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(54) Title: SURFACE-MODIFIED ACTIVATED CARBON IN SMOKING ARTICLES

(57) Abstract: A surface-modified activated carbon is provided to reduce the amount of free fine carbon particles among the activated carbon. By surface-modifying the activated carbon with a layer, the activated carbon can have increased mechanical strength and the fine carbon particles among the activated carbon can be fastened to the layer. Therefore, the layer allows for the level of free fine carbon particles among the activated carbon to be reduced. Surface-modified activated carbon can be used in smoking articles so as to allow for adsorption by the activated carbon with reduced free fine carbon particles in the smoking article and the smoke produced.



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SURFACE-MODIFIED ACTIVATED CARBON IN SMOKING ARTICLES

BACKGROUND

he present invention relates to activated carbon which is
5 treated to reduce the presence of fine particles in smoking articles.

SUMMARY

In a first embodiment, activated carbon is treated to reduce
the formation and presence of fine particles in smoking articles.
10 The surface of the activated carbon is modified to improve the
mechanical integrity of the activated carbon and thus decrease the
propensity of the activated carbon to form fine particles. The
surface of the activated carbon is also modified to attach or fasten
existing fine particles to the activated carbon to reduce the presence
15 of fine particles. The surface of the activated carbon can be
modified by forming a hydrocarbon compound layer, a polymer layer or a
carbon layer on external and internal surfaces of the activated
carbon.

In another embodiment, a cigarette, comprises a tobacco rod
20 including tobacco and a filter, wherein said filter includes a
surface-modified activated carbon comprising activated carbon; fine
carbon particles on surfaces of the activated carbon; and a layer on
an internal surface and an external surface of the activated carbon,
wherein the layer comprises a hydrocarbon compound, an additional
25 layer of carbon or a polymer on the activated carbon, wherein if the
layer is a polymer, the polymer is about 9-20 wt% of the surface-
modified activated carbon total weight.

In another embodiment, a cigarette filter, comprises a
filter with a cavity, wherein said cavity includes a surface-modified
30 activated carbon therein comprising: activated carbon; fine carbon
particles on surfaces of the activated carbon; and a layer on an
internal surface and an external surface of the activated carbon,
wherein the layer comprises a hydrocarbon compound, an additional
layer of carbon or a polymer on the activated carbon, wherein if the
35 layer is a polymer, the polymer is about 9-20 wt% of the surface-
modified activated carbon total weight.

In another embodiment, a method of manufacturing a cigarette, comprises forming surface-modified activated carbon by providing activated carbon having fine carbon particles on surfaces thereof; and forming a layer on internal and external surfaces of the activated carbon, wherein the layer comprises hydrocarbon compound, carbon or polymer on the activated carbon, wherein if the layer is polymer, the polymer is about 9-20 wt% of the surface-modified activated carbon total weight; incorporating the surface-modified activated carbon into a cigarette filter; and attaching the cigarette filter to a tobacco rod to form a cigarette.

In another embodiment, a method of treating mainstream tobacco smoke by drawing the mainstream tobacco smoke through a filter containing surface-modified activated carbon comprising: activated carbon; fine carbon particles on surfaces of the activated carbon; and a layer on an internal surface and an external surface of the activated carbon, wherein the layer comprises a hydrocarbon compound, an additional layer of carbon or a polymer on the activated carbon, wherein if the layer is a polymer, the polymer is about 9-20 wt% of the surface-modified activated carbon total weight.

DETAILED DESCRIPTION

Activated carbon is a generic term used to describe a family of carbonaceous adsorbents with an extensively developed internal pore structure. Activated carbon can be produced by activating an amorphous (non-graphitic) carbon, wherein amorphous (non-graphitic) carbon can be produced by carbonizing a precursor, such as wood, lignite, coal, coconut husk, peat, pitch, polymers, cellulose fibers, or polymer fibers, etc., to form char. Preferably, carbonization is carried out at high temperatures, i.e., 300-1000°C, preferably above 600°C in an inert atmosphere. After carbonization, activation can be carried out by heat treating the amorphous carbon or char with an oxidizing agent, e.g., carbon dioxide or steam. During activation, some of the carbon of the amorphous carbon or char is reacted with the oxidizing agent and pores of various sizes, e.g., on the order of angstroms to microns, are formed in the activated carbon.

The activated carbon could be in the form of granules, spheres, monoliths, beads, powders or fibers. In exemplary

embodiments, the activated carbon can have an average particle size of about 6 mesh to 300 mesh.

Activated carbon may include a distribution of micropores, mesopores and macropores. The term "microporous" generally refers to such materials having pore sizes of about 20 Å or less, while the term "mesoporous" generally refers to such materials with pore sizes of about 20 to 500 Å. The term "macroporous" refers to pore sizes above 500 Å. The relative amounts of micropores, mesopores and macropores can be pre-selected relative to the selected components from mainstream tobacco smoke that are to be targeted and removed. Thus, the pore sizes and pore distribution can be adjusted accordingly as needed for a certain application.

Activated carbon can be incorporated in one or more locations of the smoking article. Activated carbon is preferably placed in filters to reduce their interaction with tobacco, such as tobacco in the tobacco rod. For example, activated carbon can be placed in the passageway of a tubular free-flow filter, in the free-flow filter, intermingled with fibrous material, and/or in a void space.

Highly activated carbon is dusty in nature due to intrinsic porous structure resulting from the harsh carbonization and activation treatment. Fine particles or "dust" of carbon with particle sizes less than 10 microns are often created during either or both of the carbonization and activation processes due to the harshness of the processes on the mechanical integrity of the activated carbon. Moreover, during cigarette manufacture wherein carbon particles are added to a cavity of a cigarette filter, mechanical handling of the carbon particles can lead to additional fine particle generation.

During smoking, it would be desirable to avoid such fine particles from becoming entrained in the smoke stream drawn through the cigarette.

Conventionally, these fine particles have been removed by washing the activated carbon with water under agitation. However, additional fine particles can be formed after the washing due to the somewhat fragile nature of the activated carbon.

The quantity of fine particles and the mechanical strength of the activated carbon vary depending on the origin of the precursor

and the activation treatment. For example, activated carbon formed from lower density precursors, such as coconut husks, tend to have a lower density and a lower mechanical strength than activated carbon formed from higher density precursors, such as pitch. However, 5 processing pitch tends to be more expensive and may not be available in some forms, such as particles for example. Thus, less expensive activated carbon may have lower mechanical strength and thus may also lead to increased amounts of fine particles.

Additionally, after the activation process, fine particles 10 may also be generated due to the somewhat fragile nature of activated carbon as mentioned above. For example, when activated carbon is provided in smoking articles, fine particles may be formed in the smoking articles by attrition, abrasion between activated carbon particles and compaction of the activated carbons during the 15 packaging, transporting, and/or other processing of the activated carbons. Therefore, embodiments provided herein increase the mechanical strength of activated carbon and in turn decrease the amount of fine particles present.

As used herein "surface-modified activated carbon" includes 20 mechanically strengthened activated carbon with a layer thereon or activated carbon that has undergone surface modification by forming a layer thereon, then treating the layer to convert the layer into a higher strength surface modification.

A preferred embodiment includes a method of reducing fine 25 particles by forming a surface-modified activated carbon to reduce the presence and production of fine particles in smoking articles. By forming a surface-modified activated carbon, the activated carbon can have increased mechanical strength against breakage and reduced formation of fine particles. Additionally, by using the surface- 30 modified activated carbon, any fine particles present can be fastened on a surface of the surface-modified activated carbon, thus reducing contamination by the fine particles in smoking articles.

As used herein, the term "hydrocarbon compound" is intended to include lower molecular weight hydrocarbons, while the term 35 "polymer" is intended to include higher molecular weight hydrocarbons, as well as other polymer compositions. For example, exemplary

hydrocarbon compounds include waxes, paraffins, etc., while exemplary polymers include polypropylene, pectin, etc.

As provided, the activated carbon can be surface-modified by forming a layer of hydrocarbon compound, such as a wax, onto the activated carbon, wherein the hydrocarbon compound can adhere to external and internal surfaces of activated carbon. By this adherence, the hydrocarbon compound can strengthen the activated carbon by increasing the mechanical integrity of the activated carbon, as well as fasten fine particles by coating the fine particles into the layer.

Alternatively, the activated carbon can be surface-modified by forming a layer of polymer, such as a polypropylene or pectin, onto the activated carbon wherein the polymer, similar to the wax, can adhere to external and internal surfaces of activated carbon. Again, by this adherence, the polymer can strengthen the activated carbon by increasing the mechanical integrity of the activated carbon, as well as, fasten fine particles by coating the fine particles into the layer.

Or, as yet another alternative, a surface-modified activated carbon can be formed by providing an aromatic compound, such as pitch, on external and internal surfaces of activated carbon before heat treating the aromatic compound and the activated carbon to form a carbon layer on the activated carbon. By forming this carbon layer on the porous framework of the activated carbon, some of the pores can be filled thus changing the pore distribution of the activated carbon. Also, the addition of the carbon layer allows for the density of the activated carbon to be increased which in turn can cause the strength of the activated carbon to be increased. Also, the addition of the carbon layer allows for fine particles to be fastened by the carbon layer. Finally, the carbon layer can be formed using a precursor material with a higher density than the precursor material used to form the activated carbon. By providing, for example, a pitch precursor for forming the carbon layer while providing coconut husk precursor for the activated carbon, a carbon coated activated carbon can be formed with the increased mechanical strength from the pitch precursor carbon layer with decreased cost by providing a base of less expensive coconut husk precursor activated carbon.

As mentioned above, the surface-modified activated carbon improves the mechanical strength and reduces the amount of fine particles of the activated carbon. Desirably, the surface modification can be used to reduce breakage of the activated carbon and to reduce the amount of broken portions of the activated carbon that may become loose in a smoking article during storage of the smoking article.

If a hydrocarbon compound is used to surface-modify the activated carbon, the hydrocarbon compound can be formed on internal and external surfaces of the activated carbon. This is done by first, forming a liquid solution, preferably a homogeneous liquid solution, by melting or dissolving the hydrocarbon compound in a solvent or solvent mixture. Next, the activated carbon can be suspended in the liquid solution to impregnate the hydrocarbon compound into the activated carbon, thus covering the internal and external surfaces of the activated carbon with the hydrocarbon compound. Next, the solvent can be removed by evaporating or extracting the solvent from the activated carbon to form a hydrocarbon compound layer, preferably a thin, uniform thickness layer, on internal and external surfaces of the activated carbon.

By forming the hydrocarbon compound layer on the activated carbon, fine particles existing on internal or external surfaces of the activated carbon can be entrapped within the hydrocarbon compound layer or can be covered or fastened onto the internal or external surfaces of the activated carbon by the layer, thus reducing the number of free fine particles. Additionally, the hydrocarbon compound layer on the activated carbon can increase the mechanical integrity of the activated carbon such that if the layered activated carbon is subjected to vibration or other mechanical disturbance, fewer fine particles are formed and/or discharged, which in turn can reduce the levels of the fine particles. In other words, for example, a viscous wax layer can be formed on activated carbon, wherein the viscous wax layer sticks to both the activated carbon and the fine particles, and the viscous wax layer also increases the mechanical strength of the activated carbon because of its viscosity.

Preferably, the hydrocarbon compound is either non-polar or weakly polar to minimize surface tension between the hydrocarbon

compound layer and the activated carbon, which is often weakly polar. By using non-polar or weakly polar hydrocarbon compounds, an improved uniformity of the layer can be realized based on the polarity. Additionally, the non-polarity or weak polarity of the hydrocarbon compounds can change the selectivity of the activated carbon to target non-polar or weakly polar smoke constituents.

The hydrocarbon compound is preferably a low volatility material with a boiling point over about 150°C at about one atmosphere with a low vapor pressure at ambient conditions to ensure stability of the hydrocarbon compound on the activated carbon. Thus, the hydrocarbon compound can be provided to not vaporize during smoking of a cigarette with hydrocarbon compound coated activated carbon therein. Examples of hydrocarbon compounds that may be used to coat activated carbon include, but are not limited to: waxes, chained or branched paraffin, or polymeric hydrocarbons, wherein the hydrocarbon compounds can be provided in solid or liquid form. Preferably, such hydrocarbon compounds, however, have a high viscosity on the activated carbon to prevent migration. Exemplary solvents include, but are not limited to: organic solvents, such as ethers, acetone, MEK (methyl ethyl ketone), hexane, toluene, and xylene.

As an alternative to hydrocarbon compounds, as mentioned above, polymers can also be used to coat activated carbon. If a polymer is used to surface modify the activated carbon, the polymer can be formed on internal and external surfaces of the activated carbon. This is preferably done by first, forming a liquid solution, preferably a homogeneous liquid solution, by melting or dissolving the polymer in a solvent or a solvent mixture. Next, the polymer can be loaded into the activated carbon by allowing the liquid solution to soak into the activated carbon, thus impregnating the polymer into the activated carbon. The impregnated polymer can then form a polymer layer, preferably a thin, uniform thickness layer, on internal and external surfaces of the activated carbon. For example, the activated carbon can be layered by wetness-incipient impregnation by the liquid solution, by flowing the liquid solution through a bed of activated carbon, or by soaking the carbon in the liquid solution and then removing the excess solution. Next, a stepwise thermal treatment can be performed to release solvent and open the porous structure of the

activated carbon without adversely impacting the internal porous structure of the activated carbon. For example, a stepwise thermal treatment in a temperature range of 100 to 300°C can be used to release a solvent, such as hexane.

5 Preferably, the amount of polymer coated on the activated carbon is about 9 to 20 wt% of the total polymer coated activated carbon weight in order to provide mechanical strength, while still providing accessibility to the pores and thus the activated carbon smoke adsorption properties. Alternatively, the polymer is preferably
10 provided in about 10-18%, 11-17 wt%, 12-16 wt%, 10-12 wt%, 12-14 wt%, 14-16 wt%, 16-18 wt% or 18-20 wt% to balance the mechanical strength
of the activated carbon with the adsorption properties of the activated carbon.

 In addition to the benefits mentioned above, another benefit
15 to using a polymer layer is that the polymer layer can possess electrical charges capable of trapping fine particles with electrical forces, such as by static electricity force.

 Additionally, the permeability of a polymer layer can be tunable, thus allowing for adsorption selectivity of targeted
20 constituents by the layered activated carbon. For example, a polymer layered activated carbon in a cigarette filter can include a polymer specifically selected to allow the activated carbon to selectively adsorb carbon monoxide or other specific gaseous constituents of the cigarette smoke when the cigarette is smoked.

25 Exemplary polymers are non-toxic and are preferably biodegradable and/or smoke permeable, such that cigarette smoke can permeate the polymer to access the activated carbon. Additionally, exemplary polymers preferably have been approved by the Food and Drug Administration (FDA) and have a prolonged shelf life. Examples of
30 such polymers include, but are not limited to: synthetic polymers, such as polypropylene, polyethylene, silicone polymer, poly(ethylene oxide), poly(ethylene glycol), poly(acrylic acid), poly(vinyl acetate), poly(vinyl alcohol), various block poly(ethylene oxide)-poly(propylene oxide) copolymers, other copolymers or other block
35 copolymers or their derivatives and/or natural polymers, such as pectin, alginate or starch.

Exemplary solvents or co-solvents preferably have relatively low boiling points, and can solvate the exemplary polymers listed above, for example, exemplary solvents include, but are not limited to: water, alcohol, such as methanol or ethanol, or hexane.

5 If a carbon layer from an aromatic compound is used to surface modify the activated carbon rather than hydrocarbon compounds or polymers, the aromatic compound can be formed on internal and external surfaces of the activated carbon. This is done by first, forming a liquid solution, preferably a homogeneous liquid solution,
10 by melting or dissolving the aromatic compound in a solvent or solvent mixture. Next, the activated carbon can be suspended in the liquid solution to allow the aromatic compounds to impregnate the activated carbon, thus covering the surfaces of the activated carbon. Next, the solvent can be removed by filtering, then evaporating or extracting
15 the remaining solvent.

After the solvent is removed, the layered activated carbon can be stabilized by heating according to a predetermined heating schedule, such that the aromatic compounds can be converted into a stabilized, infusible form prior to carbonization. Next, the
20 stabilized, infusible form aromatic compounds can be carbonized by heat treating the stabilized, infusible form aromatic compounds on the activated carbon in an inert environment. By carbonizing the stabilized, infusible form aromatic compounds, a new carbon layer can thereby be formed on the surfaces of the activated carbon.

25 Preferably, the carbon layer on the activated carbon is not itself activated, as activation of the carbon layer may cause loss of at least part of the carbon layer, and a decrease of its mechanical strength. Thus, while activation of the carbon layer may be done, such activation is not preferred due to possible loss issues.

30 Examples of aromatic compounds that may be used include, but are not limited to: petroleum pitches, coal tar pitches and pine tar pitches, other natural or synthetic aromatic compounds, and mixtures thereof. These aromatic compounds are preferred because of their high density, which in turn after carbonization, leads to higher mechanical
35 strength carbon than can be achieved by carbonizing lower density carbonaceous precursors. Thus, by coating and carbonizing a pitch precursor on a lower density precursor activated carbon, the higher

mechanical strength of a carbonized pitch can be provided on a lower cost, lower density precursor activated carbon.

Examples of solvents that may be used to melt or dissolve the aromatic compounds may include, but are not limited to: N-methyl-
5 2-pyrrolidinone (NMP), quinoline, trichlorobenzene, toluene, xylene, other solvents used for dissolving aromatic compounds and mixtures thereof.

C. Smoking articles

10 The surface-modified activated carbons are preferably used in smoking articles, specifically filter portions of smoking articles. The smoking articles envisioned herein include cigarettes, such as traditional and non-traditional cigarettes, cigars and other smoking devices. Non-traditional cigarettes include, for example, cigarettes
15 for electrical smoking systems as described in commonly-assigned U.S. Patent Nos. 6,026,820; 5,988,176; 5,915,387; 5,692,526; 5,692,525; 5,666,976; and 5,499,636, the disclosures of which are incorporated by reference herein in their entireties.

A cigarette typically contains two sections, a tobacco-
20 containing portion often referred to as the tobacco or cigarette rod, and a filter portion, which may be referred to as a filter tipping. The tipping paper overlaps an end portion of the tobacco rod to hold the filter and tobacco rod together.

The tobacco rod, or tobacco containing element of the
25 cigarette, typically includes a cigarette wrapping paper in which shreds of tobacco is wrapped with an adhesive holding the seams of the paper together.

When the tobacco rod is lit or heated for smoking, mainstream tobacco smoke is drawn from the lit or heated end
30 downstream to the filter end of the tobacco rod and further downstream through the filter.

The term "mainstream smoke" includes the mixture of gases and/or aerosols passing down a smoking article, such as a tobacco rod, and issuing from an end, such as through the filter end, i.e., the
35 amount of smoke issuing or drawn from the mouth end of a cigarette during smoking of the cigarette. The mainstream smoke contains air

that is drawn in through the heated region of the cigarette and through the paper wrapper.

"Smoking" of a cigarette (or smoking article) generally involves lighting one end of the cigarette and drawing the smoke downstream through the mouth end of the cigarette, while the tobacco contained therein undergoes a combustion reaction or heating. However, the cigarette may also be smoked by other means. For example, the cigarette may be smoked by heating the cigarette using an electrical heater, as described, for example, in commonly-assigned U.S. Patent Nos. 6,053,176; 5,934,289; 5,591,368 or 5,322,075, each of which is incorporated herein by reference in its entirety.

Examples of suitable types of tobacco materials that may be used include, but are not limited to, flue-cured tobacco, Burley tobacco, Maryland tobacco, Oriental tobacco, rare tobacco, specialty tobacco, reconstituted tobacco, blends thereof and the like. The tobacco material may be provided in any suitable form, including, but not limited to, 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, blends thereof, and the like. Tobacco substitutes may also be used.

In cigarette manufacture, the tobacco is normally used in the form of cut filler, i.e., in the form of shreds or strands cut into widths ranging from about 1/10 inch to about 1/20 inch or even about 1/40 inch. The lengths of the strands range from between about 0.25 inch to about 3.0 inches. The cigarettes may further comprise one or more flavors, as described above, or other additives (e.g., burn additives, combustion modifying agents, coloring agents, binders, etc.).

The filter material of the filter may be any of the variety of fibrous materials for use in tobacco smoke filter elements. Typical materials include cellulose acetate, polypropylene or paper. Preferably, the filter material will be cellulose acetate.

Various cigarette filter constructions may be used, where exemplary filter structures that may be used include, but are not limited to, a mono filter, a dual filter, a triple filter, a single or multi-cavity filter, a recessed filter, a free-flow filter, combinations thereof and the like.

Mono filters typically contain cellulose acetate tow or cellulose paper materials. Pure mono cellulose filters or paper filters offer good tar and nicotine retention, and are highly degradable. Dual filters typically comprise a cellulose acetate mouth
5 end and a pure cellulose or cellulose acetate segment. The length and pressure drop of the segments in a dual filter may be adjusted to provide optimal sorption, while maintaining acceptable draw resistance. Triple filters may include mouth and smoking material or tobacco side segments, and a middle segment comprising paper. Cavity
10 filters include two segments, e.g., acetate-acetate, acetate-paper or paper-paper, separated by at least one cavity. Recessed filters include an open cavity on the mouth side.

Preferably, the surface-modified activated carbon is provided in filters of the smoking articles, as mentioned above. The
15 filters may also be ventilated and/or may include in addition to the surface-modified activated carbon, other sorbents, catalysts or other additives suitable for use in filters of smoking articles.

Variations and modifications of the foregoing will be apparent to those skilled in the art. Such variations and
20 modifications are to be considered within the purview and scope of the claims appended hereto.

CLAIMS:

1. A cigarette, comprising:
a tobacco rod including tobacco and a filter, wherein said filter
5 includes a surface-modified activated carbon comprising:
activated carbon;
fine carbon particles on a surface of the activated carbon;
and
a layer on a surface of the activated carbon, wherein the layer
10 comprises a hydrocarbon compound, an additional layer of carbon or a
polymer on the activated carbon, wherein if the layer is a polymer,
the polymer is about 9-20 wt% of the surface-modified activated carbon
total weight.
- 15 2. The cigarette of Claim 1, wherein the hydrocarbon compound
comprises a non-polar, weakly polar hydrocarbon compound, wax, chained
or branched paraffin or a polymeric hydrocarbon, wherein the
additional layer of carbon comprises a non-activated carbon which at
least partially fills pores in the surface-modified activated carbon,
20 or wherein the polymer is present in an amount of 10-18 wt% or 11-17
wt% of the surface-modified activated carbon total weight.
3. The cigarette of Claim 1, wherein the layer comprises an
additional layer of carbon, wherein the layer of carbon has a
25 different density than the activated carbon and modifies the pore size
distribution of the activated carbon.
4. The cigarette of Claim 1, wherein the layer comprises an
additional layer of carbon, wherein the additional layer of carbon has
30 a higher density than the activated carbon.
5. The cigarette of Claim 1, wherein the layer comprises a polymer,
wherein the polymer comprises a non-toxic, biodegradable and/or
permeable polymer.
- 35 6. The cigarette of Claim 1, wherein the layer comprises a polymer,
wherein the polymer comprises polypropylene, polyethylene, silicone

polymer, poly(ethylene oxide), poly(ethylene glycol), poly(acrylic acid), poly(vinyl acetate), poly(vinyl alcohol), pectin, alginate, starch or block poly(ethylene oxide)- poly(propylene oxide) copolymers or their derivatives.

5

7. The cigarette of Claim 1, wherein the activated carbon comprises granules, spheres, monoliths, beads, powders or fibers of activated carbon.

10 8. The cigarette of Claim 1, wherein the layer entraps the fine carbon particles within the bulk of the layer, fastens the fine carbon particles to surfaces of the layer or the activated carbon, or increases the mechanical strength of the surface-modified activated carbon to a mechanical strength greater than the activated carbon
15 without the layer.

9. The cigarette of Claim 1, wherein the layer has a thickness sufficient to at least partially cover the activated carbon and the fine carbon particles.

20

10. The cigarette of Claim 1, wherein the layer is effective for adsorbing a targeted gas phase constituent when the cigarette is smoked.

25 11. The cigarette of Claim 1, wherein the layer is electrically charged to attach the fine carbon particles on a surface of the layer with a force greater than a force of a smoke stream formed when the cigarette is smoked.

30 12. The cigarette of Claim 1, wherein the surface-modified activated carbon is located in a cavity of the filter.

13. The cigarette of Claim 1, wherein the fine carbon particles are less than 10 microns in diameter.

35

14. A cigarette filter, comprising:

a filter with a cavity, wherein said cavity includes a surface-modified activated carbon therein comprising:

activated carbon;

5 fine carbon particles on a surface of the activated carbon;
and

a layer on a surface of the activated carbon, wherein the layer comprises a hydrocarbon compound, an additional layer of carbon or a polymer, wherein if the layer is a polymer, the polymer is about 9-20
10 wt% of the surface-modified activated carbon total weight.

15 15. The cigarette filter of Claim 14, wherein the hydrocarbon compound comprises a non-polar or weak polar hydrocarbon compound, wax, chained or branched paraffin, or a polymeric hydrocarbon, wherein the additional layer of carbon comprises a non-activated carbon which at least partially fills pores in the surface-modified activated carbon, or wherein the polymer is present in an amount of 10-18 wt% or 11-17 wt% of the surface-modified activated carbon total weight.

20 16. The cigarette filter of Claim 14, wherein the layer comprises an additional layer of carbon, wherein the additional layer of carbon has a higher density than the activated carbon and modifies the pore size distribution of the activated carbon.

25 17. The cigarette filter of Claim 14, wherein the layer comprises a polymer, wherein the polymer comprises a non-toxic, biodegradable and/or permeable polymer.

30 18. The cigarette filter of Claim 14, wherein the layer comprises a polymer, wherein the polymer comprises polypropylene, polyethylene, silicone polymer, poly(ethylene oxide), poly(ethylene glycol), poly(acrylic acid), poly(vinyl acetate), poly(vinyl alcohol), pectin, alginate, starch or block poly(ethylene oxide)- poly(propylene oxide) copolymers or their derivatives.

19. The cigarette filter of Claim 14, wherein the activated carbon comprises granules, spheres, monoliths, beads, powders or fibers of activated carbon.

5 20. The cigarette filter of Claim 14, wherein the layer entraps the fine carbon particles within the bulk of the layer, fastens the fine carbon particles to surfaces of the layer or the activated carbon, or increases the mechanical strength of the surface-modified activated carbon to a mechanical strength greater than the activated carbon
10 without the layer.

21. The cigarette filter of Claim 14, wherein the layer has a thickness sufficient to at least partially cover the activated carbon and the fine carbon particles.

15

22. A method of manufacturing a cigarette, comprising:

forming surface-modified activated carbon by:

providing activated carbon having fine carbon particles on surfaces thereof; and

20 forming a layer on surfaces of the activated carbon, wherein the layer comprises hydrocarbon compound, carbon or polymer on the activated carbon, wherein if the layer is polymer, the polymer is about 9-20 wt% of the surface-modified activated carbon total weight;

incorporating the surface-modified activated carbon into a
25 cigarette filter; and

attaching the cigarette filter to a tobacco rod to form a cigarette.

23. The method of Claim 22, wherein the forming a layer on surfaces
30 of the activated carbon comprises:

melting or dissolving a layer compound in a solvent or solvent mixture to form a liquid solution;

suspending activated carbon in the liquid solution to impregnate the layer compound into the activated carbon; and

35 removing the solvent or solvent mixture.

24. The method of Claim 23, wherein the melting or dissolving the layer compound in a solvent or solvent mixture comprises:

mixing or dissolving petroleum pitch, coal tar pitch, pine tar pitch or a synthetic aromatic polymer in a solvent or solvent mixture.

5

25. The method of Claim 23, wherein the melting or dissolving the layer compound in a solvent or solvent mixture comprises:

mixing or dissolving an aromatic compound in 1-methyl-2-pyrrolidinone (NMP), quinoline, trichlorobenzene, toluene, xylene or a mixture thereof.

10

26. The method of Claim 23, wherein the melting or dissolving a layer compound in a solvent or solvent mixture comprises:

mixing or dissolving a low-volatility, non-polar or weak-polar organic compound or organic compound mixture with a boiling point above about 150°C at about one atmosphere with low vapor pressure at ambient conditions in a solvent or solvent mixture.

15

27. The method of Claim 23, wherein the melting or dissolving the layer compound in a solvent or solvent mixture comprises:

20

mixing or dissolving wax, chained or branched paraffin, a polymeric hydrocarbon, or a mixture thereof in a solvent or solvent mixture.

25

28. The method of Claim 23, wherein the melting or dissolving a layer compound in a solvent or solvent mixture comprises:

mixing or dissolving a non-toxic and biodegradable and/or permeable polymer in a solvent or solvent mixture.

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29. The method of Claim 23, wherein the melting or dissolving a layer compound in a solvent or solvent mixture comprises:

mixing or dissolving polypropylene, polyethylene, silicone polymer, poly(ethylene oxide), poly(ethylene glycol), poly(acrylic acid), poly(vinyl acetate), poly(vinyl alcohol), pectin, alginate, starch, poly(ethylene oxide)-poly(propylene oxide) copolymer or their derivatives in a solvent or a solvent mixture.

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30. The method of Claim 23, wherein the melting or dissolving a layer compound in a solvent or solvent mixture comprises:

mixing or dissolving a polymer compound in water, alcohol, hexane or a mixture thereof.

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31. The method of Claim 23, wherein the suspending activated carbon in the liquid solution to impregnate the layer compound into the activated carbon comprises:

10 suspending activated carbon granules, spheres, monoliths, beads, powders or fibers in the liquid solution to impregnate the layer compound into the activated carbon granules, spheres, monoliths, beads, powders or fibers.

32. The method of Claim 23, wherein the suspending activated carbon 15 in the liquid solution to impregnate the layer compound into the activated carbon comprises:

20 suspending activated carbon and fine carbon particles in the liquid solution to impregnate the layer compound into the activated carbon, wherein the layer compound entraps the fine carbon particles within the layer compound.

33. The method of Claim 23, wherein the suspending activated carbon in the liquid solution to impregnate the layer compound into the activated carbon, comprises suspending activated carbon and fine 25 carbon particles with a diameter of less than 10 microns in the liquid solution to impregnate the layer compound into the activated carbon and fasten the fine carbon particles on surfaces of the activated carbon.

30 34. The method of Claim 23, wherein the forming of the layer step further comprises:

35 carbonizing the layer compound by heating the layer compound after removing the solvent or solvent mixture, wherein the carbonizing of the layer compound forms a carbon layer with a density different from the activated carbon.

35. The method of Claim 34, wherein the carbonizing of the layer compound by heating the layer compound comprises heating the layer compound in an environment with a temperature between about 300°C and 1000°C.

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36. The method of Claim 23, wherein the suspending activated carbon in the liquid solution to impregnate the layer compound into the activated carbon comprises wetness-incipient impregnation of the layer compound into the activated carbon, rinsing the layer compound through
10 an activated carbon bed, or soaking activated carbon in the layer compound.

37. A method of treating mainstream tobacco smoke, comprising:

drawing smoke from the smoking article, wherein the smoke passes
15 through a filter containing surface-modified activated carbon comprising:

activated carbon; and

a layer on an internal surface and an external surface of the activated carbon, wherein the layer comprises a hydrocarbon compound,
20 an additional layer of carbon or a polymer on the activated carbon, wherein if the layer is a polymer, the polymer is about 9-20 wt% of the surface-modified activated carbon total weight.

38. The method of Claim 37, wherein the layer is adapted to reduce
25 free fine carbon particles in the smoking article that are drawn when smoke passes through the filter containing surface-modified activated carbon.