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CA 2391015 C 2009/09/29

(11)(21) **2 391 015**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) Date de dépôt PCT/PCT Filing Date: 2000/11/22
(87) Date publication PCT/PCT Publication Date: 2001/05/31
(45) Date de délivrance/Issue Date: 2009/09/29
(85) Entrée phase nationale/National Entry: 2002/05/09
(86) N° demande PCT/PCT Application No.: US 2000/031948
(87) N° publication PCT/PCT Publication No.: 2001/037970
(30) Priorité/Priority: 1999/11/23 (US60/166,990)

(51) Cl.Int./Int.Cl. *B01D 39/16* (2006.01),
B01D 39/20 (2006.01)

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(54) Titre : MILIEUX POREUX DESTINE A DISSIPER LA CHARGE ELECTRIQUE
(54) Title: POROUS MEDIA FOR DISSIPATING ELECTRICAL CHARGE

(57) Abrégé/Abstract:
Disclosed are porous media, including filter media, that dissipate electrical charges that are generated when a fluid such as a non-polar fluid moves through the porous media. The porous media include a non-conductive glass, polymeric, or ceramic fiber and a conductive polymer fiber, a non-conductive glass or ceramic fiber and a conductive material-coated fiber, a non-conductive glass fiber and a metal-impregnated conductive fiber, a non-conductive synthetic polymeric fiber and a metal-coated fiber, a non-conductive natural polymeric fiber and a conductive material-impregnated fiber, or a non-conductive glass, ceramic, or synthetic polymeric fiber and a metal fiber. A composite filter medium comprises a conductive or nonconductive fiber layer laid on and bonded to an electrically conductive substrate.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 May 2001 (31.05.2001)

PCT

(10) International Publication Number
WO 01/37970 A1

(51) International Patent Classification[7]: B01D 39/16, 39/20

(21) International Application Number: PCT/US00/31948

(22) International Filing Date: 22 November 2000 (22.11.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/166,990 23 November 1999 (23.11.1999) US

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/37970 A1

(54) Title: POROUS MEDIA FOR DISSIPATING ELECTRICAL CHARGE

(57) **Abstract:** Disclosed are porous media, including filter media, that dissipate electrical charges that are generated when a fluid such as a non-polar fluid moves through the porous media. The porous media include a non-conductive glass, polymeric, or ceramic fiber and a conductive polymer fiber, a non-conductive glass or ceramic fiber and a conductive material-coated fiber, a non-conductive glass fiber and a metal-impregnated conductive fiber, a non-conductive synthetic polymeric fiber and a metal-coated fiber, a non-conductive natural polymeric fiber and a conductive material-impregnated fiber, or a non-conductive glass, ceramic, or synthetic polymeric fiber and a metal fiber. A composite filter medium comprises a conductive or nonconductive fiber layer laid on and bonded to an electrically conductive substrate.

POROUS MEDIA FOR DISSIPATING ELECTRICAL CHARGE

TECHNICAL FIELD

The present invention generally relates to porous media that find use in treating fluids, and particularly to electrically conductive porous media such as filter media that dissipate electrical charges that are generated when a fluid such as a non-polar fluid moves through the media.

BACKGROUND OF THE INVENTION

Treatment of non-conductive fluids, e.g., a non-polar hydrocarbon such as gasoline, by the use of porous media such as filter media is known. Such fluid treatments can become difficult or challenging as a result of the build up of static or triboelectric charges. This problem has been recognized in many fields, e.g., processing of food materials such as flour, pumping coal dust or gasoline, and coating of textiles.

As high process rates are desired for economic reasons, the problem arising from the static charge build up can be significant at high fluid velocities and when porous media of small pore sizes are utilized in carrying out the processes. Since conventional porous media are generally nonconductive, the static charges tend to accumulate on the media. If the accumulated charges are not properly discharged, a spark may form with the possibility of igniting the fluid and creating certain risk to operators and property. This situation has been recognized in the filtration industry; see, for example, U.S. Patents 3,933,643; 5,527,569; and 5,229,200.

Attempts have been made to reduce such risks, for example, by providing a moist environment, nuclear ionizers, high voltage images, and wire or metal grounding. The use of porous media made of metal cloth, fiber, or powders can also help to dissipate the charges. However, the filtration efficiency and pore sizes of many of these media are limiting. These media are also expensive to manufacture. Media made of fibers such as glass or ceramic fibers, or organic fibers such as polyester, cellulose, rayon, and polypropylene are more efficient as filters. However, these media are electrically non-conductive and are not effective in discharging or reducing static build up.

BRIEF SUMMARY OF THE INVENTION

The foregoing shows that there exists a need for porous or filter media that have excellent filtration characteristics and that dissipate electrical charges. Much of the foregoing need has been fulfilled by the present invention. The porous media, including filter media, of the present invention are highly efficient filters and yet dissipate electrical charges such as triboelectric charges that are generated when a fluid such as a non-polar fluid moves therethrough.

In accordance with one aspect of the invention, a porous medium comprises in combination a non-conductive glass, polymeric, or ceramic fiber and a conductive polymeric fiber. In accordance with another aspect of the invention, a porous medium comprises in combination a non-conductive glass or ceramic fiber and a conductive material-coated fiber. In accordance with yet another aspect of the invention, a porous medium comprises in combination a non-conductive glass fiber and a metal-impregnated conductive fiber. In accordance with still another aspect of the invention, a porous medium comprises in combination a non-conductive synthetic polymeric fiber and a metal-coated fiber. In accordance with a further aspect of the invention, a porous medium comprises in combination a non-conductive natural polymeric fiber and a conductive material-impregnated fiber. In accordance with another aspect of the invention, a porous medium consists essentially of a non-conductive glass, ceramic, or synthetic polymeric fiber and a metal fiber.

In accordance with another aspect of the invention, a method of making a porous medium comprises laying fibers constituting the porous medium to form a fiber matrix.

Embodiments of the porous medium can be prepared by mixing slurries of the conductive fiber and the non-conductive fiber, with or without a binder, and forming a porous fiber matrix from the mixture. The fiber matrix may be unsupported or it may be supported by a conductive or nonconductive substrate. The porous media of this aspect of the present invention have the advantage that the electrical charges which accumulate on the non-conductive fibers can be discharged readily, as the conductive fibers are in close proximity to, e.g., in intimate contact with, the non-conductive fibers where the charges tend to accumulate.

In accordance with another aspect of the invention, a composite filter medium comprises a fiber layer or matrix laid on and bonded to a conductive porous substrate.

In accordance with another aspect of the invention, a method of making a composite filter medium comprises laying a fiber layer or matrix on a conductive substrate and bonding the fiber layer to the conductive substrate.

Embodiments of the composite filter medium can be prepared by laying, e.g., dry-laying or wet-laying, conductive and/or nonconductive fibers, including filaments, on a conductive substrate and bonding the fiber layer to the conductive substrate. The fiber layer can be chemically bonded (e.g., adhesively bonded or solvent bonded), thermally bonded, and/or mechanically bonded to the conductive substrate. The composite filter media of this aspect of the present invention have the advantage that the electrical charges accumulating on the non-conductive fibers can be discharged readily, as these fibers are in close proximity to, e.g., in intimate bonded contact with, the conductive substrate.

The advantages of the present invention, as well as additional inventive features, will be apparent from the description of the invention provided herein. While the invention is described and disclosed below in connection with certain embodiments and procedures, it is not intended to limit the invention to those specific embodiments and procedures. Rather it is intended to cover all such alternative embodiments and modifications as fall within the spirit and scope of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

The present invention provides porous media such as filter media that dissipate electrical charge such as static or triboelectric charge. The media of the present invention incorporate a conductive material and a non-conductive material. The conductive material is located in close proximity to, e.g., in intimate contact with, the non-conductive material where the electrical charge tends to accumulate. In a preferred embodiment, the location of the conductive material contributes to the advantages of the media of the present invention.

In accordance with an aspect of the invention, a porous medium consists essentially of a non-conductive glass, ceramic, or synthetic polymeric fiber and a metal fiber. Any suitable metal fiber can be employed. The term "metal" herein refers to a metal by itself as well as blends of metals such as alloys. Examples of suitable metals include iron, copper, aluminum, nickel, gold, silver, and alloys that include one or more of metals or conductive materials such as carbon. Examples of alloys include stainless steel, bronze, and brass.

In accordance with another aspect of the invention, a porous medium comprises a non-conductive synthetic polymer fiber and a metal-coated fiber. Metal-coated fibers include fibers such as metal-coated glass, ceramic and polymer fibers, and can be prepared by providing a metal coating on the glass, ceramic, or polymer fibers by methods known to those skilled in the art. For example, a metal coating can be provided by a thermal spray, metal spray, or metallizing processes. These processes include plasma arc spray, flame spray, laser spray, and electric arc spray. In general, in these processes, the coating material is melted, atomized and forced onto the fiber by a high velocity gas stream. In a preferred process, the metal is laser sprayed onto the fiber or a sheet of fibers. The laser spray uses a high power laser, such as CO_2 laser, focused onto the surface of the sheet of fibers. A carrier gas such as helium blows metal particles into the path of the laser and onto the fibers. In another process, a fabric or web of fibers can be metallized, and the resulting fabric or web is torn apart to obtain metal-coated or metallized fibers. The metal coating can cover the surface of the fiber partially or completely.

In accordance with still another aspect of the invention, a porous medium comprises a non-conductive glass fiber and a metal-impregnated fiber. The metal-impregnated fiber can be a metal-impregnated polymer, ceramic, or glass fiber. For example, a wide variety of non-conductive polymers can be impregnated with a metal. The impregnation can be carried out by any suitable method. For example, a metal powder can be combined with a polymer powder or pellet, and the resulting mixture can be processed, e.g., extruded, to form metal-impregnated fibers. Alternatively, a metal powder can be mixed with a solution of a polymer, and the resulting slurry can be spun into metal-impregnated fibers. In another example, a metal compound, such as, e.g., metal oxide, halide, carbonate, or alkoxide, can be combined with a polymer and the resulting mixture processed into a fiber. The resulting fiber can be suitably treated, e.g., treated with a reducing agent such as hydrogen, to convert the metal compound to the metal (zero valency) state.

Metal-impregnated glass fibers can be prepared from a molten glass mixture containing a metal, e.g., by known glass fiber making techniques such as melt blowing. Metal-impregnated ceramic fibers can be prepared, e.g., by combining a metal or a metal compound with a precursor of the ceramic material such as a silane polymer and shaped into a fiber, e.g., by melt spinning. The resulting fiber can be treated, e.g., heated in a suitable atmosphere, to obtain a metal-impregnated ceramic fiber.

In accordance with another aspect of the present invention, a porous medium comprises a non-conductive glass, polymeric (which can be synthetic or natural), or ceramic fiber and a conducting polymer fiber. Any suitable conducting polymer fiber, including filaments, can be incorporated with the non-conductive fiber, for example, fibers made of a conducting polymer (i.e., intrinsically conducting polymer) such as a conjugated polymer, e.g., polyacetylene, polyarylene, polyheterocycle, poly(arylene vinylene), and polyaniline, or a combination thereof, can be incorporated. Additional examples of conducting polymers include polymers which include, or are modified to include, ionic or charged groups such as carboxyl, sulfonic, phosphonic, ammonium, sulfonium, or phosphonium groups.

In accordance with another aspect of the invention, a porous medium comprises a non-conductive glass or ceramic fiber and a conductive material-coated fiber. The conductive material is coated on a non-conductive fiber. Any suitable non-conductive fiber can be employed, preferably a polymer fiber. The polymer fiber can be natural or synthetic. The conductive material can be metal, metal compound, e.g., metal oxide, carbon, ceramic, or conductive polymer.

In another aspect of the invention, a porous medium comprises a non-conductive natural polymeric fiber and a conductive material-impregnated fiber.

Further, a wide variety of non-conductive polymers, e.g., the non-conductive polymers discussed below, can be coated or impregnated with a conductive material such as carbon or metal or an ionic material. Examples of ionic materials include ionic polymers such as anionic and/or cationic charged polymers. Typical ionic charged polymers contain negatively charged groups such as carboxyl, sulfonic, or phosphonic groups, or positively charged groups such as ammonium, sulfonium, or phosphonium groups. The positively charged groups can also be present as quaternized groups. Carboxymethyl cellulose is an example of an ionic polymer.

The non-conductive fiber, in the various aspects of the invention, can include a short fiber, filament, or yarn, made of glass, polymeric (e.g., synthetic polymeric), ceramic, or combinations thereof. Examples of glass fibers include borosilicate. A wide variety of non-conductive polymeric fibers, including non-conductive synthetic polymeric fibers, are available. Examples of ceramic fibers include alumina, silica, silicates, and quartz. Glass fibers are preferred. The non-conductive glass, polymeric, or ceramic fibers can further include a coating, e.g., a coating that improves the durability, abrasion resistance, or processability of the fiber. An example of a suitable coating is a fluorocarbon coating, e.g., a fluoropolymer such as PTFE.

The fibers can have any suitable dimensions. For example, the conductive fibers or the non-conductive fibers can have a diameter of from about 1 μm or less to about 100 μm or more, preferably from about 1 μm to about 10 μm, and more preferably from about 1 μm to about 3 μm. The conductive fibers can be incorporated within the non-conductive fiber matrix in an amount that imparts the desired electrical conductivity to the porous medium, for example, less than about 50%, typically up to about 25% or more, preferably from about 15% to about 25%, and more preferably from about 22% to about 25%, by weight of the porous medium.

The porous medium can be prepared by any suitable method, including by dry-laying or wet-laying. For example, a slurry containing a mixture of conductive fibers (e.g., metal fibers) and non-conductive fibers can be prepared. Alternatively, a slurry of the conductive fiber and a slurry of the non-conductive fiber can be prepared separately and the slurries admitted to a mixing chamber where the slurries are mixed. The slurries can be prepared in any suitable carrier, e.g., water or alcohol. As the density of the metal, metal-coated, or metallized fiber is generally higher than that of most non-conductive fibers, the viscosity and/or the flow rate of the slurries may be suitably adjusted to obtain the desired metal content and uniformity of metal distribution in the porous medium. The slurries can also include additives such as binders to improve the bonding of the fibers to one another, and/or suspension aids such as surfactants or thickeners to stabilize the slurries.

The mixture is processed to form a matrix or web. The matrix can be formed by any suitable method, e.g., by methods known in the production of non-woven fabrics or webs such as paper. The mixture of fiber slurries can be laid on a surface, such as a screen, on which a matrix can be formed and from which the thus formed matrix can be later removed. The matrix of conductive and non-conductive fibers can also be laid on a porous support, such as a conductive or non-conductive substrate to form a composite filter medium. For example, a forming-machine such as an inclined-wire fourdriner or a cylinder former can be employed for forming the matrix. By applying suction or vacuum during the formation of the matrix, one can remove the carrier as well as adjust the thickness, porosity, or density of the matrix. The matrix obtained can be subjected to bonding processes, e.g., stitching, needle-felting, or calendaring, to better interlock the fibers or to improve or adjust the strength, flexibility, porosity, density, loft, and/or thickness of the matrix. Alternatively, the matrix can be formed by extruding the slurry mixture in a suitable extruder containing a die, e.g., a slot die.

The fibers of the matrix can be bonded in a variety of ways. For example, the bonding of the fibers to one another can be carried out by any suitable means, e.g., mechanical, chemical, solvent, and/or thermal means. In mechanical bonding, the fibers can be interlocked by simply laying the fibers and/or by friction methods such as needle-felting, stitchbonding, and/or hydroentangling. Chemical bonding can involve applying a resin, e.g., an adhesive resin, to the matrix by saturating, dipping, immersing, spraying, printing, and/or foaming. Alternatively, an adhesive resin can be included in the slurry mixture, and the resin can be activated to bond the fibers to one another. The resin can be activated by heat or light. The light can be of any suitable wavelength, e.g., microwave, far infrared, infrared, visible, uv, far-uv, x-ray, or gamma ray. A solvent also can be used to bond the fibers. The solvent acts by dissolving, swelling, or softening a portion of the fiber, and the polymer in the resulting solution or the swollen or softened portion acts as a binder. The solvent can be later removed. In thermal bonding, heat can be used to fuse or weld the fibers together. A combination of two or more bonding processes can also be employed.

In accordance with another aspect of the present invention, a composite filter medium comprises a fiber layer or matrix laid on and bonded to an electrically conductive substrate. The fiber matrix may be bonded by any suitable means, e.g., chemically, thermally, by the use of a solvent, and/or mechanically entangled or interlocked.

In aspects of the invention, suitable polymer fibers include natural polymer fibers and synthetic polymer fibers. Examples of natural fibers include wool fibers and cellulose fibers. Examples of cellulose fibers include cotton, ramie, hemp, jute, flax, bagasse, eucalyptus, and esparto. Examples of synthetic fibers include polyolefins, polyamides, polyimides, copolyimides, polyarylene oxides, polyarylene sulfides, polyesters, polycarbonates, polysulfones, polyketones, polyether ether ketones derivatives of cellulose, acrylics, phenolics, polyacrylonitrile, and acetates. Examples of polyolefins include polyethylene, polypropylene, and halogenated polyolefins such as PTFE, PVDF, PVC, and polychlorotrifluoroethylene, and copolymers of halogenated olefins with halogenated or non-halogenated olefins. Examples of polyamides include aliphatic polyamides such as nylon 6, nylon 66, nylon 612, and nylon 46, aromatic polyamides such as ARAMID™ or KEVLAR™, and aliphatic aromatic polyamides such as nylon 6T. Examples of phenolic fibers include NOVOLOID™ fibers. Examples of polyesters include PET and PBT. Examples of cellulose derivatives include rayon and fibers made from wood such as TENCEL™.

The fibers can be laid on the substrate by any suitable method, e.g., the fiber can be dry-laid, or preferably, wet-laid. Thus, for wet-laying, the fibers can be mixed with a carrier, such as water or alcohol, and a resin, such as an adhesive resin, and the fiber slurry containing the resin can be laid on the conductive substrate, e.g., as a thin layer. The resulting fiber-laid substrate can be dried to remove the carrier. Further, the resin can be activated to bind the fiber matrix to the substrate and form a composite filter medium. The resin can be activated, for example, by the application of a chemical, solvent, light, radiation, or preferably heat. Thus, as the resin is activated, it melts, softens, swells, dissolves, and/or cures and binds the substrate to the fiber layer and/or the fibers to one another. In another embodiment, a conductive substrate can be coated with a resin, e.g., a surface of the conductive substrate can be coated with a resin, and a mixture of fibers can be laid on the resin-coated substrate. The fiber-laid substrate can be dried to remove any carrier, and the resin can be activated to bond the fiber matrix to the conductive substrate and/or the fibers to one another, thereby forming the composite filter medium. In yet another embodiment, a resin can be introduced to the filter matrix and the conductive substrate, for example, by saturating, immersing, or spraying

Any resin suitable for providing improved bonding can be used. The resin is preferably an adhesive. The adhesive can be a thermoplastic resin such as, for example, a resin that melts or softens when heated, e.g., a hot melt adhesive, or a thermosetting resin such as a resin that hardens upon activation by heat, oxygen, moisture, or radiation, e.g., an epoxy, acrylic, vinylic, cyanoacrylate, silicone, or urethane resin. An example of a suitable resin is polyvinyl acetate.

In many embodiments, the fiber layer (or matrix) and the substrate can be bonded without the use of a resin. Thus, for example, polymer fibers can be laid on the conductive substrate, and the fiber-laid substrate heated to soften or melt and bond the substrate to the fiber layer as well as the fibers to one another, thereby forming a composite filter medium. The fibers, including non-polymer fibers, can also be mechanically bonded to the substrate. The fibers can be mechanically entangled with and interlocked to the substrate, e.g., as the fibers are laid on the substrate, thereby forming a composite filter medium. Alternatively, or additionally, fibers can be laid on the conductive substrate, followed by suitable processing, e.g., by needle-felting, to further enhance the mechanical bonding between the fibers and the substrate.

The substrate provides physical or mechanical support for the fiber layer or matrix. The substrate is porous, and typically has a pore size greater than that of the fiber matrix it supports in order to minimize or reduce pressure drop during filtration. For example, the substrate may have a nominal pore size in the range from about 20 μm or less to about 250 μm or more, and preferably in the range of from about 50 μm or to about 100 μm.

The electrically conductive substrate can be fashioned, for example, as a mesh, screen, netting, network, or woven or nonwoven sheet, fabric or web and can be composed of any suitable conductive or nonconductive base material or materials. For example, the substrate can comprise a metal, metal-coated or metallized mesh, fabric, or web. The electrically conductive substrate preferably includes a woven or non-woven fabric, web, or mesh of a non-conductive base material, such as a non-conductive polymer. More preferably, the electrically conductive substrate includes a non-woven fabric, web, or mesh made of a non-conductive polymer. An example of a non-woven mesh is an extruded polymer mesh. A preferred example of a suitable base material is a non-woven polyester fabric such as a fabric available under the trade designation REEMAY.

The non-conductive base material can be modified in a variety of ways to render the substrate electrically conductive, e.g., the base material can be coated or impregnated with a conductive material such as carbon, metal, and/or metal compound. Thus, for example, the base material can be coated with a composition comprising a carbon, e.g., graphite, and a binder. The conductive material coating or impregnation can be present at a suitable loading, e.g., in the range from about 20% or less to about 50% or more, preferably from about 30% to about 50%, and more preferably from about 40% to about 45% by weight of the base material. The conductive material can be present, e.g., as a coating, on either or both sides of, but preferably throughout, the non-conductive base material web, fabric, or mesh. Advantageously, an adhesive resin can be included along with the conductive material to improve bonding of the conductive material to the base material.

Substrates based on woven or non-woven fabric, web, or mesh of a non-conducting polymer have the advantage that they are flexible and mechanically more stable and/or robust, e.g., during fabrication and/or operation of filter devices. Alternatively, or in addition, media involving such substrates may leach fewer materials such as residues or fragments into the processed fluid streams compared to media involving substrates based on certain metal or carbon fibers.

Alternatively, the electrically conductive substrate can be a fabric, web, or mesh made of a conductive base material such as carbon. The carbon fabric, web, or mesh can be made from graphite, pitch or a carbonizable polymer fiber, web, or mesh. An example of a pitch is coal tar pitch. An example of a carbonizable polymer is polyacrylonitrile. Another example of a carbonizable polymer is a polyimide such as the polyimide available under the trade designation KAPTON. In embodiments, the carbon can be produced from a polyester such as a thermosetting polyester. A fabric, web, or mesh made of a carbonizable polymer can be heated, preferably in the absence of oxygen or air, to high temperatures to bring about the loss of hydrogen, nitrogen, and/or oxygen and the formation of a carbon fabric, web, or mesh.

The electrically conductive base material can also be made from conducting polymers such as conjugated polymers, e.g., polyacetylenes, polyarylenes, polyheterocycles, poly(arylene vinylenes), and polyanilines, or combinations thereof. The substrate can be composed entirely of a conducting polymer, or alternatively, a non-conductive base material, e.g., nylons or polyesters, can be coated with a conducting polymer to make an electrically conductive substrate.

The porous medium, matrix, or the composite filter medium of the present invention can have any suitable pore size, e.g., less than about 100 μm, preferably from about 0.05 μm to about 100 μm, more preferably from about 0.05 μm to about 25 μm, and even more preferably from about 1.0 μm to about 25 μm. Media of submicron pore size, for example, less than 1 μm, are also preferred for many filter applications. In embodiments, the media have a pore size of about 50 μm or less.

Conductive filter matrices, substrates, porous media, and composite filter media of the present invention preferably have high electrical conductivity or low electrical resistivity, e.g., a surface resistivity on the order of about 10^{12} ohms/square or less, typically on the order of about 10^{10} ohms/square or less, preferably on the order of about 10^6 ohms/square or less, more preferably on the order of about 10^4 ohms/square or less, e.g., from about $1x10^3$ ohms/square or less to about $7x10^3$ ohms/square or more. Alternatively or additionally, conductive filter matrices, substrates, porous media, and composite filter media preferably have a volume resistivity on the order of about 10^{10} ohm centimeters or less. The surface and/or volume resistivity can be determined by methods known to those skilled in the art, e.g., by the ASTM Method D257 and/or D4496.

In another aspect of the present invention, a method for dissipating charges generated during the treatment of a fluid comprises contacting the electrically conductive porous media or composite filter media described above with the fluid. The method involves placing the fluid in contact with the upstream surface of the medium and passing at least a portion of the fluid through the medium. The medium inhibits electrical charge imbalance or charge build up. Filter packs, filter elements and filter assemblies which may incorporate the porous media and/or composite filter media embodying the present invention are disclosed in PCT International Application Publication Number WO 01/037969.

The following examples further illustrate the present invention, but of course should not be construed in any way as limiting the scope of the invention.

EXAMPLE 1

This Example illustrates an advantage of a filter medium according to an embodiment of the present invention.

An aqueous fiber slurry is prepared by mixing 100 lbs. of glass fibers of 1.0 μm nominal diameter and 10 lbs. polyvinyl acetate resin in 100 gallons of water. The slurry is then laid on a non-woven fabric of 1 oz/square yard basis weight containing 2 denier polyester fibers. The wet fibers are laid such that 6 grams of dry fiber are ultimately available per square foot of the substrate. The fibers are dried by applying heat and the resin is heat activated to form a composite filter medium. The resulting filter medium has an average pore size of 6 μm.

The surface resistivity of the composite filter medium is measured by a method substantially as disclosed in ASTM D4496. Thus, the surface resistivity is measured on a 1x4 inch sample using a set of 4 brass 1x1 inch sheets clipped on either end of the samples. This test arrangement provides a 1x2 inch section for surface resistivity measurement. The measured resistance is multiplied by the width of the sample and divided by the gage length. The surface resistivity is greater than 10^6 ohms/square.

Four samples of the filter media, also of 6 µm grade, in accordance with the present invention are similarly prepared by wet-laying a slurry mixture of glass fiber and polyvinyl acetate resin on a non-woven substrate composed of a polyester base material that has been previously coated with conductive carbon. The fiber layer is dried and the resin is heat activated. The resulting filter media are tested for surface resistivity as above. The surface resistivities of the samples are 1.8×10^3, 1.5×10^3, 3.9×10^3, and 6.3×10^3 ohms/square. It is believed that the observed conductivity (or low resistivity) is mainly due to the conductive substrate. The filter media of the present invention have higher conductivities than certain media that do not include a conductive substrate.

EXAMPLE 2

This Example illustrates an advantage of a porous medium according to an embodiment of the present invention. An aqueous slurry mixture containing glass fibers 75% by weight of the fiber mixture and stainless steel fibers 25% by weight is prepared by mixing 25 grams of 2 µm stainless steel fibers, 75 grams of 2 µm glass fibers, and 2000 grams of water. The resulting slurry is laid on a screen to form a layer. The residual water in the fiber is removed by heating the fiber layer. The dried fibers of the layer are entangled or interlocked by needle-felting. The surface resistivity of the medium is measured as in Example 1 and is less than 10^6 ohms/square.

EXAMPLE 3

This Example illustrates an advantage of a porous medium according to another embodiment of the present invention. A porous glass fiber media sheet is aluminum coated by laser arc spray coating. The aluminized media sheet is re-pulped by tearing apart the sheet and blended with unmetallized glass fibers. The amount of metallized fibers is kept at about 25% by weight of the fiber mixture. The resulting mixture is fabricated into a porous medium as discussed in Example 2. The surface resistivity of the medium is measured as in Example 1 and is found to be less than 10^6 ohms/square.

While this invention has been described with an emphasis upon certain embodiments, it will be obvious to those of ordinary skill in the art that variations of the embodiments may be used and that it is intended that the invention may be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications encompassed within the spirit and scope of the invention as defined by the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A porous medium comprising non-conductive glass, ceramic, or synthetic polymeric fibers and conductive fibers, wherein the conductive fibers are in close proximity to the non-conductive fibers and the conductive fibers include metal, carbon, or conductive polymeric fibers, the conductive fibers comprising less than about 50% by weight of the conductive and nonconductive fibers and having diameters in the range from about 1 μm or less to about 10 μm.

2. The porous medium according to claim 1, wherein the porous medium has a pore size of about 50 μm or less.

3. The porous medium according to claim 1 or 2, wherein the conductive fiber is incorporated in an amount of up to about 25% by weight of the porous medium.

4. The porous medium according to any one of claims 1 to 3, which includes a binder that bonds the fibers to one another.

5. The porous medium according to claim 4, wherein the binder is an adhesive resin.

6. The porous medium according to any one of claims 1 to 5, wherein the conductive fibers and the non-conductive fibers are mechanically bonded to one another.

7. A composite filter medium comprising a fiber layer including non-conductive glass, ceramic, or synthetic polymeric fibers and conductive fibers, wherein the conductive fibers are in close proximity to the non-conductive fibers and the conductive fibers include metal, carbon, or conductive polymeric fibers, the conductive fibers comprising less than about 50% by weight of the conductive and nonconductive fibers and having diameters in the range from about 1 μm or less to about 10 μm and a substrate, wherein the fiber layer is disposed on the substrate.

8. The composite filter medium according to claim 7, wherein the substrate is electrically conductive.

9. The composite filter medium according to claim 7, wherein the substrate is electrically non-conductive.

10. The composite filter medium according to any one of claims 7 to 9, wherein the fiber layer is bonded to the substrate.

11. The composite filter medium according to any one of claims 7 to 10, wherein the fiber layer includes a binder that bonds the fibers to one another.

12. The composite filter medium according to claim 11, wherein the binder is an adhesive resin.

13. The composite filter medium according to any one of claims 7 to 12, wherein an adhesive resin is present in the interface between the fiber layer and the substrate.

14. The composite filter medium according to any one of claims 7 to 13, wherein the fiber layer includes a conductive fiber incorporated in an amount of up to about 25% by weight of the conductive and nonconductive fibers.

15. The composite filter medium according to any one of claims 7 to 14, wherein the fiber layer has a pore size of about 50 µm or less.

16. The composite filter medium according to any one of claims 7 to 15, wherein the fiber layer has a pore size of about 25 µm or less.

17. A method for preparing a porous medium comprising laying non-conductive glass, ceramic, or synthetic polymeric fibers and laying conductive metal, carbon, or polymeric fibers in an amount that is less than about 50% by weight of the conductive and nonconductive fibers and in close proximity to the non-conductive fibers, wherein

the conductive fibers have diameters in the range from about 1 μm or less to about 10 μm, to form a porous medium.

18. The method for preparing a porous medium according to claim 17, further comprising laying the porous medium on a substrate and bonding the porous medium to the substrate.

19. A method for dissipating charges generated during treatment of a fluid comprising contacting the fluid with the porous medium as defined in any one of claims 1 to 6.

20. A method for dissipating charges generated during treatment of a fluid comprising contacting the fluid with the composite filter medium as defined in any one of claims 7 to 16.