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(54) **COMPOSITIONS AND METHODS OF REMEDIATION DEVICES WITH NANOSTRUCTURED SORBENT**

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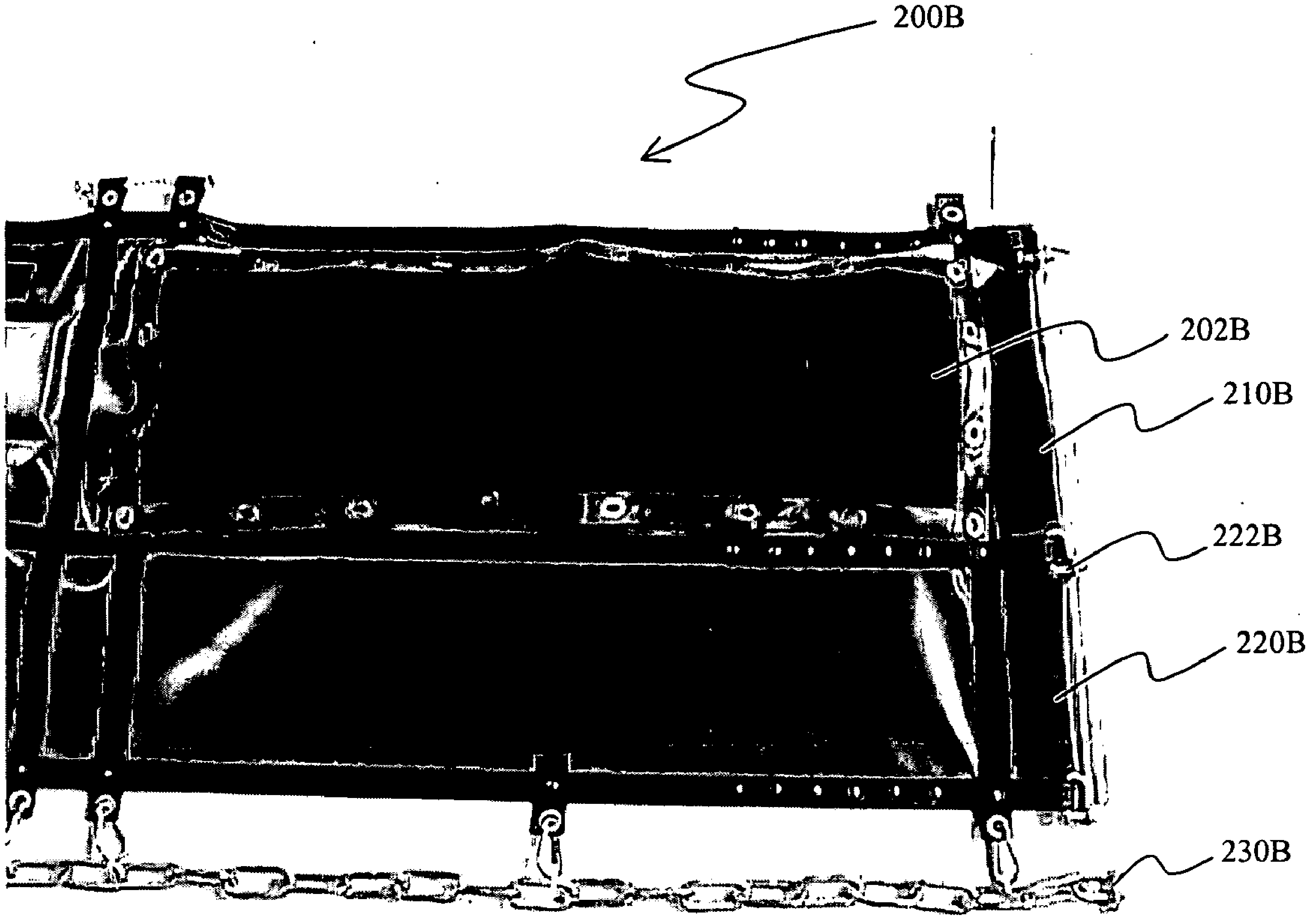
(57) **ABSTRACT**

Contemplated remediation devices include a substantially completely hydrophobic, non-porous, and carbonaceous, and most preferably nanostructured material enclosed in a retaining structure. In further preferred aspects, the material inside the retaining structure adsorbs a contaminant from a medium located outside the retaining structure. Especially preferred nanostructured materials comprise graphene, while preferred contaminants include optionally substituted hydrocarbons, organic solvents, and acids.



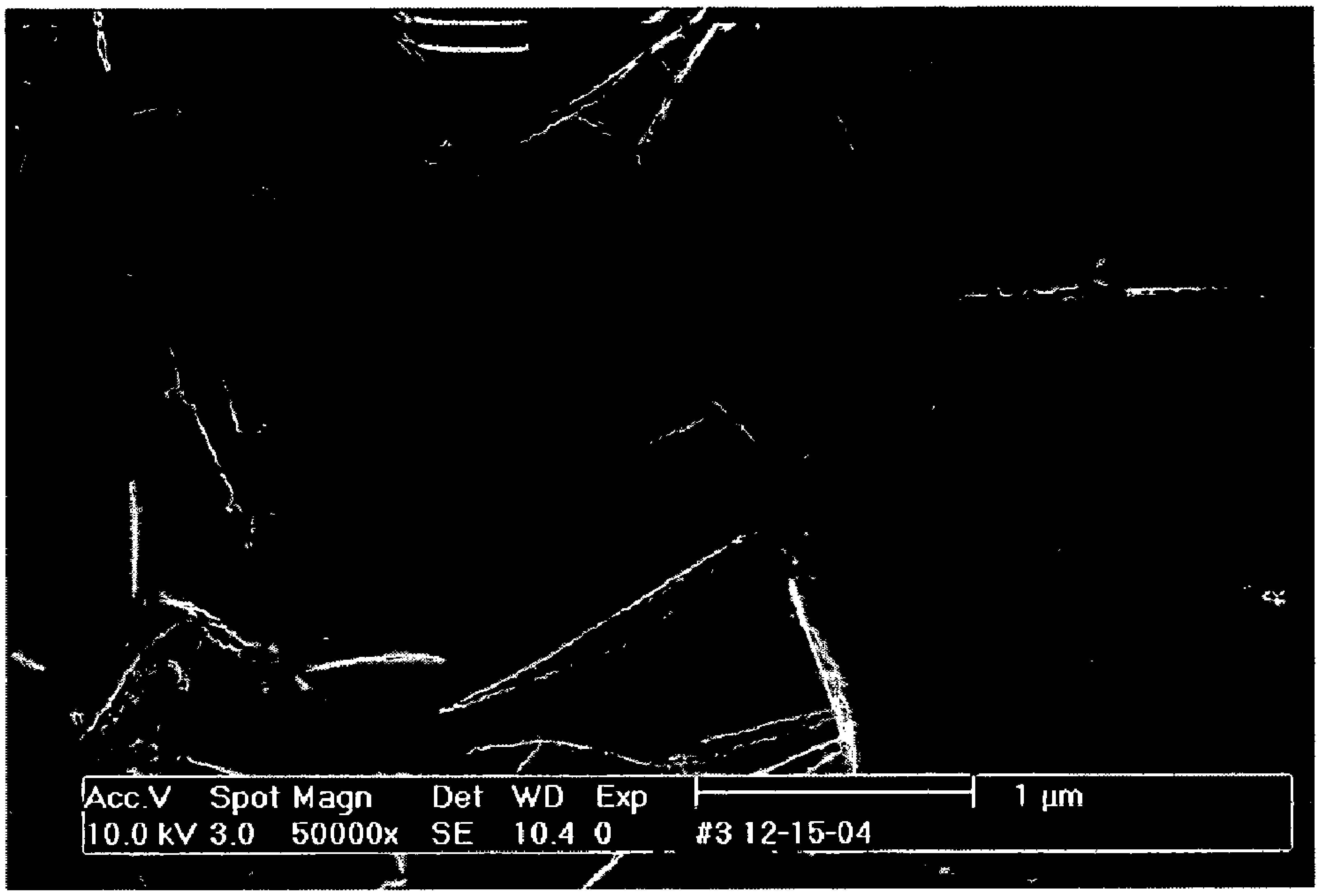


Figure 1A

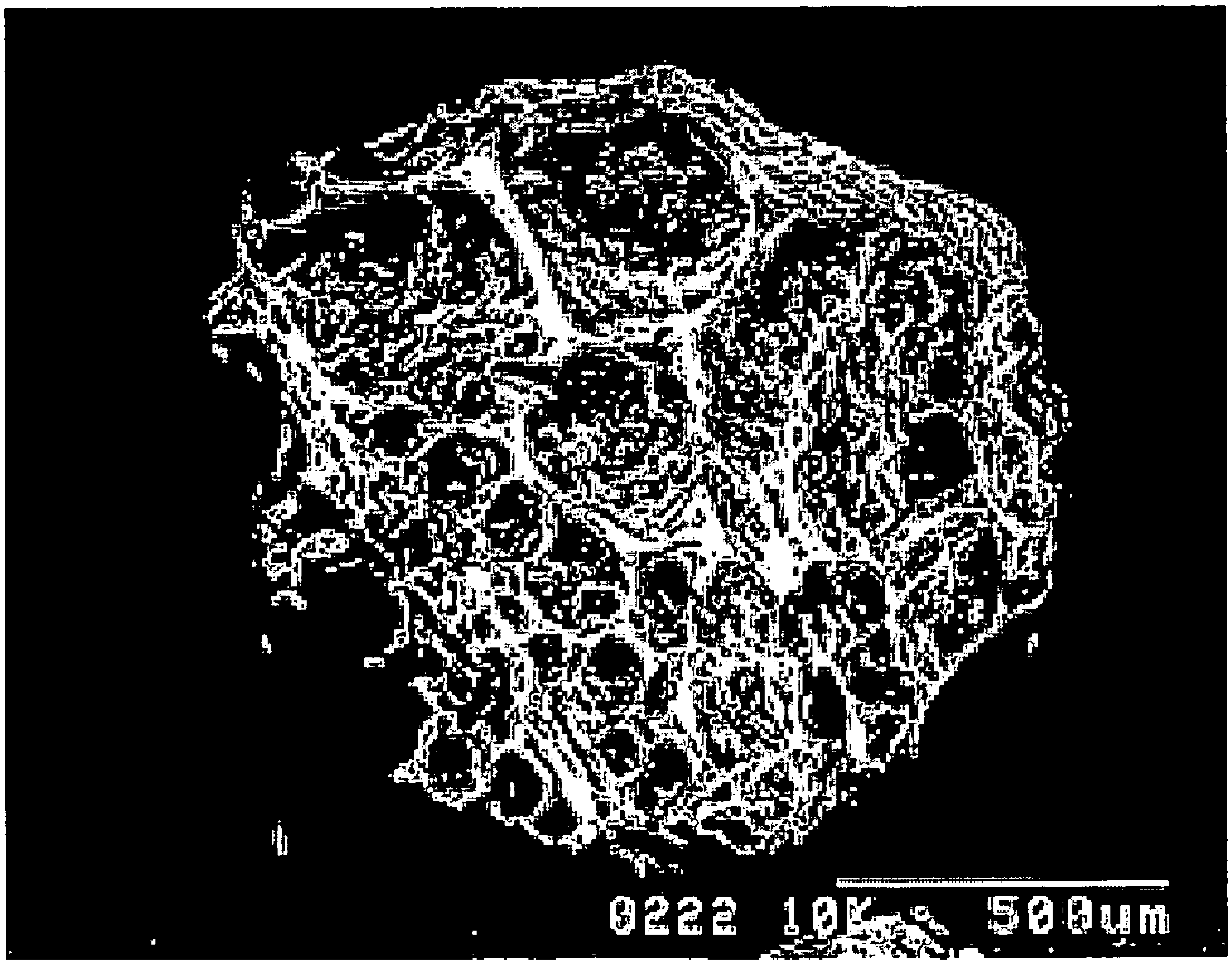


Figure 1B

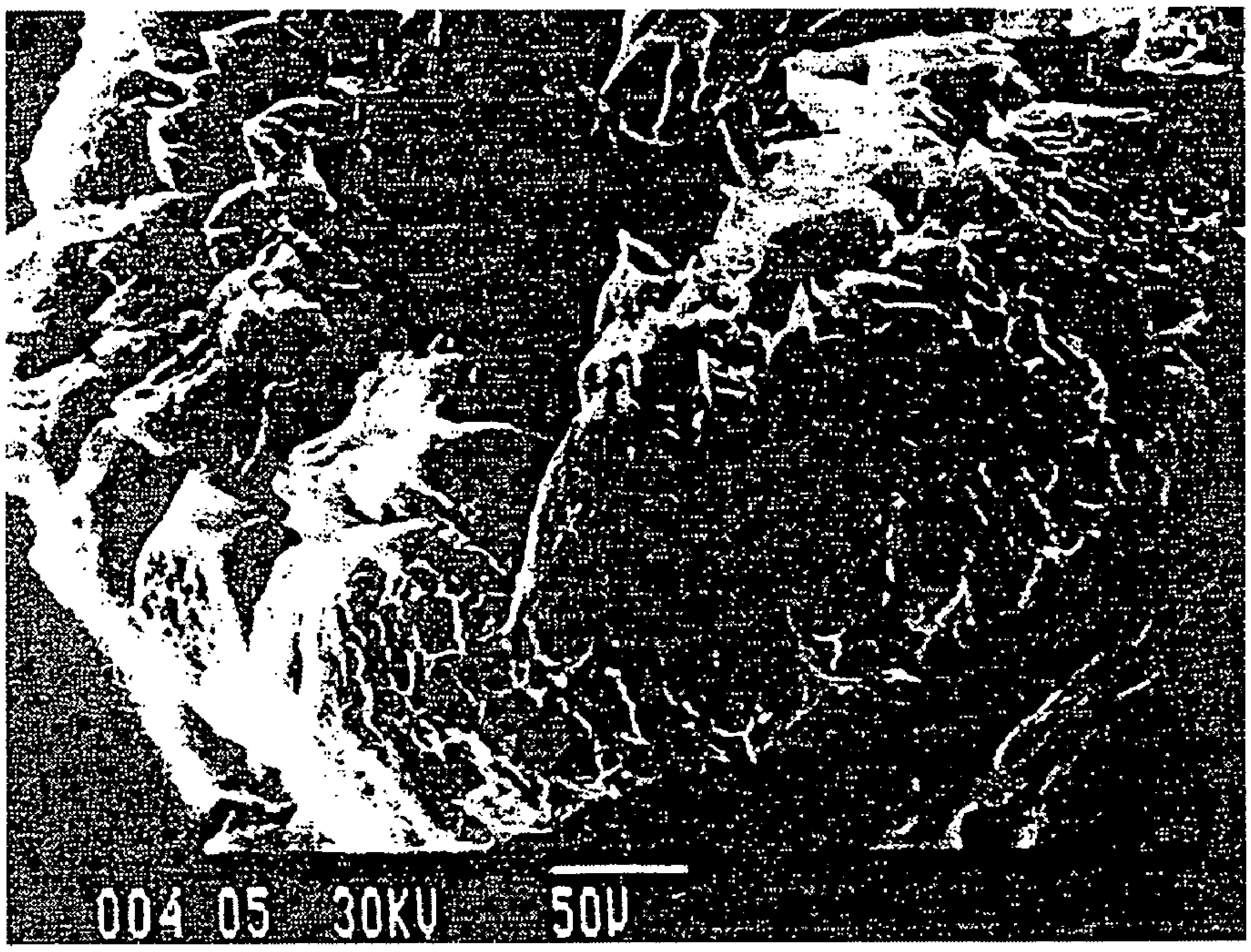


Figure 1C

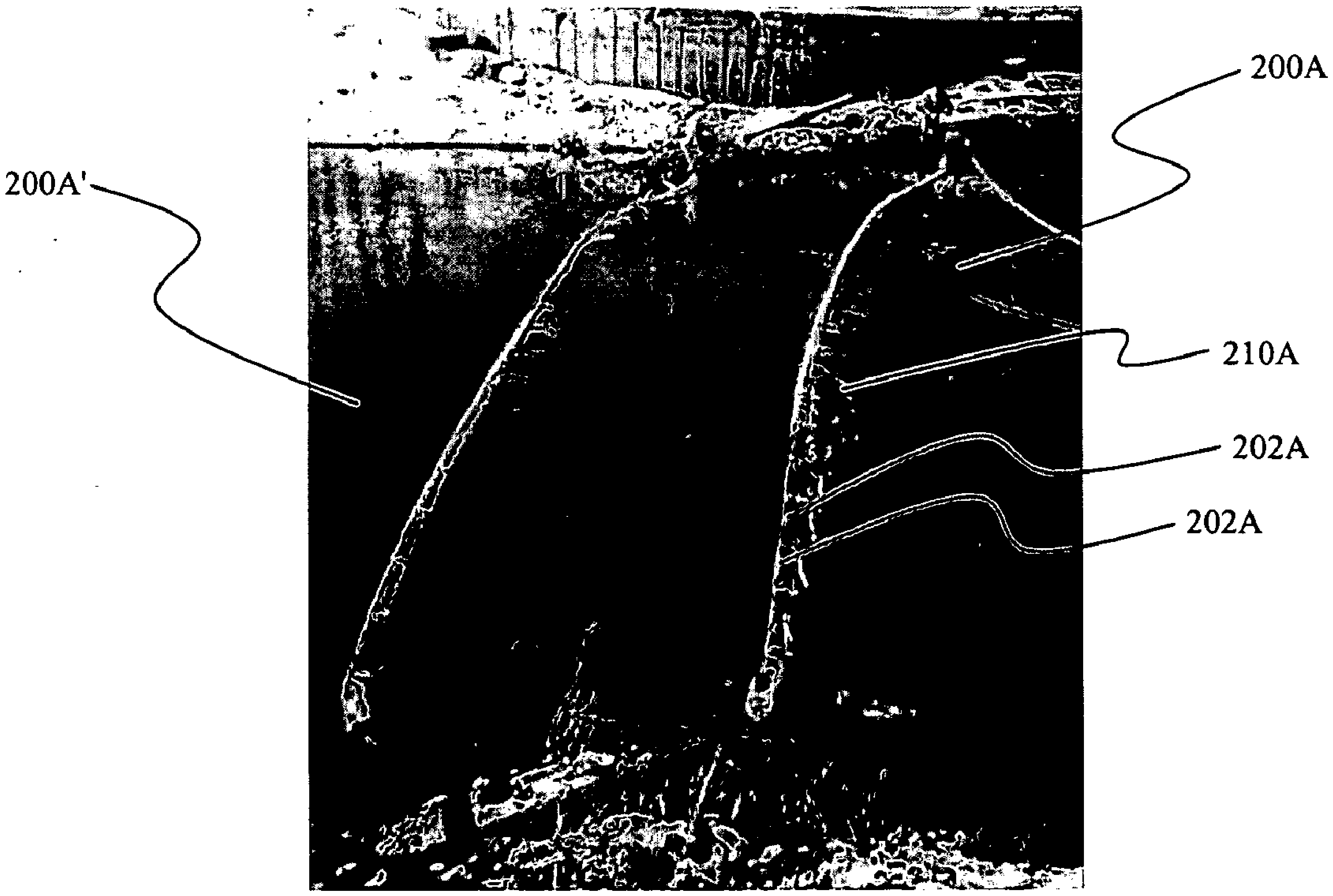


Figure 2A

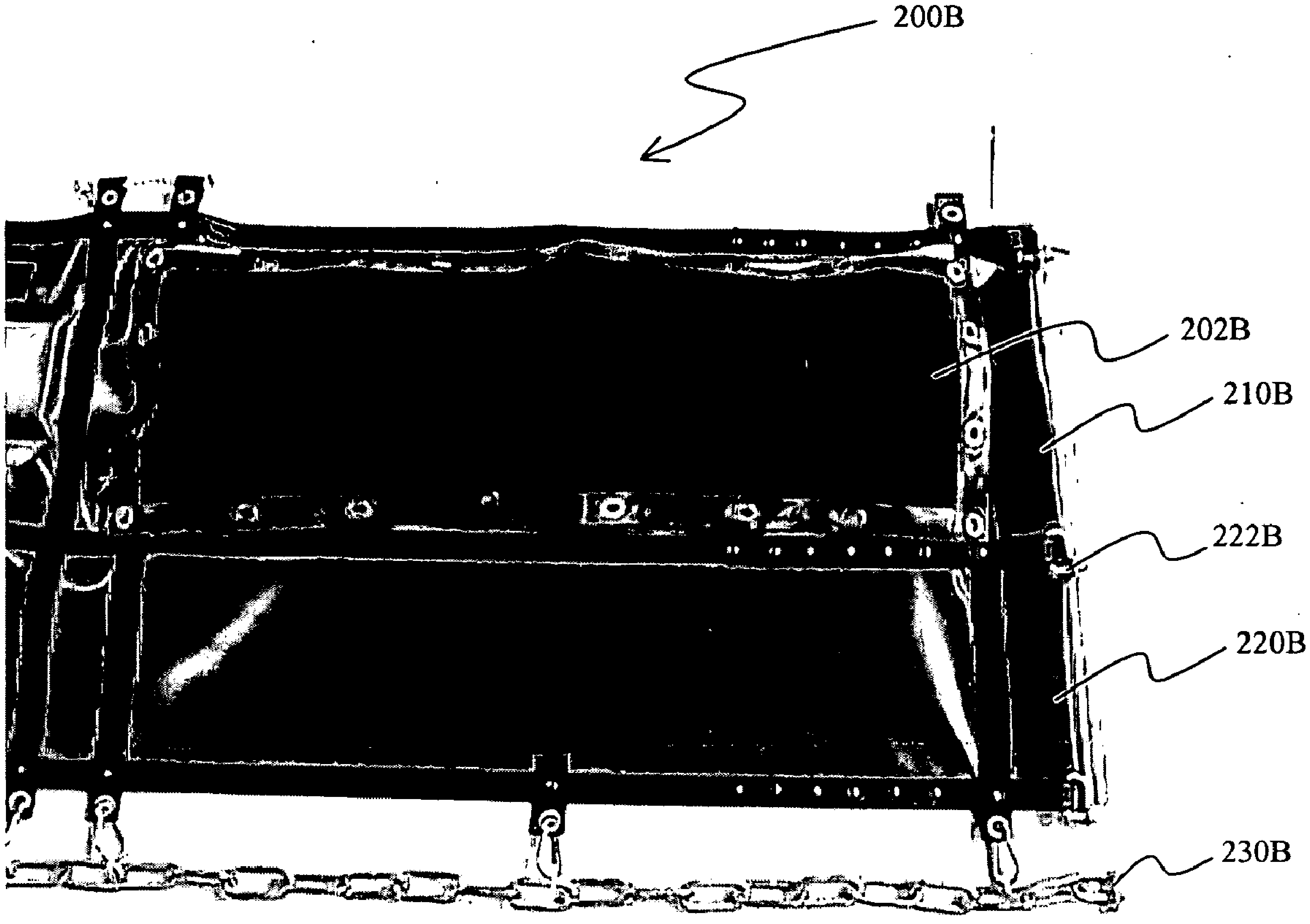


Figure 2B

COMPOSITIONS AND METHODS OF REMEDIATION DEVICES WITH NANOSTRUCTURED SORBENT

FIELD OF THE INVENTION

[0001] The field of the invention is remediation devices comprising non-porous carbonaceous material, and especially carbonaceous nanostructures as a sorbent.

BACKGROUND OF THE INVENTION

[0002] Activated charcoal is a common sorbent for numerous compounds and has been used in a large variety of filters, including potable water and air filtration. Among other advantages, such charcoal is relatively inexpensive, biologically inert and non-toxic, and can be easily disposed of. However, despite numerous desirable properties, activated charcoal has several disadvantages.

[0003] For example, the sorption capacity of activated charcoal is relatively limited and typically determined by the pore size and volume. Moreover, not all compounds are retained by activated charcoal. Still further, most activated charcoal preparations are at least somewhat hydrophilic and therefore suffer from loss of capacity where the activated charcoal is used in a humid or aqueous environment. Similarly, expanded graphite can be employed as a sorbent as described, for example, in WO 94/08902, and U.S. Pat. No. 5,282,975. While at least some of the expanded graphite has a relatively high sorptive capacity for selected hydrocarbons, various disadvantages nevertheless remain. Among other things, expanded graphite has still a relatively high degree of porosity, which tends to increase retention of the bound contaminant often resulting in limited re-use. Furthermore, undesirable water binding remains problematic to the relatively high degree of porosity.

[0004] To circumvent at least some of the above disadvantages, single-wall carbon nanotubes (SWNT) or multiwall carbon nanotubes (MWNT) can be employed as sorbing agents. While SWNT and MWNT often exhibit superior sorbent characteristics as compared to activated charcoal, various new disadvantages arise. Most significantly, the substantial cost of industrial scale production is often prohibitive for use of such nanotubes in filtration devices. Furthermore, and especially where the nanotubes need to be assembled to a filtration element, manufacture of such elements remains a largely academic endeavor.

[0005] Therefore, while various materials and methods for remediation devices with carbon-based sorbents are known in the art, all or almost all of them suffer from various disadvantages. Consequently, there is still a need to provide improved devices and methods for manufacture of remediation devices, and especially those comprising carbon nanostructures.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to remediation devices and methods that include a substantially completely hydrophobic, non-porous, and carbonaceous, and most preferably nanostructured material enclosed in a retaining structure, wherein the material adsorbs numerous contaminants, and especially optionally substituted hydrocarbons, organic solvents, and various acids.

[0007] In one aspect of the inventive subject matter, the remediation device has a cavity that at least partially encloses a non-porous carbonaceous material, wherein the cavity is fluidly coupled to a medium containing a contaminant, and wherein the cavity has a volume sufficient to allow adsorption of the contaminant in an amount that is at least ten-fold by weight as compared to the weight of the non-porous carbonaceous material in the cavity. Most preferably, the carbonaceous material is substantially completely hydrophobic and comprises graphene. Additionally, the device may also include a microorganism that utilizes a hydrocarbon as a carbon source.

[0008] In another aspect of the inventive subject matter, the remediation device comprises a substantially completely hydrophobic and nanostructured material, wherein the nanostructured material is a material other than a carbon nanotube, and wherein the nanostructured material is at least partially enclosed in a retaining structure that is configured to allow adsorption of a contaminant to the hydrophobic material from a medium that is in contact with the device. In particularly contemplated aspects, the nanostructured material is a carbonaceous material having a smallest dimension of less than 50 nm, and even more typically of less than 10 nm. Therefore, in at least some aspects of the inventive subject matter, the nanostructured material comprises at least 0.01 wt %, and more typically at least 1.0 wt % graphene.

[0009] In still further aspects of the inventive subject matter, the remediation device comprises graphene enclosed in a retaining structure that is configured to allow adsorption of a contaminant (e.g., optionally substituted hydrocarbon) to the graphene from an aqueous medium (e.g., lake, bay, ocean, or river) that is in contact with the device.

[0010] Various objects, features, aspects and advantages of the present invention will become more apparent from the figures and the following detailed description of preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWING

[0011] **FIG. 1A** is an electronmicrograph of exemplary substantially completely hydrophobic, non-porous, nanostructured carbonaceous material.

[0012] **FIG. 1B** is an electronmicrograph of an exemplary activated charcoal grain.

[0013] **FIG. 1C** is an electronmicrograph of an exemplary expanded graphite.

[0014] **FIG. 2A** is an exemplary remediation device in operation on a river.

[0015] **FIG. 1C** is another remediation device comprising a pocket and skirt for operation on a body of water having wave action.

DETAILED DESCRIPTION

[0016] The inventors have discovered that nanostructured materials, and especially non-porous carbonaceous materials, and most preferably graphene-containing materials can be employed as highly active sorbents for numerous contaminants. It is especially preferred that the material is employed in the separation of optionally substituted hydrocarbons from an aqueous medium, and most preferably while the material is present in a boom.

[0017] Among other advantages, it should be particularly appreciated that adsorption of various hydrocarbons in and/or on aqueous media is highly effective due to the substantially completely hydrophobic nature of the carbonaceous material over even extended periods of time. Viewed from another perspective, while heretofore known carbonaceous adsorbents become waterlogged after a relatively short time (most typically due to the porous nature of such known materials), the carbonaceous materials according to the inventive subject matter can remain in/on an aqueous medium without losing sorption capacity and/or adsorbing water.

[0018] As used herein, the term "carbonaceous" in conjunction with a material refers to a material that comprises at least 50 atom %, more typically at least 70 atom %, and most typically at least 90 atom % carbon. As further used herein, the term "nanostructured" in conjunction with a material refers to a material with a smallest dimension of equal or less than 50 nm, more typically less than 10 nm, and most typically less than 2 nm. Most preferably, nanostructured materials contemplated herein include graphene in an amount of at least 0.01 wt %, more typically at least 0.1 wt %, even more typically at least 1-10 wt %, and most more typically at least 10-95 wt %, and even more.

[0019] As still further used herein, the term "graphene" refers to a molecule in which a plurality of carbon atoms (e.g., in the form of five-membered rings, six-membered rings, and/or seven-membered rings) are covalently bound to each other to form a (typically sheet-like) polycyclic aromatic molecule. Consequently, and at least from one perspective, a graphene may be viewed as a single layer of carbon atoms that are covalently bound to each other (most typically sp^2 bonded). It should be noted that such sheets may have various configurations, and that the particular configuration will depend (among other things) on the amount and position of five-membered and/or seven-membered rings in the sheet. For example, an otherwise planar graphene sheet consisting of six-membered rings will warp into a cone shape if a five-membered ring is present the plane, or will warp into a saddle shape if a seven-membered ring is present in the sheet. Furthermore, and especially where the sheet-like graphene is relatively large, it should be recognized that the graphene may have the electron-microscopic appearance of a wrinkled sheet. It should be further noted that under the scope of this definition, the term "graphene" also includes molecules in which several (e.g., two, three, four, five to ten, one to twenty, one to fifty, or one to hundred) single layers of carbon atoms (supra) are stacked on top of each other to a maximum thickness of less than 100 nanometers. Consequently, the term "graphene" as used herein refers to a single layer of aromatic polycyclic carbon as well as to a plurality of such layers having a thickness of less than 100 nanometers. Typically, the dangling bonds on the edge of the graphene are saturated with a hydrogen atom. **FIG. 1A** is an electronmicrograph depicting a typical sample of contemplated carbonaceous materials. Clearly, the carbonaceous material is non-porous and has nanosized dimensions. In contrast, **FIG. 1B** depicts an electronmicrograph of a micronized grain of activated charcoal with apparent macro- and mesopores, while **FIG. 1C** is an electronmicrograph of expanded graphite with porous vermicular structure.

[0020] As yet further used herein, the term "non-porous" in conjunction with a material refers to a porosity (i.e., void space within the material itself as opposed to void space formed by the material) of the material of less than 1 vol %, and even more typically of less than 0.5 vol %. For example, a material having a total volume of 10 cubic micrometer is considered non-porous is that material has a total pore volume of less than 0.1 cubic micrometer. It should be noted that the annular space defined by a carbocyclic ring is not considered a pore under the definition provided herein. Also, where a material has a contorted shape (e.g., a graphene in a wrinkled, sheet-like configuration) within a given volume, the void space between the material in that volume is not considered a pore under the definition provided herein. The term "about" where used in conjunction with a numeral refers to a numeric range of +/−10% of the numeral, inclusive. For example, the term "about 100" refers to a numerical value of between 90 and 110, inclusive.

[0021] As further used herein, the term "carbon nanotube" refers to a cylindrical single- or multi-walled structure in which the wall(s) is (are) predominantly composed of carbon, wherein the diameter may be uniform or decreasing over the length of the nanotube. As still further used herein, the term "substantially completely hydrophobic" when used in conjunction with a material refers to the characteristic of the material to adsorb less than 0.5 wt % water, and more typically less than 0.1 wt % water as measured after mixing in water and subsequent withdrawal of water from the material via Buechner filter using tap vacuum.

[0022] In one preferred aspect of the inventive subject matter, the inventors contemplate that a remediation device is configured as a boom. Most typically, the boom has an elongated cylinder shape with an outer diameter of between about 2 to about 20 inches and a length between about 10 inches to about 100 inches. In further preferred aspects, the boom is fabricated from a textile material and is filled with the carbonaceous materials contemplated herein. **FIG. 2A** depicts an exemplary aspect of use of contemplated devices. Here remediation device **200**A is formed from a plurality of booms **202**A, wherein each of the booms **202**A includes a snap-type connector and a hook-and-loop type fastener (not shown) at the longitudinal ends to facilitate coupling of the booms to form a larger structure that encircles a spill or that spans a stream into which a contaminant has been released. The booms are in this case coupled to a steel wire **210**A that spans the stream, and a secondary structure **200**A' is installed downstream to either adsorb residual contaminant that may not have been adsorbed in the upstream booms, and/or to allow continuous operation.

[0023] Alternatively, as depicted in **FIG. 2B**, the boom **200**B may include a pocket **202**B in which a container, typically pillow-shaped, containing the carbonaceous material (not shown) is placed. The boom further includes skirt portion **220**B which is continuous with the top portion **210**B in which the pocket is located. Further coupled to the boom is a chain or other linking structure **230**B that will preferably provide sufficient weight to maintain the boom in a vertical position in the water. Additional coupling elements **222**B may be provided to coupled two booms together to form a linear or circular floating barrier. As most of the pocket of the boom in **FIG. 2B** will contact the water/air interface, contaminant that would otherwise escape from a portion underneath the pocket by wave action will now be retained by the skirt **220**B.

[0024] With respect to the material that retains at least part of the carbonaceous sorbent within the boom, it is generally preferred that the material comprises a (most preferably hydrophobic) textile material that allows penetration of the contaminant (i.e., the compound that is to be adsorbed by the carbonaceous material) through the textile material. For example, suitable materials include rubberized or waxed cotton, synthetic polymers, wire mesh, and all reasonable combinations thereof. Further contemplated materials especially include those that are flame resistant or fireproof. In most preferred aspects, contemplated materials may be integral with or even form the entire remediation device. However, in alternative aspects, the materials may also be coupled to the device via wires, ropes, or other structures.

[0025] Where the material forms most or all of the remediation device, it should be recognized that the device may be in numerous forms, and the particular manner of use will at least in part determine the actual shape of the device. For example, where the contaminant is disposed on land or on a solid surface, contemplated forms may include relatively flat forms (where thickness is at least 10 times less than width and dept), including an envelope, blanket, pillow, etc. Such relatively flat forms may have a smallest dimension of between about less than an inch to 5-10 inches, and even more, while the largest dimension may be between about 2 inches to over 200 inches. Alternatively, and especially where the contaminant is a relatively small spill, suitable forms of the remediation device also include small regularly (e.g., spherical, flat triangular or square, cubes, etc.) or irregularly shaped (e.g., worm-shaped, zigzag shaped, etc.) forms having a largest dimension of preferably less than 5 inches, more preferably less than 3 inches, and even more preferably less than 1 inch. Such devices could be manually deployed onto a spill, moved and/or recovered in a relatively simple manner.

[0026] Alternatively, and especially where the contaminant is floating on the surface of a body of water (e.g., river, bay, lake, ocean, etc.), it is preferred that the material and/or remediation device is configured as a boom that has substantial flexibility to conform to slight surface waves (typically in the range of less than an inch to 2-3 inches). Thus, suitable shapes include cylindrical shapes, and shapes having rectangular cross section. Where the boom is deployed in a body of water with wave action, the boom may also be configured as a generally flat barrier that is substantially vertically disposed in the water (i.e., +/−35 degrees of the absolute vertical to the water surface) such that a lower portion of the boom prevents slippage of contaminant underneath an upper portion containing the carbonaceous adsorbent, while the upper portion of the device adsorbs the contaminant via the carbonaceous adsorbent. With respect to further shapes, sizes, and configurations, it should be appreciated that there are numerous booms known in the art, and all shapes, forms, and sizes of such known booms are also deemed suitable herein.

[0027] In yet further alternative aspects of the inventive subject matter, it is also contemplated that the carbonaceous material may also be applied as bulk material to the medium that has the contaminant. Most preferably, such application of the carbonaceous material is together with a carrier that allows directed application of the carbonaceous material. For example, suitable carriers include liquefied carbon dioxide, hydrophilic gelling agents and binders, and/or water, wherein the carbonaceous material is admixed with the carrier prior to application. Most typically, such application is performed as spray application and/or by pouring the mixture to the contaminated medium.

[0028] Preferred carbonaceous materials are bulk graphene preparations that are commercially available (e.g., from SupraCarbonic, 1030 West 17th Street, Costa Mesa, Calif. 92627). Thus, in one aspect of the inventive subject matter, preferred remediation devices include a boom or other floating structure that includes graphene enclosed in a retaining structure that is configured to allow adsorption of a contaminant to the graphene from an aqueous medium that is in contact with the device.

[0029] Alternatively, contemplated graphene composition may also be prepared from graphite, coal, tar, etc. as described in our copending application with the Ser. No. 11/007,614, which is incorporated by reference herein. Depending on the starting material, reaction conditions, and other parameters, the non-porous carbonaceous material will typically have a smallest dimension of less than 50 nm, more typically less than 20 nm, and most typically less than 10 nm. It should be noted that (similar to purified carbon nanotubes) a significant fraction of the graphene material will aggregate to form a light-weight material in which the graphene layers typically have a contorted configuration. Where more disaggregated material or even isolated graphene layers are desired, it should be recognized that the aggregated material may be dispersed using chemical and/or physical treatments (e.g., one or more solvents, heat, microwave radiation, and/or ultrasound irradiation).

[0030] Still further contemplated alternative suitable materials include carbon fractals, branched nanotubes, and other irregularly shaped carbonaceous material so long as such material is non-porous and has a smallest dimension of less than 100 nm, and more typically of less than 50 nm. Exemplary materials are disclosed in our copending application with the Ser. No. 11/007,614 (supra). Additionally, it should be appreciated that the materials contemplated herein may be derivatized in numerous manners, and especially contemplated derivatizations include metal deposition (and especially with noble metals), derivatization with elements or compounds that produce semi-conductor characteristics (e.g., boron doped), and chemical modification of one or more carbon atoms within the graphene plane and/or edge. Most preferably, metal deposition is performed in which the metal provided from a gas phase (e.g., CVD, PVD, etc.), but other forms are also deemed suitable, including electroless deposition, electrolytic deposition, etc. Chemical modification of the graphene will generally follow known procedures for chemical derivatization of carbon nanotubes, which is well known in the art (e.g., exemplary covalent derivatization methods are described in *J. Mater. Res.*, Vol. 13, No. 9, (1998) p2423-2431; in *Chem. Eur. J.* 2003, 9, 4000-4008, or in U.S. Pat. Nos. 6,187,823, 6,426,134, WO 98/39250, and WO 00/17101, all of which are incorporated by reference herein). Non-covalent derivatization may be achieved by adding derivatized polycyclic aromatic compounds to the graphene compositions to achieve Van-der-Waals anchoring to the graphene.

[0031] Depending on the particular use, it should be recognized that the non-porous carbon composition may be at least partially disaggregated (e.g., to provide isolated graphene layers via solvent disaggregation and dilution), at least partially aggregated (e.g., to increase particle size), compacted, or even compressed to form a solid material that can be further reshaped if desired. Where the carbonaceous material is derivatized, it should be recognized that the derivatization groups may be employed to crosslink the carbonaceous material, or to covalently or non-covalently bind the carbonaceous material to another material. Furthermore, and especially where a relatively low density of the carbonaceous material is desirable, hydrophobic and/or hydrophilic fillers may be admixed to the carbonaceous material. For example, suitable fillers include glass fibers, polymeric fibers, vermiculite, fumed silica, mineral products (e.g., clay, carbonates, . . .), etc. While not limiting to the inventive concept presented herein, it is typically preferred that the carbonaceous non-porous material is used in bulk quantities, which are typically quantities of at least 0.5 gram, more typically at least 5 gram, even more typically at least 50 gram, and most typically at least 500 gram.

[0032] In still further preferred aspects, contemplated carbonaceous materials further include one or more microorganisms that utilize hydrocarbons as carbon source, wherein the microorganism is dispersed or otherwise contained in the carbonaceous material. There are numerous microorganisms known in the art that degrade numerous contaminants adsorbed by contemplated sorbents. For example, certain Pseudomonas strains are known to degrade aromatic halogen-containing wastes and other hydrocarbons as described in U.S. Pat. Nos. 4,477,570 and 4,508,824. Other bacterial strains include those from the genera of *Achromobacter, Arthorobacter, Aspergillus, Bacillus, Candida, Cladosporium, Corynebacterium, Myrothecium, Nocardia, Punicillium, Phialorphora, Rhodotorula, Streptomyces*, and *Trichoderma*. While not limiting to the inventive subject matter, such bacteria may be immobilized in or onto a carrier to avoid or reduce undesired or inadvertent elution from the boom. Such immobilized cultures are known in the art (see e.g., Applied and Environmental Microbiology 67: 1675-1681) and commercially available (e.g., TERI, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi 110 003, INDIA).

[0033] Regardless of the aggregation and/or optional presence of fillers and other ingredients, it is preferred that the carbonaceous material is substantially completely hydrophobic to reduce, and more typically completely avoid waterlogging of the sorbent. Therefore, preferred remediation devices will have a substantially completely hydrophobic and nanostructured material (most typically a material other than a carbon nanotube), wherein the nanostructured material is at least partially enclosed in a retaining structure that is configured to allow adsorption of a contaminant to the hydrophobic material from a medium that is in contact with the device.

[0034] With respect to the contaminant or other compound that is adsorbed to the non-porous carbonaceous material, it is should be recognized that the nature of the contaminant may vary considerably, and a person of ordinary skill in the art will readily be able to determine suitability of a particular compound (e.g., by determining the wt/wt adsorption). Particularly suitable contaminants and compounds that can be adsorbed to contemplated materials include optionally substituted hydrocarbons (e.g., linear, branched cyclic, or polycyclic), wherein suitable substituents include halogens, alkyls, nitrogen containing groups (e.g., secondary or tertiary amines, amides, imides), oxygen-containing groups (e.g., ether, alcohol, aldehyde, acid, ester), and sulfur-containing groups (e.g., thiols, thioesters, disulfides, etc.). Such hydrocarbons may be saturated, contain one or more double bonds, and/or may be aromatic. Additionally contemplated contaminant or other compound include metals (and especially mercury), organic and inorganic acids, oil-based paint, and volatile organic compounds (VOC) having a boiling point at or below room temperature (about 20° C.).

[0035] An exemplary listing of compounds that can be adsorbed by the non-porous carbonaceous materials presented herein is listed in Table 1 in comparison with adsorption capacities for the same compounds using granulated activated carbon. In Table 1 below, NPC refers to non-porous carbonaceous material, GAC refers to granulated activated charcoal, and the numerical values given in the columns refer to gram of contaminant adsorbed per gram of MPC or GAC. The ratio of adsorption using NPC and GAC are indicated in the last column as absolute fold difference.

TABLE 1

CONTAMINANT	NPC	GAC	RATIO NPC:GAC
Acetonitrile	32.1	0.244	131.56
Benzene	31.63	0.272	116.28
Chloroform	24.55	0.264	92.99
Crude Oil	74.51	0.19	392
Dichloromethane	32.76	0.204	160.58
Diesel	36.65	0.222	165
Gasoline	29.76	0.28	106.28
Hexane	27.54	0.262	105.11
Isopropyl Alcohol	22.79	0.212	107.5
Kerosene	40.16	0.224	179.28
Mineral Spirits	29.21	0.188	155.37
Naphtha	24.14	0.202	119.5
Nitric Acid	51.33	0.208	246.77
Phosphoric Acid	60.28	0.232	259.82
Sulfuric Acid	36.54	0.218	167.61
Tetrachloroethane	38.22	0.282	135.53
Toluene	34.89	0.19	183.63
Turpentine	26.68	0.178	149.88
Xylenes	38.61	0.194	199

[0036] Thus, it should be recognized that the non-porous carbonaceous material in the boom or other structure can be loaded at least with 50 wt % of the contaminant or other compound. However, and more typically, the contaminant or other compound is adsorbed on the material in an amount of at least the same weight (with respect to the non-porous carbonaceous material), more preferably at least five times the weight, even more preferably at least ten times the weight, and most preferably at least twenty times the weight of the non-porous carbonaceous material. Of course, it should be recognized that contemplated non-porous carbonaceous materials may adsorb more than one type of compound.

[0037] Consequently, the boom or other structure will have a cavity that is sufficiently sized to allow volume increase provided by such large adsorptive capacity. Viewed from another perspective, it is contemplated that a remediation device will have a cavity that at least partially encloses the non-porous carbonaceous material (the cavity is preferably in fluid contact with the medium containing the contaminant), and wherein the cavity has a volume sufficient to allow adsorption of the contaminant in an amount that is at least five-fold, more typically at least ten-fold, and most typically at least twenty-fold by weight as compared to the weight of the non-porous carbonaceous material in the cavity.

[0038] Thus, specific embodiments and applications of compositions and methods for remediation devices with nanostructured materials have been disclosed. It should be apparent, however, to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive concepts herein. The inventive subject matter, therefore, is not to be restricted except in the spirit of the appended claims. Moreover, in interpreting both the specification and the claims, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced. Furthermore, where a definition or use of a term in a reference, which is incorporated by reference herein is inconsistent or contrary to the definition of that term provided herein, the definition of that term provided herein applies and the definition of that term in the reference does not apply.

1. A remediation device comprising a cavity that at least partially encloses a non-porous carbonaceous material with a sheet-like configuration having a smallest dimension of less than 50 nm, wherein the cavity is fluidly coupled to a medium containing a contaminant, and wherein the cavity has a volume sufficient to allow adsorption of the contaminant in an amount that is at least ten-fold by weight as compared to the weight of the non-porous carbonaceous material in the cavity.

2. The remediation device of claim 1 wherein the carbonaceous material is substantially completely hydrophobic and comprises graphene in an amount of at least 1-10 wt %.

3. The remediation device of claim 2 wherein the device is configured as a boom that at least partially floats on water.

4. The remediation device of claim 3 wherein the boom further comprises a skirt that is at least partially disposed in the water when the boom is in operation.

5. The remediation device of claim 3 wherein the non-porous carbonaceous material is disposed in an envelope that is at least partially enclosed by the cavity.

6. The remediation device of claim 1 further comprising a microorganism that utilizes a hydrocarbon as a carbon source, wherein the microorganism is dispersed in the non-porous carbonaceous material.

7. The remediation device of claim 1 further comprising a connector that couples the device to another remediation device.

8. A remediation device comprising a substantially completely hydrophobic and nanostructured material, wherein the nanostructured material is a material other than a carbon nanotube and has a sheet-like configuration having a smallest dimension of less than 50 nm, and wherein the nanostructured material is at least partially enclosed in a retaining structure that is configured to allow adsorption of a contaminant to the hydrophobic material from a medium that is in contact with the device.

9. The remediation device of claim 8 wherein the nanostructured material is a carbonaceous material.

10. The remediation device of claim 9 wherein the nanostructured material has a smallest dimension of less than 50 nm.

11. The remediation device of claim 9 wherein the nanostructured material has a smallest dimension of less than 10 nm.

12. The remediation device of claim 9 wherein the nanostructured material comprises at least 0.01 wt % graphene.

13. The remediation device of claim 9 wherein the nanostructured material comprises at least 1.0 wt % graphene.

14. The remediation device of claim 8 wherein the device is configured as at least one of a floating boom, a pillow, and an envelope.

15. The remediation device of claim 6 further comprising a microorganism that utilizes a hydrocarbon as a carbon source, wherein the microorganism is dispersed in the non-porous carbonaceous material.

16. The remediation device of claim 8 further comprising a connector that couples the device to another remediation device.

17. A floating remediation device comprising graphene having a sheet-like configuration and a smallest dimension of less than 50 nm and being enclosed in a retaining structure that is configured to allow adsorption of a contaminant to the graphene from an aqueous medium that is in contact with the device.

18. The floating remediation device of claim 17 wherein the contaminant is a hydrocarbon, and wherein the retaining structure is permeable to the hydrocarbon.

19. The floating remediation device of claim 17 wherein the aqueous medium is selected from the group consisting of a lake, a bay, an ocean, and a river.

20. The floating remediation device of claim 17 further comprising a microorganism that utilizes a hydrocarbon as a carbon source, wherein the microorganism is dispersed in the non-porous carbonaceous material.

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