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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 October 2015 (01.10.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/148471 A1

(51) International Patent Classification:
C23C 16/40 (2006.01) *B65D 23/02* (2006.01)
C23C 16/36 (2006.01) *A61J 1/05* (2006.01)
C23C 16/04 (2006.01) *B65D 25/34* (2006.01)
C23C 16/50 (2006.01) *B65D 1/02* (2006.01)

(21) International Application Number:
PCT/US2015/022189

(22) International Filing Date:
24 March 2015 (24.03.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/971,975 28 March 2014 (28.03.2014) US

(71) Applicant: **SIO2 MEDICAL PRODUCTS, INC.** [US/US]; 350 Enterprise Drive, Auburn, Alabama 36832 (US).

(72) Inventors: **YAMAMOTO, Tadashi**; 300 E. Longleaf Drive, Auburn, Alabama 36832 (US). **WEIKART, Christopher**; 319 Bentley Court, Auburn, Alabama 36830 (US). **FELTS, John T.**; 2624 Calhoun Street, Alameda, California 94501 (US). **BERGGREN, John**; 2255 Springhill Drive, Auburn, Alabama 36830 (US).

(74) Agent: **GORNISH, David B.**; SiO2 Medical Products, Inc., 2570 Boulevard of the Generals, Suite 215, Norristown, Pennsylvania 19403 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Continued on next page]

(54) Title: ANTISTATIC COATINGS FOR PLASTIC VESSELS

(57) Abstract: A method of reducing static charge of a plastic container is provided. The method includes providing a PECVD coating of SiCOH, SiO_x or SiOH to an external support surface of the container. The PECVD coating reduces static charge of the container compared to a reference container that is essentially identical to the container except that the reference container is uncoated.

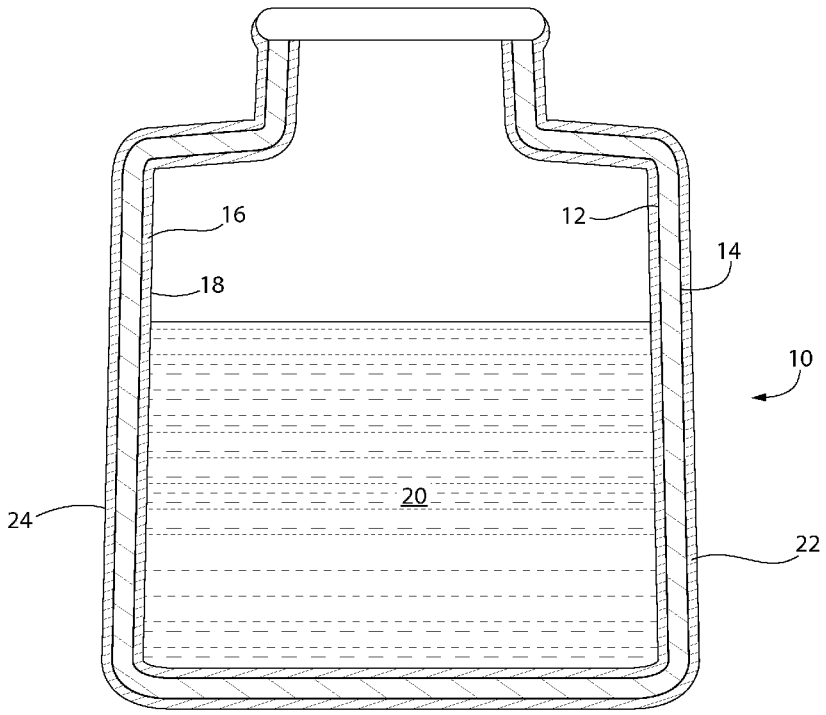


FIG. 1

WO 2015/148471 A1

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ANTISTATIC COATINGS FOR PLASTIC VESSELS

FIELD OF INVENTION

[0001] The invention relates generally to coatings for plastic vessels, e.g., containers, to reduce or prevent static charge on the vessels. More particularly, the invention relates to use of vapor deposition coatings on plastic containers to reduce attraction of charged particles to the containers, in order to decrease particulate contamination.

BACKGROUND

[0002] An important consideration in manufacturing packaging for regulated products, e.g., pharmaceuticals, is to ensure that the pharmaceutical product to be contained within a package is substantially free of contaminants. Therefore, processes for manufacturing and filling pharmaceutical packages with product, are typically performed under cleanroom conditions.

[0003] One cause of potential contamination is particulates. Particulate contamination may originate from various sources, which may be generally divided into two categories: (1) intrinsic contaminants; and (2) extrinsic contaminants. Intrinsic contaminants are product and process related or generated particulates, for example, laser etching residues, filter media, cleanroom uniform fibers, rubber and plastic particles from filter housing, and needle shields. Extrinsic contamination comes from sources unrelated to product or process, for example, hair, skin cells, pollen, clothing fibers, salt and soil.

[0004] While filtration systems and good manufacturing practices can limit the surface and airborne particulate count in an area where containers are being manufactured or filled, these things do not always reduce particulate count on the container surfaces to acceptable levels. One particular challenge is presented by static charges of manufactured plastic containers, which tend to attract charged particles. Even if the airborne/surface particulate count is relatively low, a plastic container with a strong static charge can act as a magnet of sorts to attract particulate contaminants and cause them to adhere to the container.

[0005] Attempted solutions to this problem include use of antistatic additives for polymers, such as ethoxylated alkylamines, ethoxylated alkyl amides, glycerol stearates, fatty acid esters, esters or ethers of polyols and sodium alkyl sulfonates. The amounts of such additives in polymers typically vary from 0.1% to 3% by weight. While these additives are somewhat effective in reducing the static charges of plastic articles or vessels that incorporate them, the additives are mobile in the polymer matrix and tend to bloom to the surface. Additives that bloom to the surface can contaminate the surface and the contents, especially liquid contents, of a container made from a polymer with such additives.

[0006] There is therefore a need for plastic articles or vessels that are treated to reduce their static charge without the use of typical antistatic additives, which may themselves be a source of contamination. Likewise, there is a need for methods of treating plastic articles or vessels to reduce their static charge without the use of typical antistatic additives.

SUMMARY

[0007] Accordingly, in one aspect, the invention is a method of reducing static charge of a plastic vessel. The method includes providing a PECVD coating of SiCOH, SiO_x or SiOH to an external support surface of the vessel. The PECVD coating reduces static charge of the coated vessel compared to a reference container that is essentially identical to the coated vessel except that the reference container is uncoated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a schematic sectional view of a vial according to an embodiment of the present invention.

[0009] Fig. 2 is a schematic sectional view of a vial according to an alternative embodiment of the present invention.

[0010] Fig. 2A is an enlarged detail view of a portion of the vial wall and coatings of Fig. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] A "vessel" in the context of the present invention can be any type of vessel with at least one opening and a wall defining an interior surface. The term "at least" in the context of the present invention means "equal or more" than the integer following the term. Thus, a vessel in the context of the present invention has one or more openings. One or two openings, like the openings of a sample tube (one opening) or a syringe barrel (two openings) are generally contemplated, although vessels with many openings (e.g., microtiter plates) are within the scope of the invention. If the vessel has two openings, they can be of same or different size. If there is more than one opening, one opening can be used for the gas inlet for a PECVD coating method according to an aspect of the invention, while the other openings are either capped or open. A vessel according to the present invention can be, for example, a sample tube, e.g. for collecting or storing biological fluids like blood or urine, a parenteral container, such as a cartridge or syringe (or a part thereof, for example a syringe barrel) for storing or delivering a biologically active compound or composition, e.g. a medicament or pharmaceutical composition, a vial for storing biological materials or biologically active compounds or compositions, a pipe, e.g. a catheter for transporting biological materials or biologically active compounds or compositions, or a cuvette for holding fluids, e.g. for holding biological materials or biologically active compounds or compositions, or secondary packaging (e.g., vial trays). Vessels of other types are also contemplated. A vessel can be of any shape, a vessel having a substantially cylindrical wall adjacent to at least one of its open ends being preferred. Generally, in optional embodiments, the interior wall of the vessel is cylindrically shaped, like, e.g. in a sample tube, syringe barrel or vial.

[0012] In the present disclosure, "thermoplastic material" is defined as including polymeric resin compositions. In certain embodiments, the polymeric resin compositions can be injection moldable resin compositions, which are preferred because injection molded containers can be made inexpensively, with narrow tolerances and a high level of automation. Several specific examples of the polymers from which thermoplastic compositions can be made, any of which are contemplated for any embodiment, are: an olefin polymer; polypropylene (PP); polyethylene (PE); cyclic olefin copolymer (COC); cyclic olefin polymer (COP); polymethylpentene; polyester; polyethylene terephthalate; polyethylene naphthalate; polybutylene terephthalate (PBT); polyvinylidene chloride

(PVdC); polyvinyl chloride (PVC); polycarbonate; polylactic acid; polystyrene; hydrogenated polystyrene; polycyclohexylethylene (PCHE); epoxy resin; nylon; polyurethane polyacrylonitrile; polyacrylonitrile (PAN); an ionomeric resin; Surlyn® ionomeric resin; or a combination of any two or more of the foregoing.

[0013] In vessels according to the present invention such as containers (e.g., laboratory ware, parenteral containers or vials), a chemical vapor deposition coating is applied directly or indirectly on a support surface of the vessel. In the non-limiting exemplary embodiment of a plastic (in this case, COP) vial according to the present invention shown in Fig. 1, the vial 10 includes an internal support surface 12 and an external support surface 14. A coating 16 (which may include a single layer or a coating set of more than one layer) applied to the internal support surface 12, defines a contact surface 18, i.e., adapted to contact contents 20 (e.g., liquid contents) of the vial 10 when the vial 10 is filled. A coating 22 is also applied to the external support surface 14, which defines an antistatic surface 24 adapted to reduce static charge of the vial 10 compared to a plastic vial without an antistatic surface (i.e., a reference vial).

[0014] The coatings 16, 22 are preferably applied using a vapor deposition process. While various vapor deposition processes may be used, a preferred example of a vapor deposition process for use according to the present invention is plasma enhanced chemical vapor deposition (PECVD). PECVD apparatus and methods for depositing any of the coatings defined in this specification, for example the coatings comprising silicon, oxygen, and optionally carbon identified in this specification, are disclosed, for example, in WO2013/071,138, published May 16, 2013, which is incorporated here by reference.

[0015] The antistatic surface 24 formed by the PECVD coating 22 optionally can have many different properties and advantages, depending on how it is applied and the materials of the external support surface 14 and the coating 22. Some advantages that can be realized in certain embodiments of the technology are provided here. The disclosed or claimed technology is not limited, however, to embodiments implementing one or more of these advantages and features.

[0016] An optional advantage realized in certain embodiments is that the contact surface 18 and antistatic surface 24 formed by the PECVD coatings 16, 22 have improved cleanliness, defined as reduced levels of foreign substances such as particulates, compared to the support surfaces 12, 14

before application of the coatings 16, 22, or compared to a reference vessel or container that is uncoated but otherwise essentially the same (in terms of size, shape, materials and conditions of the ambient environment it is exposed to). Another optional advantage realized in certain embodiments is that the contact surface 18 and antistatic surface 24 formed by the PECVD coating 16, 22 have reduced particulates and optionally enhanced scratch resistance compared to the support surfaces 12, 14 before application of the chemical vapor deposition coating 22, or compared to a reference vessel or container that is uncoated but otherwise at least essentially the same. As discussed further herein, it is contemplated that the coating 22 and antistatic surface 24 have antistatic properties that reduce the vial's propensity to attract particulate contaminants. Optionally, the coating 16 and contact surface 18 also have antistatic properties that reduce the vial's propensity to attract particulate contaminants.

[0017] Optionally, instead of a single PECVD coating on a support surface of a vessel, a coating or layer set may be applied thereon. For example, as shown in the alternative vial 30 embodiment of Figs. 2 and 2A, the internal support surface 32 of the vial 30 comprises a tie coating or layer 34, a barrier coating or layer 36, and a pH protective coating or layer 38. This embodiment of the container coating or layer set 40 is referred to herein as a "trilayer coating" in which the barrier coating or layer 36 of SiO_x optionally is protected against contents having a pH otherwise high enough to remove it by being sandwiched between the pH protective coating or layer 38 and the tie coating or layer 34, each an organic layer of SiO_xC_y as defined in this specification. In this embodiment, the pH protective coating or layer 38 (i.e., the outer most layer of the coating set 40) defines a contact surface 44, i.e., adapted to contact contents 20 (e.g., liquid contents) of the vial 30 when the vial 30 is filled. The trilayer coating and the contact surface 44 of the trilayer coating may optionally have antistatic properties.

[0018] Optionally, a single PECVD coating 42 having antistatic properties may be applied to the external support surface 46 of the vial 30. The coating 42 has an antistatic surface 48. Alternatively, a vial includes only a single PECVD coating on its internal support surface and its external support surface, or, alternatively, is uncoated on its internal support surface and is only coated with a single antistatic coating on the external support surface. If a single coating is applied to the external support surface (or internal support surface), the coating may optionally be SiO_x or

SiOH, or SiCOH. Optionally, the vapor deposited coating 42 has a thickness of 1nm to 1000 nm, optionally 1nm to 900 nm, optionally 1nm to 800 nm, optionally 1 nm to 700 nm, optionally 1 nm to 600 nm, optionally 5 nm to 500 nm, optionally 5 nm to 400 nm, optionally 5 nm to 300 nm, optionally 5 nm to 200 nm, optionally 5 nm to 100 nm, optionally 10 nm to 100 nm, optionally 10 nm to 75 nm, optionally 10 nm to 50 nm.

[0019] Properties of various coatings or layers are now described with reference to Fig 2A. The tie coating or layer 34, sometimes referred to as an adhesion coating or layer, is provided. The tie coating or layer 34 optionally functions to improve adhesion of a barrier coating or layer 36 to a substrate, in particular a thermoplastic substrate, e.g., a wall of the vial 30.

Tie Coating or Layer

[0020] Optionally, the tie coating or layer 34 comprises SiO_xC_y or SiN_xC_y, preferably can be composed of, comprise, or consist essentially of SiO_xC_y, wherein x is from about 0.5 to about 2.4 and y is from about 0.6 to about 3. The atomic ratios of Si, O, and C in the tie coating or layer 34 optionally can be: Si 100 : O 50–150 : C 90-200 (i.e. x = 0.5 to 1.5, y = 0.9 to 2); Si 100 : O 70–130 : C 90-200 (i.e. x = 0.7 to 1.3, y = 0.9 to 2); Si 100 : O 80–120 : C 90-150 (i.e. x = 0.8 to 1.2, y = 0.9 to 1.5); Si 100 : O 90-120 : C 90-140 (i.e. x = 0.9 to 1.2, y = 0.9 to 1.4); or Si 100 : O 92-107 : C 116-133 (i.e. x = 0.92 to 1.07, y = 1.16 to 1.33). The atomic ratio can be determined by XPS. Taking into account the H atoms, which are not measured by XPS, the tie coating or layer 34 may thus in one aspect have the formula $Si_wO_xC_yH_z$ (or its equivalent SiO_xC_y), for example where w is 1, x is from about 0.5 to about 2.4, y is from about 0.6 to about 3, and z is from about 2 to about 9. Typically, tie coating or layer 34 would hence contain 36% to 41% carbon normalized to 100% carbon plus oxygen plus silicon.

[0021] Optionally, the tie coating or layer can be similar or identical in composition with the pH protective coating or layer 38 described elsewhere in this specification, although this is not a requirement.

[0022] Optionally, the tie coating or layer 34 is on average between 5 and 200 nm (nanometers), optionally between 5 and 100 nm, optionally between 5 and 20 nm thick. These thicknesses are not critical. Commonly but not necessarily, the tie coating or layer 34 will be relatively thin, since its function is to change the surface properties of the substrate. Optionally, the

tie coating or layer is applied by PECVD, for example of a precursor feed comprising octamethylcyclotetrasiloxane (OMCTS), tetramethyldisiloxane (TMDSO), or hexamethyldisiloxane (HMDSO).

Barrier Coating or Layer

[0023] A barrier coating or layer 36 optionally can be deposited by plasma enhanced chemical vapor deposition (PECVD) or other chemical vapor deposition processes on the vessel of a pharmaceutical package, for example a thermoplastic package, to prevent oxygen, carbon dioxide, or other gases from entering the vessel, the barrier coating 36 optionally being effective to reduce the ingress of atmospheric gas into vial 30 compared to an uncoated reference vial or container, and/or to prevent leaching of the pharmaceutical material into or through the vial wall.

[0024] The barrier coating or layer 36 optionally can be applied directly or indirectly to the thermoplastic wall 50 of the vial 30 (for example the tie coating or layer 34 can be interposed between them) so that in the filled vial 30, the barrier coating or layer 36 is located between the internal support surface 32 of the wall 50 and the interior of the vial 30 that is adapted to contain a fluid, e.g., liquid contents 20, to be stored. The barrier coating or layer 36 of SiO_x is supported by the thermoplastic wall 50. The barrier coating or layer 36, as described elsewhere in this specification, or in U.S. Patent No. 7,985,188, can be used in any embodiment.

[0025] The barrier layer 36 optionally is characterized as an "SiO_x" coating, and contains silicon, oxygen, and optionally other elements, in which x, the ratio of oxygen to silicon atoms, is from about 1.5 to about 2.9, or 1.5 to about 2.6, or about 2. One suitable barrier composition is one where x is 2.3, for example.

[0026] Optionally, the barrier coating or layer 36 is from 2 to 1000 nm thick, optionally from 4 nm to 500 nm thick, optionally between 10 and 200 nm thick, optionally from 20 to 200 nm thick, optionally from 20 to 30 nm thick, and comprises SiO_x, wherein x is from 1.5 to 2.9. For example, the barrier coating or layer such as 36 of any embodiment can be applied at a thickness of at least 2 nm, or at least 4 nm, or at least 7 nm, or at least 10 nm, or at least 20 nm, or at least 30 nm, or at least 40 nm, or at least 50 nm, or at least 100 nm, or at least 150 nm, or at least 200 nm, or at least 300 nm, or at least 400 nm, or at least 500 nm, or at least 600 nm, or at least 700 nm, or at least 800 nm, or at least 900 nm. The barrier coating or layer can be up to 1000 nm, or at most 900 nm, or at most

800 nm, or at most 700 nm, or at most 600 nm, or at most 500 nm, or at most 400 nm, or at most 300 nm, or at most 200 nm, or at most 100 nm, or at most 90 nm, or at most 80 nm, or at most 70 nm, or at most 60 nm, or at most 50 nm, or at most 40 nm, or at most 30 nm, or at most 20 nm, or at most 10 nm, or at most 5 nm thick.

[0027] Ranges of from 4 nm to 500 nm thick, optionally from 7 nm to 400 nm thick, optionally from 10 nm to 300 nm thick, optionally from 20 nm to 200 nm thick, optionally from 20 to 30 nm thick, optionally from 30 nm to 100 nm thick are contemplated. Specific thickness ranges composed of any one of the minimum thicknesses expressed above, plus any equal or greater one of the maximum thicknesses expressed above, are expressly contemplated.

[0028] The thickness of the SiO_x or other barrier coating or layer can be measured, for example, by transmission electron microscopy (TEM), and its composition can be measured by X-ray photoelectron spectroscopy (XPS).

[0029] Optionally, the barrier coating or layer 36 is effective to reduce the ingress of atmospheric gas into the vial 30 compared to a reference vial or container without a barrier coating or layer. Optionally, the barrier coating or layer 36 provides a barrier to oxygen that has permeated the wall 50. Optionally, the barrier coating or layer 36 is a barrier to extraction of the composition of the wall 50 by the contents 20 of the lumen vial 30. Optionally, the barrier coating or layer 36 functions to dissipate static charge of the vial 30, e.g., to reduce the vial's propensity to attract particulate contaminants.

pH Protective Coating or Layer

[0030] Certain barrier coatings or layers 36 such as SiO_x as defined here have been found to have the characteristic of being subject to being measurably diminished in barrier improvement factor in less than six months as a result of attack by certain relatively high pH contents of the coated vessel as described elsewhere in this specification, particularly where the barrier coating or layer directly contacts the contents. The inventors have found that barrier layers or coatings of SiO_x are eroded or dissolved by some fluids, for example aqueous compositions having a pH above about 5. Since coatings applied by chemical vapor deposition can be very thin – tens to hundreds of nanometers thick – even a relatively slow rate of erosion can remove or reduce the effectiveness of the barrier layer in less time than the desired shelf life of a product package. This is particularly a

problem for aqueous fluid pharmaceutical, diagnostic or biological compositions, since many of them have a pH of roughly 7, or more broadly in the range of 4 to 8, alternatively from 5 to 9, similar to the pH of blood and other human or animal fluids. The higher the pH of the contents of a coated container (e.g. the vial 30), the more quickly it erodes or dissolves the SiO_x coating. Optionally, this problem can be addressed by protecting the barrier coating or layer 36, or other pH sensitive material, with a pH protective coating or layer 38.

[0031] The pH protective coating or layer 38 optionally provides protection of the underlying barrier coating or layer 36 against contents 20 of the vial 30 having a pH from 4 to 8, including where a surfactant is present. For a prefilled pharmaceutical package, for example, that is in contact with the contents of the package from the time it is manufactured to the time it is used, the pH protective coating or layer 38 optionally prevents or inhibits attack of the barrier coating or layer 36 sufficiently to maintain an effective oxygen barrier over the intended shelf life of the prefilled syringe. The rate of erosion, dissolution, or leaching (different names for related concepts) of the pH protective coating or layer 38, if directly contacted by a fluid, is less than the rate of erosion of the barrier coating or layer 36, if directly contacted by the fluid having a pH of from 5 to 9. The pH protective coating or layer 38 is effective to isolate a fluid (e.g., 20) having a pH between 5 and 9 from the barrier coating or layer 36, at least for sufficient time to allow the barrier coating to act as a barrier during the shelf life of the pharmaceutical package or other vessel, e.g., the vial 30.

[0032] The inventors have further found that certain pH protective coatings or layers of SiO_xC_y or SiN_xC_y formed from polysiloxane precursors, which pH protective coatings or layers have a substantial organic component, do not erode quickly when exposed to fluids, and in fact erode or dissolve more slowly when the fluids have pHs within the range of 4 to 8 or 5 to 9. For example, at pH 8, the dissolution rate of a pH protective coating or layer made from the precursor octamethylcyclotetrasiloxane, or OMCTS, is quite slow. These pH protective coatings or layers of SiO_xC_y or SiN_xC_y can therefore be used to cover a barrier layer of SiO_x, retaining the benefits of the barrier layer by protecting it from the fluid in the pharmaceutical package. The protective layer is applied over at least a portion of the SiO_x layer to protect the SiO_x layer from contents stored in a vessel, where the contents otherwise would be in contact with the SiO_x layer. The pH protective

coating or layer 38 optionally is effective to keep the barrier coating or layer 36 at least substantially undissolved as a result of attack by the fluid 20 for a period of at least six months.

[0033] The pH protective coating or layer 38 can be composed of, comprise, or consist essentially of $Si_wO_xC_yH_z$ (or its equivalent SiO_xC_y) or $Si_wN_xC_yH_z$ or its equivalent SiN_xC_y), each as defined previously, preferably SiO_xC_y, wherein x is from about 0.5 to about 2.4 and y is from about 0.6 to about 3. The atomic ratios of Si, O, and C in the pH protective coating or layer 286 optionally can be: Si 100 : O 50–150 : C 90-200 (i.e. x = 0.5 to 1.5, y = 0.9 to 2); Si 100 : O 70–130 : C 90-200 (i.e. x = 0.7 to 1.3, y = 0.9 to 2); Si 100 : O 80–120 : C 90-150 (i.e. x = 0.8 to 1.2, y = 0.9 to 1.5); Si 100 : O 90-120 : C 90-140 (i.e. x = 0.9 to 1.2, y = 0.9 to 1.4); or Si 100 : O 92-107 : C 116-133 (i.e. x = 0.92 to 1.07, y = 1.16 to 1.33); or Si 100 : O 80–130 : C 90-150.

[0034] The thickness of the pH protective coating or layer as applied optionally is between 10 and 1000 nm; alternatively from 10 nm to 900 nm; alternatively from 10 nm to 800 nm; alternatively from 10 nm to 700 nm; alternatively from 10 nm to 600 nm; alternatively from 10 nm to 500 nm; alternatively from 10 nm to 400 nm; alternatively from 10 nm to 300 nm; alternatively from 10 nm to 200 nm; alternatively from 10 nm to 100 nm; alternatively from 10 nm to 50 nm; alternatively from 20 nm to 1000 nm; alternatively from 50 nm to 1000 nm; alternatively from 50 nm to 800 nm; optionally from 50 to 500 nm; optionally from 100 to 200 nm; alternatively from 100 nm to 700 nm; alternatively from 100 nm to 200 nm; alternatively from 300 to 600 nm. The thickness does not need to be uniform throughout the vessel, and will typically vary from the preferred values in portions of a vessel.

[0035] Optionally, the pH protective coating or layer 38 is at least coextensive with the barrier coating or layer 36. The pH protective coating or layer 38 alternatively can be less extensive than the barrier coating, as when the fluid does not contact or seldom is in contact with certain parts of the barrier coating absent the pH protective coating or layer. The pH protective coating or layer 38 alternatively can be more extensive than the barrier coating, as it can cover areas that are not provided with a barrier coating.

[0036] The pH protective coating or layer 38 optionally can be applied by plasma enhanced chemical vapor deposition (PECVD) of a precursor feed comprising an acyclic siloxane, a monocyclic siloxane, a polycyclic siloxane, a polysilsesquioxane, a monocyclic silazane, a polycyclic

silazane, a polysilsesquiazane, a silatrane, a silquasilatrane, a silproatrane, an azasilatrane, an azasilquasiatrane, an azasilproatrane, or a combination of any two or more of these precursors. Some particular, non-limiting precursors contemplated for such use include octamethylcyclotetrasiloxane (OMCTS).

[0037] In the presence of a fluid composition having a pH between 5 and 9 contained in the vial 30, the calculated shelf life of the vessel vial is more than six months at a storage temperature of 4°C. Optionally, the rate of erosion of the pH protective coating or layer 38, if directly contacted by a fluid composition having a pH of 8, is less than 20% optionally less than 15%, optionally less than 10%, optionally less than 7% , optionally from 5% to 20% , optionally 5% to 15%, optionally 5% to 10%, optionally 5% to 7%, of the rate of erosion of the barrier coating or layer 38, if directly contacted by the same fluid composition under the same conditions. Optionally, the fluid composition removes the pH protective coating or layer 38 at a rate of 1 nm or less of pH protective coating or layer thickness per 44 hours of contact with the fluid composition.

[0038] PECVD apparatus, a system and precursor materials suitable for applying any of the PECVD coatings or layers described in this specification, specifically including the tie coating or layer 34, the barrier coating or layer 36, or the pH protective coating or layer 38, are described in U.S. Patent No. 7,985,188 and PCT Pub. WO2014164928, which are incorporated herein by reference in their entireties.

[0039] Other precursors and methods can be used to apply the pH protective coating or layer or passivating treatment. For example, hexamethylene disilazane (HMDZ) can be used as the precursor. HMDZ has the advantage of containing no oxygen in its molecular structure. This passivation treatment is contemplated to be a surface treatment of the SiO_x barrier layer with HMDZ. To slow down and/or eliminate the decomposition of the silicon dioxide coatings at silanol bonding sites, the coating must be passivated. It is contemplated that passivation of the surface with HMDZ (and optionally application of a few mono layers of the HMDZ-derived coating) will result in a toughening of the surface against dissolution, resulting in reduced decomposition. It is contemplated that HMDZ will react with the –OH sites that are present in the silicon dioxide coating, resulting in the evolution of NH_3 and bonding of $S\text{-}(CH_3)_3$ to the silicon (it is contemplated that hydrogen atoms will be evolved and bond with nitrogen from the HMDZ to produce NH_3).

Antistatic Coatings or Layers

[0040] In one aspect, the present invention is a method for applying a PEVCD coating that dissipates charge build up on a plastic vessel or article, including a film or container. According to some embodiments, and while not being limited by the following theory, it is preferred that an antistatic coating is hydrophilic so that water vapor from the environment would be attracted to the antistatic coated surface of the vessel. The water molecules would bond with the antistatic coated surface through hydrogen bonding. The water hydration layer would be an effective surface to dissipate charge due to its conductive properties and thus reduced surface resistance.

[0041] In one embodiment, the antistatic coating is a PECVD applied silicon oxide coating on the vessel, for example, an external support surface of a container. It is preferred that a silicon oxide coating according to the present invention is not a dense and high barrier oxide. High barrier oxides are highly cross-linked networks of siloxane (i.e. Si-O) bonds with few to no terminating bonds in the network. Terminating bonds such as silanol (SiOH), silane (Si-H), carboxyl, carbonyl (C=O) and aliphatic bonds (-CH_3) would be eliminated to form a dense matrix. In the case of antistatic coatings, polar terminating bonds are desirable because of their strong affinity for water. The invention, therefore, according to one aspect, is a silicon oxide coating loaded with silanol bonds or other polar groups. These silicone oxides are not expected to have high barrier due to their low cross-link density. It is contemplated that an external support surface of a plastic container with a silicon oxide antistatic coating according to the present invention, would reduce the attraction of charged particulates to the container, thus reducing contamination.

[0042] One benefit of embodiments of the invention is that while the antistatic coating may provide similar antistatic properties of known antistatic additives (e.g., as described above) in polymeric materials, such additives are mobile in the polymer matrix and bloom to the surface, thus causing contamination. Antistatic coatings according to aspects of the invention are permanently and covalently bonded to the underlying polymer material. Such permanently bonded surface coatings are advantageous in that they are immobile and do not serve as a source of contamination like antistatic additives. Ultimately, the reduction of static charge reduces the vessel's affinity for visible and sub-visible particulates, which are contaminants that affect product yield loss.

[0043] Optionally, an anti-static coating according to an aspect of the invention also provides resistance to scratch (particularly if applied to thicknesses in micrometers). The coating also optionally provides a clean surface (e.g. substantially free of particulates and resistance to mar and dirt) and additional barrier for air permeation.

[0044] Various aspects of the invention will be illustrated in more detail with reference to the following Examples, but it should be understood that the present invention is not deemed to be limited thereto.

EXAMPLES

Example 1

[0045] A study was conducted to evaluate static loading potential and static dissipation on vial surfaces. 5ml vials were studied, including the following groups: (Group 1) uncoated COP vials; (Group 2) glass vials; (Group 3) COP vials with internal trilayer coating set; (Group 4) internally uncoated COP vials with external SiO_2 coating; (Group 5) internally uncoated COP vials with external SiOH or SiCOH coating; (Group 6) COP vials with internal trilayer coating set and with external SiO_2 coating; and (Group 7) COP vials with internal trilayer coating set and with external SiOH coating.

[0046] Static was dissipated from parts and work surface with a Static Clean 300mm static bar prior to loading. Parts static loading was achieved via a ~500mm stroke across a cut piece of silk/polyester fabric and readings were taken from parts hand placed onto a cut piece of ceramic (insulator). Readings were taken with a grounded static meter at a distance of ~3cm. The results are as follows:

Group 1: COP Positive (+) Control
(Test stopped after 60 seconds)

	Initial Voltage kV %	**Final Voltage kV%**	**Time to Dissipate**
Vial 1	100%	102%	---
Vial 2	100%	106%	---

Group 2: Glass Negative (-) Control
(Test stopped after 60 seconds)

	Initial Voltage kV %	Final Voltage kV%	Time to Dissipate
Vial 1	0%	0%	---
Vial 2	0%	0%	---

Group 3: Trilayer
(Test stopped after 60 seconds)

	Initial Voltage kV %	Final Voltage kV%	Time to Dissipate
Vial 1	100%	73%	---
Vial 2	100%	85%	---

Group 4: SiO_2 on COP

	Initial Voltage kV %	Final Voltage kV%	Time to Dissipate
Vial 1	100%	18%	15 sec
Vial 2	100%	18%	15 sec

Group 5: SiOH on COP

	Initial Voltage kV %	Final Voltage kV%	Time to Dissipate
Vial 1	100%	16%	15 sec
Vial 2	100%	16%	15 sec

Group 6: SiO_2 on Trilayer

	Initial Voltage kV %	Final Voltage kV%	Time to Dissipate
Vial 1	100%	29%	15 sec
Vial 2	100%	29%	15 sec

Group 7: SiOH on Trilayer

	Initial Voltage kV %	Final Voltage kV%	Time to Dissipate
Vial 1	100%	16%	15 sec
Vial 2	100%	15%	15 sec

[0047] As the foregoing data show, uncoated COP has significant static loading potential and glass, which is an insulator, does not. The Applicants contemplated that incorporating glass-like insulation via PECVD coatings on external surfaces of a plastic substrate, e.g., as described above, would facilitate static charge dissipation of the coated substrate (e.g., vial). As the data show, surprisingly, externally coated vials (Groups 4 through 7) dissipate static charge much more quickly and to a significantly greater degree, compared to uncoated COP (Group 1) and even COP vials with a trilayer but without an external antistatic coating (Group 3). It is therefore contemplated that materials with an external antistatic coating (e.g., vials of Groups 4 through 7) are far less prone to attract charged particles, and hence less prone to particulate contamination, than uncoated plastic vessels (Group 1) and the trilayer vials without an external antistatic coating (Group 3).

[0048] While the invention has been described in detail and with reference to specific examples thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope thereof.

CLAIMS

What is claimed is:

1. A method of reducing static charge of a plastic vessel comprising providing a vapor deposited coating selected from the group consisting of SiCOH, SiO_x and SiOH, to an external support surface of the vessel, wherein the vapor deposited coating acts to reduce static charge of the container compared to a reference container that is essentially identical to the vessel except that the reference container has an uncoated external support surface.

2. The method of claim 1, wherein the plastic vessel is made from plastic comprising, consisting essentially of or consisting of one or more of the group consisting of: an olefin polymer, polypropylene (PP), polyethylene (PE), cyclic olefin copolymer (COC), cyclic olefin polymer (COP), polymethylpentene, polyester, polyethylene terephthalate, polyethylene naphthalate, polybutylene terephthalate (PBT), polyvinylidene chloride (PVdC), polyvinyl chloride (PVC), polycarbonate, polylactic acid, polystyrene, hydrogenated polystyrene, polycyclohexylethylene (PCHE), epoxy resin, nylon, polyurethane polyacrylonitrile, polyacrylonitrile (PAN), and an ionomeric resin.

3. The method of claims 1 or 2, wherein the vapor deposited coating is applied by PECVD.

4. The method of any preceding claim, the vessel further comprising an internal support surface wherein at least a portion of the internal support surface comprises a PECVD trilayer coating set, the trilayer coating set comprising a tie layer deposited onto the internal support surface, a barrier layer deposited onto the tie layer and a pH protective layer deposited onto the barrier layer, wherein the tie layer comprises SiO_xC_y or SiN_xC_y, in which x for the tie layer is from about 0.5 to about 2.4 and y for the tie layer is from about 0.6 to about 3, wherein the barrier layer comprises SiO_x in which x for the barrier layer is from about 1.5 to about 2.9 and wherein the pH protective layer comprises SiO_xC_y or SiN_xC_y in which x for the pH protective layer is from about 0.5 to about 2.4 and y for the protective layer is from about 0.6 to about 3.

5. The method of any preceding claims, wherein the vessel is selected from the group consisting of: a sample tube, a cartridge, a syringe, a vial, a pipe, a catheter, a cuvette and secondary packaging.

6. The method of any preceding claims, wherein the vapor deposited coating has a thickness of 1nm to 1000 nm, optionally 1nm to 900 nm, optionally 1nm to 800 nm, optionally 1 nm to 700 nm, optionally 1 nm to 600 nm, optionally 5 nm to 500 nm, optionally 5 nm to 400 nm, optionally 5 nm to 300 nm, optionally 5 nm to 200 nm, optionally 5 nm to 100 nm, optionally 10 nm to 100 nm, optionally 10 nm to 75 nm, optionally 10 nm to 50 nm.

7. A method of reducing particulate surface contamination of a plastic vessel, the method comprising providing a vapor deposited coating selected from the group consisting of SiCOH, SiO_x and SiOH, to an external support surface of the container, wherein the vapor deposited coating acts to reduce particulate surface contamination of the vessel compared to a reference container that is essentially identical to the vessel except that the reference container has an uncoated external support surface and wherein the reference container is exposed to essentially the same ambient conditions as the vessel.

8. The method of claim 7, wherein the plastic vessel is made from plastic comprising, consisting essentially of or consisting of one or more of the group consisting of: an olefin polymer, polypropylene (PP), polyethylene (PE), cyclic olefin copolymer (COC), cyclic olefin polymer (COP), polymethylpentene, polyester, polyethylene terephthalate, polyethylene naphthalate, polybutylene terephthalate (PBT), polyvinylidene chloride (PVdC), polyvinyl chloride (PVC), polycarbonate, polylactic acid, polystyrene, hydrogenated polystyrene, polycyclohexylethylene (PCHE), epoxy resin, nylon, polyurethane polyacrylonitrile, polyacrylonitrile (PAN), and an ionomeric resin.

9. The method of claim 7 or 8, wherein the vapor deposited coating is applied by PECVD.

10. The method of any preceding claim 7 to 9, the vessel further comprising an internal support surface wherein at least a portion of the internal support surface comprises a PECVD trilayer coating set, the trilayer coating set comprising a tie layer deposited onto the internal support surface, a barrier layer deposited onto the tie layer and a pH protective layer deposited onto the barrier layer, wherein the tie layer comprises SiO_xC_y or SiN_xC_y, in which x for the tie layer is from about 0.5 to about 2.4 and y for the tie layer is from about 0.6 to about 3, wherein the barrier layer comprises SiO_x in which x for the barrier layer is from about 1.5 to about 2.9 and wherein the pH protective

layer comprises SiO_xC_y or SiN_xC_y in which x for the pH protective layer is from about 0.5 to about 2.4 and y for the protective layer is from about 0.6 to about 3.

11. The method of any preceding claim 7 to 10, wherein the vessel is selected from the group consisting of: a sample tube, a cartridge, a syringe, a vial, a pipe, a catheter, a cuvette and secondary packaging.

12. The method of any preceding claim 7 to 11, wherein the vapor deposited coating has a thickness of 1nm to 1000 nm, optionally 1nm to 900 nm, optionally 1nm to 800 nm, optionally 1 nm to 700 nm, optionally 1 nm to 600 nm, optionally 5 nm to 500 nm, optionally 5 nm to 400 nm, optionally 5 nm to 300 nm, optionally 5 nm to 200 nm, optionally 5 nm to 100 nm, optionally 10 nm to 100 nm, optionally 10 nm to 75 nm, optionally 10 nm to 50 nm.

13. A plastic vessel for containing a liquid product, the vessel comprising an inner surface and an external support surface, wherein at least a portion of the external support surface comprises a vapor deposited coating selected from the group consisting of SiCOH, SiO_x and SiOH.

14. The plastic vessel of claim 13, wherein the vessel is made from plastic comprising, consisting essentially of or consisting of one or more of the group consisting of: an olefin polymer, polypropylene (PP), polyethylene (PE), cyclic olefin copolymer (COC), cyclic olefin polymer (COP), polymethylpentene, polyester, polyethylene terephthalate, polyethylene naphthalate, polybutylene terephthalate (PBT), polyvinylidene chloride (PVdC), polyvinyl chloride (PVC), polycarbonate, polylactic acid, polystyrene, hydrogenated polystyrene, polycyclohexylethylene (PCHE), epoxy resin, nylon, polyurethane polyacrylonitrile, polyacrylonitrile (PAN), and an ionomeric resin.

15. The plastic vessel of claim 13 or 14, wherein the vapor deposited coating is applied by PECVD.

16. The plastic vessel of any preceding claim 13 to 15, the vessel further comprising an internal support surface wherein at least a portion of the internal support surface comprises a PECVD trilayer coating set, the trilayer coating set comprising a tie layer deposited onto the internal support surface, a barrier layer deposited onto the tie layer and a pH protective layer deposited onto the barrier layer, wherein the tie layer comprises SiO_xC_y or SiN_xC_y, in which x for the tie layer is from about 0.5 to about 2.4 and y for the tie layer is from about 0.6 to about 3, wherein the barrier layer comprises SiO_x in which x for the barrier layer is from about 1.5 to about 2.9 and wherein the pH

protective layer comprises SiO_xC_y or SiN_xC_y in which x for the pH protective layer is from about 0.5 to about 2.4 and y for the protective layer is from about 0.6 to about 3.

17. The vessel of any preceding claim 13 to 16, wherein the vessel is selected from the group consisting of: a sample tube, a cartridge, a syringe, a vial, a pipe, a catheter, a cuvette and secondary packaging.

18. The vessel of any preceding claim 13 to 17, wherein the vapor deposited coating has an effect of dissipating static charge of the vessel.

19. The vessel of any preceding claim 13 to 18, wherein the vapor deposited coating further provides one or more of the following features: resistance to scratch, resistance to mar and dirt and a barrier for air permeation.

20. The vessel of any preceding claim 13 to 19, wherein the vapor deposited coating has a thickness of 1nm to 1000 nm, optionally 1nm to 900 nm, optionally 1nm to 800 nm, optionally 1 nm to 700 nm, optionally 1 nm to 600 nm, optionally 5 nm to 500 nm, optionally 5 nm to 400 nm, optionally 5 nm to 300 nm, optionally 5 nm to 200 nm, optionally 5 nm to 100 nm, optionally 10 nm to 100 nm, optionally 10 nm to 75 nm, optionally 10 nm to 50 nm.

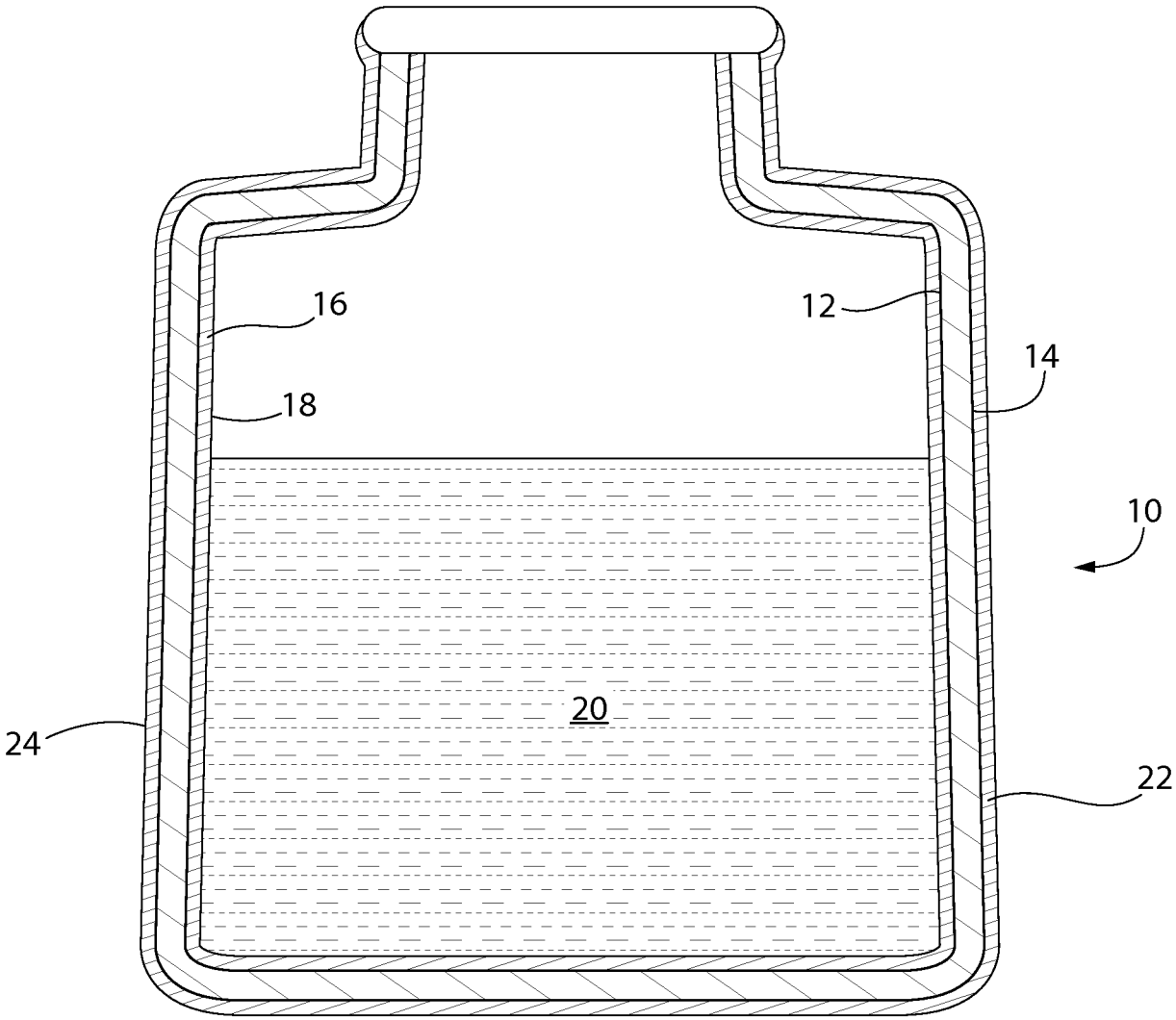


FIG. 1

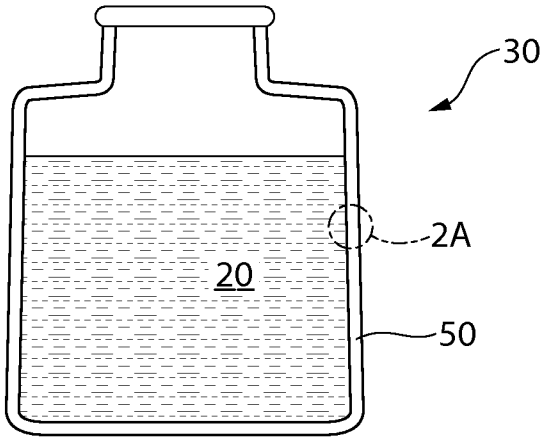


FIG. 2

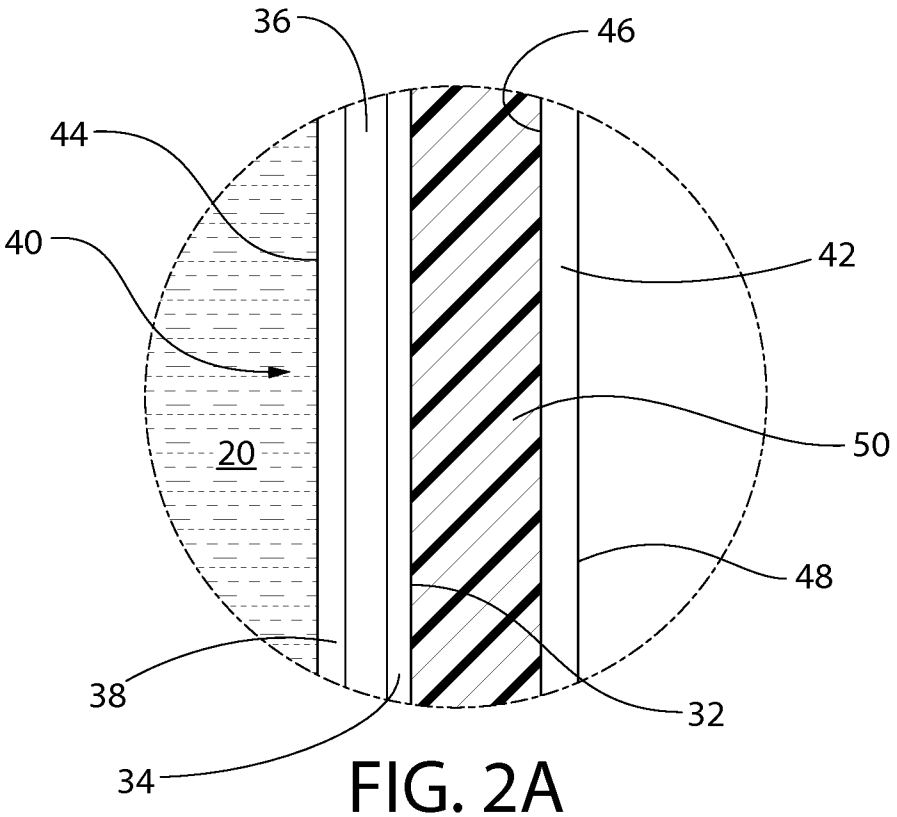


FIG. 2A

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/022189

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C16/40 C23C16/36 C23C16/04 C23C16/50 B65D23/02
A61J1/05 B65D25/34 B65D1/02
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C23C B65D A61J B32B B05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 667 302 A1 (TETRA LAVAL HOLDINGS & FINANCE [CH]) 16 August 1995 (1995-08-16) column 3, line 5 - line 10 column 4, line 21 - line 31 column 2, line 23 - line 30 -----	1-3,5-9, 11-15, 17-20
X	EP 1 630 250 A1 (TOYO SEIKAN KAISHA LTD [JP]) 1 March 2006 (2006-03-01) paragraphs [0026], [0027], [0029] example 3 paragraph [0058] -----	1-3,5-9, 11-15, 17-20
X	EP 1 921 015 A1 (YOSHINO KOGYOSHO CO LTD [JP]) 14 May 2008 (2008-05-14) paragraphs [0009], [0016], [0001]; figure 1 -----	1-3,7-9, 13-15
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 May 2015	26/05/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kudelka, Stephan

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/022189

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 728 723 A1 (YOSHINO KOGYOSHO CO LTD [JP]) 6 December 2006 (2006-12-06) paragraph [0027]; table 2	1-3,7-9, 13-15
A	US 2010/298738 A1 (FELTS JOHN T [US] ET AL) 25 November 2010 (2010-11-25) paragraph [0557]	1-20

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/022189

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0667302 A1	16-08-1995	AU 1156995 A	17-08-1995
		CA 2141832 A1	05-08-1995
		CH 687614 A5	15-01-1997
		EP 0667302 A1	16-08-1995
		JP H07257585 A	09-10-1995
		US 5721027 A	24-02-1998
EP 1630250 A1	01-03-2006	EP 1630250 A1	01-03-2006
		KR 20060006015 A	18-01-2006
		US 2006264044 A1	23-11-2006
		WO 2004087989 A1	14-10-2004
EP 1921015 A1	14-05-2008	AU 2006286041 A1	08-03-2007
		CA 2620551 A1	08-03-2007
		CN 101253101 A	27-08-2008
		EP 1921015 A1	14-05-2008
		JP 5275543 B2	28-08-2013
		JP 2007062794 A	15-03-2007
		KR 20080033459 A	16-04-2008
		US 2009104392 A1	23-04-2009
		WO 2007026554 A1	08-03-2007
EP 1728723 A1	06-12-2006	AU 2005226340 A1	06-10-2005
		CA 2561360 A1	06-10-2005
		EP 1728723 A1	06-12-2006
		JP 4711285 B2	29-06-2011
		JP 2005306482 A	04-11-2005
		KR 20060132994 A	22-12-2006
		TW 200535058 A	01-11-2005
		US 2007178265 A1	02-08-2007
		WO 2005092715 A1	06-10-2005
US 2010298738 A1	25-11-2010	AU 2011252925 A1	13-12-2012
		CA 2799213 A1	17-11-2011
		CA 2799220 A1	17-11-2011
		CN 102884412 A	16-01-2013
		CN 102917805 A	06-02-2013
		EP 2569611 A1	20-03-2013
		EP 2579996 A2	17-04-2013
		JP 2013526710 A	24-06-2013
		JP 2013528117 A	08-07-2013
		RU 2012153671 A	20-06-2014
		SG 185520 A1	28-12-2012
		US 2010298738 A1	25-11-2010
		US 2013209766 A1	15-08-2013
		WO 2011143329 A2	17-11-2011