(e) to U.S. provisional Application No. 60/787,506, filed on Mar. 31, 2006, the entire content of which is incorporated herein by reference.

BACKGROUND

[0002] Cigarettes typically comprise filter elements that may have incorporated therein adsorbent materials such as carbon. Filter elements adapted to be incorporated in a filter cigarette may comprise, for example, particles or granules of carbon such as activated carbon or activated charcoal and/or other adsorbent materials incorporated within the cellulose acetate tow or in cavities between cellulose acetate material.

[0003] During smoking of a cigarette, to the extent that adsorbent particles or fragments of adsorbent particles could possibly be entrained in mainstream smoke and issue through (i.e., break through) the mouth end of the cigarette, techniques to reduce the amount of adsorbent particles in mainstream smoke would be of interest.

SUMMARY

[0004] Disclosed is a filter element adapted to be incorporated into a filter cigarette, as well as a cigarette comprising the filter element. The filter element comprises filter material, particles of a magnetized adsorbent material, and at least one magnetic substrate. In a preferred filter element, the particles of the magnetized adsorbent are incorporated throughout the filter material.

[0005] The at least one magnetic substrate preferably has a magnetic field strength effective to attract the magnetized adsorbent particles and/or fragments of the magnetized adsorbent particles that are entrained in the mainstream smoke of a cigarette. Via magnetic attraction, a magnetic substrate can trap the magnetized adsorbent particles or fragments thereof within the filter element. Thus, in a cigarette comprising the filter element, the at least one magnetic substrate can reduce the amount of magnetized adsorbent particles that issue from the mouth end of the cigarette during smoking.

[0006] The magnetized adsorbent material comprises particles of a magnetic material incorporated in particles of an adsorbent material. An exemplary magnetized adsorbent material comprises particles of iron and/or an oxide of iron incorporated in particles of activated carbon. The magnetized adsorbent can have an average particle size suitable for incorporation in the filter element of a cigarette (e.g., less than about 5 mm).

[0007] The at least one magnetic substrate, which preferably has at least one dimension of greater than about 1 mm or greater than about 2 mm, can be in the shape of beads, a disc, ring, cylinder, ribbon, foil, mesh or rod. The magnetic substrate can comprise a permanent magnet or an electromagnet. Preferred magnetic substrates consist essentially of a ferrite magnet, a neodymium iron boron magnet, a samarium cobalt magnet, or an aluminum nickel cobalt magnet, and can have a Curie temperature of at least about 300° C.

[0008] In an exemplary embodiment, the at least one magnetic substrate can be incorporated at least partially around the filter material. For example, the at least one magnetic substrate can be disposed on an inner surface of plug wrap that is used to wrap the filter material. In a further exemplary embodiment, the at least one magnetic substrate can be incorporated into one or more filter parts selected from the group consisting of a shaped paper insert, a plug, a space between plugs, cigarette filter paper, a cellulose acetate sleeve, a polypropylene sleeve and a free-flow sleeve. The magnetized adsorbent particles and/or the at least one magnetic substrate can be incorporated in the filter material prior to forming the filter material into the filter rod.

[0009] An exemplary cigarette comprises a tobacco rod wrapped in cigarette paper, which is attached to the filter element with tipping paper. The at least one magnetic substrate can be incorporated axially between the filter element and the tobacco rod. A cigarette comprising the filter element can further comprise magnetized adsorbent particles incorporated in the tobacco rod and/or cigarette paper used to form the cigarette.

[0010] In a preferred cigarette, the magnetized adsorbent particles and/or the at least one magnetic substrate can change the chemical composition of mainstream smoke that flows through the filter element during smoking of the cigarette. In an embodiment, the magnetized adsorbent particles can adsorb one or more gas-phase constituents in mainstream smoke. In a further embodiment, the magnetized adsorbent particles can catalyze the conversion of one or more gas phase constituents in mainstream smoke. As an example, in a cigarette comprising the filter element, the magnetic particles that are incorporated in the magnetized adsorbent particle can catalyze the conversion of carbon monoxide to carbon dioxide and/or nitric oxide to nitrogen during smoking of the cigarette.

[0011] A method of treating cigarette smoke comprises heating or lighting the cigarette to form smoke and drawing the smoke through the cigarette wherein the magnetized particles and/or fragments of the magnetized particles entrained in the smoke are magnetically attracted to the at least one magnetic substrate and trapped in the filter element.

[0012] A method of making a filter element comprising filter material, magnetized adsorbent particles and at least one magnetic substrate comprises (i) providing filter material and plug wrap material; (ii) forming the filter material into a filter rod; (iii) incorporating the magnetized adsorbent particles and the at least one magnetic substrate in and/or on at least one of the filter rod and the plug wrap material; and (iv) wrapping the filter rod in the plug wrap material to form the filter element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a perspective view of a cigarette comprising magnetized adsorbent particles and magnetic beads that are incorporated throughout the filter material of a filter element of the cigarette.

[0014] FIG. **2** is a perspective view of a cigarette comprising magnetized adsorbent particles and magnetic beads that are incorporated within a filter element as a gas permeable bed.

[0015] FIG. **3** is a perspective view of a cigarette comprising magnetized adsorbent particles and a magnetic ring that is formed around a filter rod of the cigarette.

[0016] FIG. **4** is a perspective view of a cigarette comprising magnetized adsorbent particles and magnetic rods that are incorporated along a surface of a filter rod of the cigarette.

[0017] FIG. **5** is a perspective view of a cigarette comprising magnetized adsorbent particles and magnetic rods that are incorporated axially within a filter rod of the cigarette.

[0018] FIG. **6** is a perspective view of a cigarette comprising magnetized adsorbent particles and a magnetic mesh that is incorporated along an outer surface of a filter rod of the cigarette.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0019] Disclosed is a filter element adapted to be incorporated into a filter cigarette. The filter element comprises cigarette filter material, particles of a magnetized adsorbent material, and at least one magnetic substrate. During smoking of a cigarette comprising the filter element, the magnetic substrate can attract the magnetized adsorbent particles and/or fragments of the magnetized adsorbent particles and trap the magnetized adsorbent particles within the filter element.

[0020] The term "magnetic substrate" as used herein refers to a monolithic magnetic material preferably having at least one dimension of at least 1 mm. For example, a magnetic substrate can comprise a length, width, thickness and/or diameter of at least 1 mm. Generally, the field strength of a permanent magnet made from a particular magnetic material is proportional to the magnet's size (e.g., volume). Preferred magnetic substrates are sized and shaped to be effective filters for magnetized adsorbent particles during smoking of a cigarette comprising the filter element. A magnetic substrate can have any size and shape suitable for incorporation in a filter element.

[0021] An exemplary magnetic substrate can comprise one or more magnetic beads. Preferred magnetic beads can have an average particle size of greater than 1 mm (e.g., at least 2, 3, 4 or 5 mm). The shape of the magnetic beads can be substantially spherical or non-spherical. A more preferred magnetic substrate can be in the shape of a disc, ring, cylinder, ribbon, foil, mesh or rod. In embodiments where the magnetic substrate is a rod or cylinder, preferably the length of the rod or cylinder is greater than 4 times its diameter.

[0022] The filter element can comprise a magnetic substrate made from any magnetic material capable of attracting and trapping magnetized adsorbent particles. In an exemplary embodiment, the magnetic material used to form the magnetic substrate is selected from the group consisting of ferrite magnets (e.g., magnetic compositions comprising iron oxide and strontium oxide or barium oxide), neodymium iron boron (NdFeB) magnets, samarium cobalt magnets (e.g., $SmCo_5$, Sm_2Co_{17}, etc.), aluminum nickel cobalt magnets (e.g., alloys of aluminum, nickel, cobalt and iron) and mixtures thereof.

[0023] The magnetic substrate can comprise an electromagnet or a permanent magnet. In embodiments where the magnetic substrate is an electromagnet, a power supply can be used to delivery an electric current to the electromagnet in order to magnetize the electromagnet. The magnetic strength of a permanent magnet can vary with temperature. Generally, the spontaneous magnetization of a magnetic material decreases with increasing temperature. The temperature above which spontaneous magnetization cannot occur in a magnetic substrate is known as the Curie temperature. Accordingly, the range of effective filtration temperatures of a magnetic substrate made from a permanent magnet is below its Curie temperature. The Curie temperature of neodymium iron boron magnets is typically in the range of about 300 to 350° C. Samarium cobalt magnets and aluminum nickel cobalt magnets typically have a Curie temperature in the range of about 750 to 800° C., and about 800 to 900° C., respectively. Preferably the magnetic substrate is made from a material having a Curie temperature sufficiently high to retain its magnetic properties during the smoking of a cigarette. In a preferred embodiment, a magnetic substrate has a Curie temperature of greater than about 300° C.

[0024] The magnetic substrate can be a sintered material which is a fully dense monolith or a partially dense monolith. Thus, the magnetic substrate can comprise a monolith having 100% or less of its theoretical density (e.g., a magnet that is at least about 50, 60, 70, 80 or 90% dense). An exemplary magnetic substrate can be in the shape of a fully dense ring or disc of magnetic material, or the magnetic substrate can be in the shape of a porous (e.g., gas permeable) ring or disc.

[0025] The filter element is adapted to be incorporated in a filter cigarette. Cigarette filters are made in a variety of designs. Typically, cigarette filters comprise four main components: a filter tow such as a bundle of cellulose acetate fibers or paper that comprise the bulk of the filter; a plasticizer (i.e., a softening agent added to bind the filter fibers together into a continuous filter rod); a plug wrap (i.e., a paper wrapper that is used to contain the filter material); and an adhesive used to secure the plug wrap to the continuous filter rod.

[0026] Filter rods for making cigarette filters, which can be attached to tobacco rods (e.g., attached with tipping paper) to produce filter cigarettes, can be made by forming a bundle or tow of filter material into a rod using a rod forming apparatus. Typically, a filter rod comprises up to thirty thousand filaments of filter material. A preferred filter material used to form a filter rod is cellulose acetate, which is a cellulose ester. Cigarette filter rods can also be made from other cellulose ester fibers (e.g., cellulose triacetate), regenerated cellulose (e.g., rayon), polyamide fibers (e.g., nylon), polyimide fibers, acrylic fibers, polyester fibers, polycarbonate fibers, polyethylene fibers, polyvinyl chloride fibers, filamentary polyolefin materials, polypropylene fibers, wood pulp fibers, cotton, flax, jute, wool, silk, ramie, protein fibers and paper. Cigarette filter rods can be formed from combinations of these materials.

[0027] Conventionally, a plasticizer or binder such as triacetin is added to the tow before it is passed into the rod forming apparatus. Furthermore, the tow can be spread and fluffed up, or "bloomed," usually by placing the tow under tension and passing it over air jets. The bloomed tow can be passed through a funnel or other constricting device and then through a shaped aperture to form the filter rod.

[0028] The plasticizer, which can be added to the tow during or after blooming, can enhance the bonding of the filaments to each other at their cross-over points when the tow is gathered. Thus, addition of a plasticizer can increase the firmness of the filter rod formed from the tow. The plasticizer may also have filtration properties. The attributes

of the finished filter rod (e.g., filtration efficiency, firmness, dimensional stability, etc.) can be improved by curing (e.g., heating) the plasticizer.

[0029] The filter rod can be provided with an outer layer (e.g., plug wrap) to maintain its shape. The outer layer can comprise a wrapping of cigarette paper or other sheet material. A cigarette wrapper can be any wrapping suitable for surrounding the filter material, including wrappers containing flax, hemp, kenaf, esparto grass, rice straw, cellulose and so forth. Optional filler materials, flavor additives, and burning additives can be included in the cigarette wrapper. The wrapper can have more than one layer in cross-section, such as in a bi-layer wrapper as disclosed in commonly-owned U.S. Pat. No. 5,143,098, the entire content of which is herein incorporated by reference.

[0030] Various filter constructions can be used to form the filter element. Exemplary filter structures include, but are not limited to, a mono filter, a dual filter, a triple filter, a cavity filter, a recessed filter, a free-flow filter or combinations thereof. Mono filters typically contain cellulose acetate tow or cellulose paper materials. Pure mono cellulose filters or paper filters can be effective filters for tar and/or nicotine, and are typically readily bio-degradable. Dual filters typically comprise a cellulose acetate mouth end and a pure cellulose or cellulose acetate segment. The length and pressure drop of the segments in a dual filter can be adjusted to provide the desired filtration (i.e., adsorption and/or absorption) and resistance to draw (RTD). Triple filters can include mouth and tobacco side segments, and a middle segment comprising paper. Cavity filters typically have two segments, e.g., acetate-acetate, acetate-paper or paper-paper, separated by a cavity. Recessed filters include an open cavity at the mouth end. The filter element can be ventilated and/or comprise flavorants, catalysts or other additives suitable for use in a filter element.

[0031] The magnetic substrate can be incorporated into the filter element in a number of ways. The magnetic substrate may be incorporated into the filter material before, during and/or after its manufacture into a filter rod. For example, the magnetic substrate can be incorporated in filter material used to form a filter rod and/or incorporated in a pre-formed filter rod. A magnetic substrate can be incorporated into a filter rod such that the magnetic substrate is substantially surrounded by the filter material, or, in an alternative embodiment, a magnetic substrate can be formed wholly or partially around the filter rod. In yet a further embodiment, a magnetic substrate can be incorporated into a space or cavity within the filter rod. The at least one magnetic substrate can be incorporated into one or more cigarette filter parts selected from the group consisting of a shaped paper insert, a plug, a space between plugs, cigarette filter paper, a cellulose acetate sleeve, a polypropylene sleeve, and a free-flow sleeve.

[0032] The filter element can be attached to a tobacco rod to form a filter cigarette. In production of a cigarette, a cut filler composition can be combined with other cigarette additives and provided to a cigarette-making machine to produce a tobacco column, which is then wrapped in cigarette paper to form a tobacco rod that is cut into sections, and optionally tipped with a filter. The resulting cigarettes can be manufactured to desired specifications using standard or modified cigarette making techniques and equipment. Cigarettes may range from about 50 mm to about 120 mm in length. The circumference is typically from about 15 mm to about 30 mm, preferably around 25 mm. The tobacco packing density is typically between the range of about 100 mg/cm^3 to about 300 mg/cm^3, and preferably 150 mg/cm^3 to about 275 mg/cm^3.

[0033] Tobacco cut filler is normally in the form of shreds or strands cut into widths ranging from about 1/10 inch to about 1/20 inch or even 1/40 inch. The lengths of the strands range from between about 0.25 inches to about 3 inches. The cigarettes may further comprise one or more flavorants or other additives (e.g., burn additives, combustion modifying agents, coloring agents, binders, etc.).

[0034] Any suitable tobacco mixture may be used for the cut filler. Examples of suitable types of tobacco materials include flue-cured, Burley, Bright, Md. or Oriental tobaccos, the rare or specialty tobaccos, and blends thereof. The tobacco material can be provided in the form of tobacco lamina, processed tobacco materials such as volume expanded or puffed tobacco, processed tobacco stems such as cut-rolled or cut-puffed stems, reconstituted tobacco materials, or blends thereof. The tobacco can also include tobacco substitutes.

[0035] The term "mainstream" smoke refers to the mixture of gases passing down the tobacco rod and issuing through the filter end, i.e., the amount of smoke issuing or drawn from the mouth end of a cigarette during smoking of the cigarette. The mainstream smoke contains smoke that is drawn in through both the lighted region, as well as through the cigarette paper wrapper. The term "side stream" smoke refers to smoke produced during static burning.

[0036] In a cigarette comprising the filter element, magnetized adsorbent particles can be filtered from mainstream smoke via magnetic attraction to the one or more magnetic substrates that are incorporated in the filter element. By filter is meant that the magnetic substrate can magnetically attract and trap the magnetized adsorbent particles and/or fragments of the magnetized adsorbent particles within the filter element. Preferably, a magnetic substrate can substantially reduce the amount of magnetized adsorbent particles (e.g., magnetized activated carbon particles) issuing from the mouth end of a cigarette during smoking. In a preferred cigarette, the filter element can reduce the amount (e.g., by weight) of magnetized adsorbent particles issuing from the mouth end of the filter during smoking of the cigarette by at least about 10 wt. % (e.g., at least 20, 30, 40, 50 wt. % or more).

[0037] In alternate embodiments, the at least one magnetic substrate can be evenly or unevenly distributed throughout the filter element. For example, magnetic beads can be more heavily loaded at the tobacco rod end, mouth end, or in the intermediate region between the tobacco rod end and the mouth end of a filter rod. In a preferred example, a magnetic ring can be incorporated at the mouth end of a filter rod.

[0038] One or more magnetic substrates can be incorporated in a hollow portion of a cigarette filter element. For example, some cigarette filters have a plug/space/plug configuration wherein the plugs comprise a fibrous filter material and the space is simply a void between two filter plugs. That void can be filled partially or wholly with one or more magnetic substrates. A packed bed of magnetic substrates can be incorporated into such a void. For example, a bed of magnetic beads can be located in a space between plugs of a standard cellulose acetate filter rod.

[0039] A magnetic substrate or plurality of substrates can be incorporated in a filter element after the filter rod has been

formed. As an example, a magnetic substrate can be formed around a pre-formed filter rod. A magnetic ring, for example, can be formed (e.g., crimped) around a pre-formed filter rod such that the ring has an outer diameter that is approximately equal to the diameter of the filter rod. The radial thickness and/or the axial width of a magnetic ring can range from about 0.05 mm to 1 mm or more. For example, a magnetic ring can have a thickness and/or a width of at least about 0.1, 0.2, 0.5, 1 or 2 mm. By way of a further example, a magnetic substrate can be formed on an exterior surface of a pre-formed filter rod before the rod is wrapped in cigarette paper (e.g., plug wrap) to form the filter element. Magnetic rods or strips, for example, can be arranged axially along an exterior surface of a filter rod, between the filter rod and the plug wrap formed around the filter rod.

[0040] In yet a further example, a magnetic substrate in the shape of a sheet (e.g., magnetic foil) or mesh (e.g., perforated magnetic foil) can be formed around a filter rod that is in turn wrapped in cigarette paper (e.g., plug wrap) to form the filter element. The sheet or mesh can be first combined with the plug wrap to form a laminate that is wrapped around the filter rod to form the filter element. An adhesive can be used to secure the magnetic substrate to the filter rod and/or the plug wrap. Preferably, a magnetic foil-laminated plug wrap is adapted to be formed around a filter rod such that the magnetic foil is positioned on the inner surface of the plug wrap (e.g., in contact with the filter material).

[0041] The magnetic substrate(s), whether blended directly with the filter material, incorporated as a packed bed, or incorporated after formation of a filter rod, may be used alone in the filter element or may be incorporated with other known materials having gas phase activity such as catalysts, flavorants and the like.

[0042] The size, distribution and position of the at least one magnetic substrate incorporated in the filter element either by way of incorporation into and/or around the filter material can be determined through routine experimentation as a function of, inter alia, the amount of magnetized adsorbent particles incorporated within the cigarette, the amount of gas phase constituents to be removed from the mainstream smoke, and/or the magnetic strength of the magnetic substrate(s).

[0043] In addition to a magnetic substrate, the filter element comprises particles of a magnetized adsorbent. Particles of magnetized adsorbent comprise magnetic particles incorporated in particles of an adsorbent. By incorporating magnetic particles into the adsorbent particles, the adsorbent particles can be attracted and trapped within the filter element by a magnetic substrate. Typically, prior to incorporating magnetic particles in the adsorbent particles, the adsorbent particles are non-magnetic.

[0044] The adsorbent particles can comprise any suitable adsorbent media. Exemplary adsorbents include molecular sieves such as zeolites, silicas, silicates, aluminas and carbons (e.g., activated carbon). A preferred adsorbent media is activated carbon. By "activated carbon" is meant any porous, high surface area form of carbon. Activated carbon can be derived via thermal treatment of any suitable carbon source. The activation treatment typically increases the porosity, and activated carbon can be provided with a wide range of pore sizes or the pore sizes can be controlled to provide a desired pore size distribution.

[0045] A particularly preferred activated carbon is commercially available (e.g., from PICA USA, Inc., Truth or Consequences, N. Mex.). The activated carbon could also be manufactured via the carbonization of coconut husk, coal, wood, pitch, peat, cellulose fibers, lignite and olive pits. Carbonization is usually carried out at elevated temperatures, e.g., 400-1000° C. in an inert atmosphere, followed by activation (i.e., calcining) under reducing or oxidizing conditions. The activated carbon can be in the form of beads, granules and/or fibers.

[0046] The adsorbent particles can comprise granulated particles ranging in size from about 100 microns to about 5 mm. For example, particles of activated carbon can have an average size of from about 0.2 to 2 mm (e.g., about 200, 500, 1000 or 2000 microns).

[0047] Particles of adsorbent material can have any desired pore size distribution that comprises pores such as micropores, mesopores and macropores. The term "microporous" generally refers to such materials having pore sizes of about 20 Angstroms or less while the term "mesoporous" generally refers to such materials with pore sizes of about 20-500 Angstroms. Magnetic particles can be incorporated into the pores of the adsorbent particles via impregnation, mechanical mixing, in situ thermal decomposition of organic precursor materials or other technique.

[0048] The adsorbent particles can be selected to have an appropriate surface area to preferentially adsorb selected constituents from cigarette smoke. For example, activated carbon typically has a surface area greater than about 50 m^2/g (e.g., at least about 100, 200, 500, 1000 or 2000 m^2/g). Typically, the absorptive capacity of the adsorbent particles increases with increasing surface area. Furthermore, surface area typically increases with decreasing particle size. When used as cigarette filter media, however, adsorbent particles having a small particle size may pack together too densely to permit mainstream smoke to flow through the filter with desired resistance to draw (RTD) during smoking. On the other hand, if the particle size is too large there may be insufficient surface area to accomplish the desired degree of filtration. Therefore, such factors can be taken into account in selecting adsorbent particles suitable for filtration of mainstream and/or sidestream smoke.

[0049] The magnetized adsorbent particles preferably comprise particles of a magnetic material incorporated in particles of an adsorbent material. The magnetized adsorbent particles can be formed by combining adsorbent particles with magnetic particles or by combining adsorbent particles with a precursor (e.g., a precursor solution) that can be treated to form magnetic particles within the pores of the adsorbent particles.

[0050] According to one method, adsorbent particles such as activated carbon particles may be combined with solid magnetic particles optionally using a binder to improve the adhesion between the adsorbent particles and the magnetic particles.

[0051] According to a further method, adsorbent particles can be immersed in an aqueous or non-aqueous solution comprising a precursor compound that can be treated with a chemical reagent and/or with heat to form the magnetic particles. A preferred precursor compound is an iron salt, which can be treated with a reducing agent or with heat to form particles of elemental iron and/or oxides of iron that are magnetic. The precursor can be incorporated into the adsorbent particles in a single step or in multiple steps. The adsorbent particles can be provided with a loading of about 1 to 150% by weight of the magnetic particles.

[0052] The magnetic particles, whether combined with the adsorbent particles or formed in situ within the adsorbent particles via the decomposition of a precursor compound, can comprise nanoscale particles. By "nanoscale" is meant that the magnetic particles have an average particles size of less than 1 micron. Nanoscale magnetic particles can have an average particle size of 10, 20, 30, 40, 50, 60, 70, 80 or 90 nm±5 nm up to about 100, 200, 300, 400, 500, 600, 700, 800, 900 nm±50 nm.

[0053] As an example, magnetized adsorbent particles can be formed by impregnating PICA carbon with an aqueous solution of iron nitrate at room temperature to form a mixture. Optionally, the pressure over the mixture can be reduced (e.g., to about 2 mm Hg) to improve infiltration of the iron nitrate solution in to the pores of the carbon. The infiltrated carbon particles can be washed to remove excess iron nitrate from the particles, and then dried prior to heating to decompose the iron nitrate. Initially, magnetic particles of iron oxide (Fe_2O_3) can be formed by heating the iron nitrate-infiltrated carbon particles in air at a temperature of about 350° C. Further heating in a reducing atmosphere (e.g., a gas mixture comprising carbon monoxide and helium) at a temperature of between about 400-700° C. can reduce Fe_2O_3 to form magnetic particles comprising Fe_3O_4 and/or Fe.

[0054] Magnetized adsorbent particles can be incorporated into the filter element in a number of ways. Magnetized adsorbent particles may be provided in the form of a dry powder, paste or dispersion in a liquid. Magnetized adsorbent particles can be dusted on, sprayed on, or combined with the filter material. For example, the magnetized adsorbent particles can be mixed with a liquid (e.g., deionized water) to form a slurry. The slurry can then be dispersed on the filter material used to form a filter rod. In a further example, filter material (e.g., cellulose acetate material or paper filler) may be rinsed or dip-coated with a slurry containing the magnetized adsorbent particles.

[0055] The magnetized adsorbent particles may be added to cigarette filter material supplied to a filter-making machine or incorporated directly on a filter rod prior to wrapping a cigarette wrapper around the rod to form a filter element. Preferably the magnetized adsorbent particles are provided continuously along the length of a filter element, though the magnetized adsorbent particles can be provided at discrete locations along the length of a filter rod. Thus, the magnetized adsorbent particles may be homogeneously or non-homogeneously distributed along the length of a filter rod. For example, a filter element can comprise a first loading of magnetized adsorbent particles at one location along the filter rod and a second loading of magnetized adsorbent particles at a second location along the filter rod. A preferred filter rod comprising magnetized adsorbent particles has a first loading of magnetized adsorbent particles at the mouth end of the filter rod and a second loading of magnetized adsorbent particles at the tobacco side of the filter rod, wherein the first loading is less than the second loading.

[0056] Magnetized adsorbent particles can be incorporated in paper or other substrate material that is fitted into a passageway in a filter element. The magnetized adsorbent particles may also be incorporated in a liner or a plug in the interior of a filter element. Alternatively, or in addition, the magnetized adsorbent particles can be incorporated into the fibrous wall portions of a filter element.

[0057] By way of example, the magnetized adsorbent particles can be incorporated into or onto a support such as paper (e.g., liner, plug wrap or tipping paper) that is located along a filter portion of a cigarette. The magnetized adsorbent particles can also be loaded onto a support such as lightly or tightly folded paper inserted into a hollow portion of the cigarette filter. The support is preferably in the form of a sheet material such as crepe paper, filter paper, or tipping paper. However, other suitable support materials such as organic or inorganic cigarette compatible materials can also be used.

[0058] The magnetized adsorbent particles may be incorporated in cigarette paper (e.g., paper wrapper and/or paper filler) before or after the cigarette paper is incorporated into a cigarette. The magnetized adsorbent particles can be incorporated into the cellulosic web of the paper by depositing the magnetized adsorbent particles directly on the cellulosic web or on web-filler material that is incorporated in the paper. Magnetized adsorbent particles can be incorporated into cigarette paper and/or into the raw materials used to make cigarette paper (e.g., incorporated into the paper stock of a cigarette paper making machine).

[0059] The magnetized adsorbent particles can be incorporated in cigarette paper and/or filter material by spraying or otherwise coating the particles onto the base material. For example, magnetized adsorbent particles can be incorporated in cigarette paper by spray coating the magnetized adsorbent particles onto a wet base (e.g., cellulosic) web, an intermediate web or a finished web. In another method, slurry (e.g., aqueous slurry) of the magnetized adsorbent particles can be incorporated into the head box of a paper-making machine and the magnetized adsorbent particles can be incorporated into cigarette paper during the paper-making process. Magnetized adsorbent particles in the form of a dry powder can be physically admixed with cigarette paper and/or filter material during the manufacturing process.

[0060] Any conventional or modified cigarette filter may incorporate the magnetized adsorbent particles. The magnetized adsorbent particles can be incorporated in a hollow portion of a cigarette filter. For example, some cigarette filters have a plug/space/plug configuration in which the plugs comprise a fibrous filter material (e.g., polypropylene or cellulose acetate fibers) and the space is simply a void between the two filter plugs. That void can be filled partially or wholly with the magnetized adsorbent particles. The magnetized adsorbent particles can be used in granular form or loaded onto a suitable support such as a fiber or thread.

[0061] The quantity, location and distribution in a cigarette of the magnetized adsorbent particles can be selected as a function of the airflow characteristics exhibited during smoking in order to adjust, e.g., increase or maximize, adsorption of at least one gas phase constituent in the mainstream smoke of the cigarette during smoking. A typical filter element will include from about 10 mg to about 200 mg of the magnetized adsorbent particles, although the amount needed can also be determined by routine experimentation and/or adjusted accordingly. The magnetized adsorbent particles can selectively adsorb/filter specific constituents from the mainstream smoke of a cigarette. Furthermore, as disclosed below, the distribution of magnetized adsorbent particles can be selected such that the amount of carbon monoxide and/or the amount of nitric oxide in mainstream smoke is reduced during smoking of a cigarette.

[0062] In addition to incorporating the magnetized adsorbent particles in the filter element or in cigarette paper, the magnetized adsorbent particles may be incorporated in the cut filler used to form a cigarette.

[0063] In all such filter element configurations, the resistance to draw (RTD) of the filter element comprising magnetized adsorbent particles and at least one magnetic substrate is preferably less than about 5 inches of water when measured at an air flow velocity of about 1050 cc/min.

[0064] The following examples are illustrative. In an embodiment, magnetized adsorbent particles and magnetic beads can be incorporated into the filter material of the filter element itself. This embodiment is illustrated in FIG. **1**, which shows a cigarette **2** comprised of a tobacco rod **4** and a filter element **6**. The filter element **6** can comprise a tube or plug of material such as cellulose acetate fibers **8** having magnetized adsorbent particles **9** and magnetic beads **10** dispersed therein. The magnetized adsorbent particles and/or the magnetic beads can be supported by the cellulose acetate fibers. The tobacco rod **4** and the filter element **6** can be joined together with tipping paper (not shown).

[0065] In a further embodiment, magnetic beads can be incorporated into the filter element as a gas permeable bed. A magnetic substrate may be incorporated into more than one component of a filter element such as by being incorporated into a void space as a bed of packed particles. FIG. **2** shows a cigarette **2** comprised of a tobacco rod **4** and filter element **6**. This arrangement is similar to that of FIG. **1** except the magnetic beads **10** are incorporated in a space **20** of the filter element. Preferably, space **20** is free of cellulose acetate and is located at or near the distal end of the cigarette. As in Example **1**, the tobacco rod **4** and filter element **6** can be joined together with tipping paper (not shown).

[0066] A magnetic substrate can be formed around (e.g., crimped around) an exterior surface of the filter rod prior to wrapping the filter rod in the plug wrap. Referring to FIG. **3**, cigarette **2** comprises tobacco rod **4** and filter element **6**. The filter element further comprises magnetized adsorbent particles **9**, and at least one magnetic ring **30** that is disposed radially around the filter rod. The thickness of the magnetic ring is preferably about 1 mm, and can be any suitable axial length that is less than the length of the filter rod. The tobacco rod **4** and the filter element **6** can be joined together with tipping paper (not shown). Further, the filter element **6** may include a filter overwrap (not shown). Preferably the magnetic ring is external to the filter rod and the filter overwrap is wrapped around both the filter rod and the magnetic ring. The magnetic ring **30** is preferably located at or near the distal end of the cigarette.

[0067] Other exemplary embodiments of a cigarette are shown in FIGS. **4-5**, wherein cigarette **2** comprises tobacco rod **4** and filter element **6**. In FIG. **4** the filter element further comprises magnetized adsorbent particles **9**, and magnetic rods **40** that are arranged axially along the length of the filter element. In FIG. **5** the filter element further comprises magnetized adsorbent particles **9**, and magnetic rods **50** that are arranged axially along the length of the filter element. In FIG. **4**, the magnetic rods are external to the filter rod **44** and a filter overwrap **46** is wrapped around both the filter rod and the magnetic rods.

[0068] A magnetic substrate, such as one or more magnetic rods, can be incorporated into the filter material such that the filter material substantially surrounds the magnetic substrate. In FIG. **5**, the magnetic rods **50** are disposed axially within the filter rod such that the filter material substantially surrounds the magnetic rods.

[0069] A further exemplary embodiment of a cigarette comprising a magnetic mesh is shown in FIG. **6**. Cigarette **2** comprises tobacco rod **4**, magnetized adsorbent particles **9** incorporated within the filter rod, and a magnetic mesh **60** external to the filter rod. A filter overwrap is preferably wrapped around both the filter rod and the magnetic mesh.

[0070] The magnetized adsorbent particles and/or the magnetic substrate can affect the organoleptic properties (e.g., aroma and/or taste) of mainstream smoke. Both the magnetized adsorbent particles and the magnetic substrate can change the chemical composition of mainstream gas that flows through a filter element. For example, the magnetized adsorbent particles can adsorb one or more gas phase constituents. Thus, the magnetized adsorbent particles can reduce the content in mainstream smoke of one or more gaseous constituents such as 1,3-butadiene, acrolein, isoprene, propionaldehyde, acrylonitrile, benzene, toluene, styrene, acetaldehyde and hydrogen cyanide. Preferably, however, the magnetized adsorbent particles do not substantially reduce the concentration in mainstream smoke of flavor components of the smoke.

[0071] As disclosed above, the magnetized adsorbent particles comprise magnetic particles incorporated within the adsorbent particles. The magnetic particles, which can be elemental metals (e.g., iron) or compound oxides (e.g., iron oxides), can affect the concentration of one or more gas phase constituents of mainstream smoke. For example, the magnetic particles, which can comprise nanoscale particles, can catalyze the conversion of one or more gas phase constituents during the smoking of a cigarette. As used herein, a catalyst can affect the rate of a chemical reaction without participating as a reactant or product of the reaction.

[0072] The magnetic particles, which are preferably capable of acting as both an oxidant and as a catalyst (e.g., low temperature or near-ambient temperature catalyst) for the conversion of carbon monoxide to carbon dioxide and/or nitric oxide to nitrogen, and can reduce the amount of carbon monoxide and/or nitric oxide in the mainstream smoke of a cigarette during smoking.

[0073] The amount of magnetized adsorbent particles can be selected such that the amount of carbon monoxide and/or nitric oxide in mainstream smoke is reduced during smoking of a cigarette. Preferably, the amount of magnetized adsorbent particles will be a catalytically effective amount; e.g., an amount sufficient to catalyze and/or oxidize at least 10%, more preferably at least 25%, of the carbon monoxide in mainstream smoke to carbon dioxide. A catalytically effective amount of magnetized adsorbent particles can catalyze and/or reduce at least 10%, more preferably at least 25%, of the nitric oxide in mainstream smoke to nitrogen.

[0074] A filter element can comprise a mixture of different magnetized adsorbent particles. The composition of the magnetized adsorbent particles (i.e., the stoichiometry and/or size of the catalyst particles and/or the stoichiometry and/or size of the adsorbent particles) can be selected to adsorb, catalyze and/or reduce gas phase constituents of mainstream smoke in a given temperature range.

[0075] Yet another embodiment provides a method of treating mainstream smoke of a cigarette comprising a filter element. "Smoking" of a cigarette means the heating or combustion of the cigarette to form smoke, which can be

drawn through the cigarette. Generally, smoking of a cigarette involves lighting one end of the cigarette and, while the tobacco contained therein undergoes a combustion reaction, drawing smoke from the combustion through the mouth end of the filter element. The cigarette may also be smoked by other means. For example, the cigarette may be smoked by heating the cigarette and/or heating using electrical heater means as described in commonly-assigned U.S. Pat. Nos. 6,053,176; 5,934,289; 5,591,368 or 5,322,075.

[0076] A method of making a filter element comprising filter material, magnetized adsorbent particles and at least one magnetic substrate comprises (i) providing filter material and plug wrap material; (ii) forming the filter material into a filter rod; (iii) incorporating the magnetized adsorbent particles and the at least one magnetic substrate in and/or on at least one of the filter rod and the plug wrap material; and (iv) wrapping the filter rod in the plug wrap material to form the filter element.

[0077] While preferred embodiments have been described, it is to be understood that variations and modifications may be resorted to as will be apparent to those skilled in the art. Such variations and modifications are to be considered within the purview and scope of the claims appended hereto.

[0078] All of the above-mentioned references are herein incorporated by reference in their entirety to the same extent as if each individual reference was specifically and individually indicated to be incorporated herein by reference in its entirety.

What is claimed is:

1. A filter element adapted to be incorporated into a filter cigarette, the filter element comprising filter material, particles of a magnetized adsorbent, and at least one magnetic substrate.

2. The filter element of claim **1**, wherein the magnetized adsorbent comprises particles of a magnetic material incorporated in particles of an adsorbent material.

3. The filter element of claim **1**, wherein the magnetized adsorbent comprises particles of iron and/or an oxide of iron incorporated in particles of activated carbon.

4. The filter element of claim **1**, wherein the magnetized adsorbent has an average particle size of less than about 5 mm and the at least one magnetic substrate has at least one dimension of greater than about 1 mm or greater than about 2 mm.

5. The filter element of claim **1**, wherein the particles of the magnetized adsorbent are incorporated throughout the filter material.

6. The filter element of claim **1**, wherein the at least one magnetic substrate is selected from the group consisting of a disc, ring, cylinder, ribbon, foil, mesh or rod.

7. The filter element of claim **1**, wherein the at least one magnetic substrate consists essentially of a ferrite magnet, a neodymium iron boron magnet, a samarium cobalt magnet, an aluminum nickel cobalt magnet or an electromagnet.

8. The filter element of claim **1**, wherein the at least one magnetic substrate has a Curie temperature of at least about 300° C. and/or a magnetic field strength effective to attract and trap magnetized adsorbent particles and/or fragments of magnetized adsorbent particles within the filter element.

9. The filter element of claim **1**, wherein the filter material is wrapped in plug wrap and the at least one magnetic substrate is disposed on an inner surface of the plug wrap and/or is at least partially around the filter material.

10. The filter element of claim **1**, wherein the at least one magnetic substrate is incorporated into one or more filter parts selected from the group consisting of a shaped paper insert, a plug, a space between plugs, cigarette filter paper, a cellulose acetate sleeve, a polypropylene sleeve and a free-flow sleeve.

11. A cigarette comprising the filter element of claim **1**.

12. The cigarette of claim **11**, wherein the at least one magnetic substrate is adapted to reduce the amount of magnetized adsorbent particles or fragmented magnetized adsorbent particles entrained in the mainstream smoke of the cigarette.

13. The cigarette of claim **11**, comprising a tobacco rod attached to the filter element with tipping paper, wherein the at least one magnetic substrate is incorporated axially between the filter element and the tobacco rod.

14. The cigarette of claim **13**, wherein magnetized adsorbent particles are incorporated in the tobacco rod and/or the cigarette paper.

15. The cigarette of claim **11**, wherein the magnetized adsorbent particles and/or the at least one magnetic substrate are adapted to change the chemical composition of mainstream smoke that flows through the filter element.

16. The cigarette of claim **11**, wherein the magnetized adsorbent particles are incorporated in the filter element in an amount effective to catalyze the conversion of carbon monoxide to carbon dioxide and/or nitric oxide to nitrogen during smoking of the cigarette.

17. A method of treating mainstream smoke from the cigarette of claim **11**, the method comprising drawing the smoke through the cigarette wherein the magnetized particles and/or fragments of the magnetized particles are magnetically attracted to the at least one magnetic substrate and removed from the mainstream smoke.

18. A method of making a cigarette filter element comprising filter material, magnetized adsorbent particles and at least one magnetic substrate, comprising:

providing filter material and plug wrap material;

forming the filter material into a filter rod;

incorporating the magnetized adsorbent particles and the at least one magnetic substrate in and/or on at least one of the filter rod and the plug wrap material; and

wrapping the filter rod in the plug wrap material to form the filter element.

19. The method of claim **18**, wherein the magnetized adsorbent particles and/or the at least one magnetic substrate are incorporated in the filter material prior to forming the filter material into the filter rod.

20. The method of claim **18**, comprising forming the at least one magnetic substrate at least partially around the filter rod prior to wrapping the filter rod in the plug wrap, and/or incorporating the at least one magnetic substrate on an interior surface of the plug wrap prior to wrapping the filter rod in the plug wrap.

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