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(54) Title: METHODS AND DEVICES FOR DETECTING AND SEPARATING TARGET ANALYTE SPECIES USING ANISOTROPIC MICRO-PARTICLES

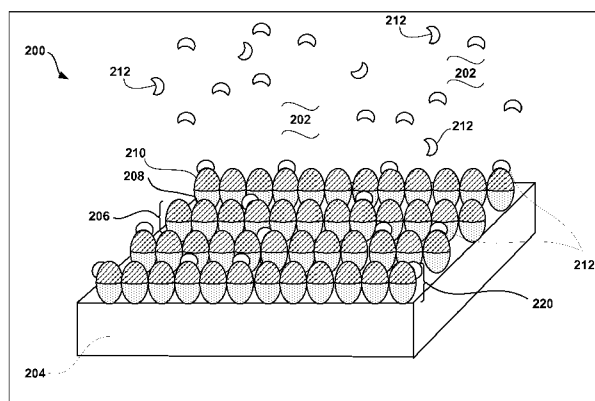


FIG. 4

(57) Abstract: The present disclosure provides new methods for detection and/or separation of target species from a fluid composition, particularly for biological target species, like prokaryotic cells, eukaryotic cells, genetic materials, proteins, polypeptides, biomolecules, viruses, saccharides, antigens, and the like. A target species in a fluid composition is contacted with a plurality of anisotropic multi-compartment micro-particles. At least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed binding surface, which optionally comprises a moiety selected for binding to the target species. Such anisotropic multi-compartment micro-particles are thus employed to detect and/or separate the target species from the fluid composition. Analytical assays, detection and sensor devices, and separation devices may likewise employ such principles for detection, quantification, and/or separation of target species.



METHODS AND DEVICES FOR DETECTING AND SEPARATING TARGET
ANALYTE SPECIES USING ANISOTROPIC MICRO-PARTICLES

CROSS-REFERENCE TO RELATED APPLICATIONS

5 **[0001]** This application claims the benefit of U.S. Provisional Application
No. 61/548,056, filed on October 17, 2011. The entire disclosure of the above
application is incorporated herein by reference.

FIELD

10 **[0002]** The present disclosure relates to detection and separation processes
for biological target analytes by employing anisotropic multi-compartment particles and
systems and devices for conducting such processes.

BACKGROUND

15 **[0003]** This section provides background information related to the present
disclosure which is not necessarily prior art.

[0004] Diagnostic assays, sensors, and separations processes are used in a
wide variety of applications in the medical, industrial, and research fields for detecting a
variety of components. For example, biological detection or separation of biological
20 target analytes (like drugs, hormones, enzymes, proteins, polypeptides, cells, genetic
materials like DNA and RNA, antibodies, infectious agents, and the like) from biological
fluids or tissue is important for diagnostic and research purposes.

[0005] Numerous analytical devices in a vast array of shapes, configurations
and formats have been developed for detecting the presence of a target analyte in a fluid
25 test sample, including chromatographic test strips, dipsticks, lateral flow and flow-
through systems, for example. Many assays detect a target analyte of interest (*e.g.*, a
ligand) in a fluid test sample (*e.g.*, solvent, whole blood, plasma, serum, urine, saliva,
and the like). A visually detectable indicator reagent can be included in the reaction to
produce a detectable output indicating that a reaction has occurred when the target
30 analyte is present. However, many conventional analytical devices are complex and
entail numerous involved steps, which require significant time and expertise for proper
execution. There is need for cost effective and accurate methods to perform analytical

tests or separations processes, which improve the quality and efficiency of separations or detection of target analytes.

SUMMARY

5 **[0006]** This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0007] In certain aspects, the present disclosure provides a method for detecting a target species in a fluid composition. The method optionally comprises contacting a fluid composition comprising the target species with a plurality of
10 anisotropic multi-compartment micro-particles in a detection device. At least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed surface for binding to the target species, so that the anisotropic multi-compartment micro-particle binds with the target species present in the fluid composition to form a conjugate species. The conjugate species has at least one property that
15 enhances detection of the target species from the fluid composition as compared to the target species alone. The method also includes detecting the presence of the conjugate species in the fluid composition and providing an output from the detection device corresponding to the presence of the conjugate species.

[0008] In other aspects, a method for separating a target species from a fluid
20 composition is provided, which may comprise contacting a fluid composition comprising the target species with a plurality of anisotropic multi-compartment micro-particles. At least one distinct compartment of each of the anisotropic multi-compartment micro-particle defines an exposed binding surface for binding to the target species, so that the anisotropic multi-compartment micro-particle binds with the target species present in the
25 fluid composition to form a conjugate species. The conjugate species has at least one property that facilitates separation of the target species from the fluid composition as compared to the target species alone. The method further comprises separating the conjugate species from the fluid composition.

[0009] In other aspects, methods for applying a target species to a surface
30 coating are contemplated. Such methods may optionally comprise contacting a surface coating comprising a plurality of anisotropic multi-compartment micro-particles with a fluid composition comprising the target species contained in a reservoir. At least one

distinct compartment of the anisotropic multi-compartment micro-particles defines an exposed surface that comprises a binding surface to bind with the target species, so that after contacting the surface coating with the fluid composition, at least a portion of the target species present in the fluid composition forms a conjugate species with the anisotropic multi-compartment micro-particles disposed along one or more regions of the surface coating.

[0010] In yet other aspects, the present disclosure provides an analytical assay device comprising a region for contacting a fluid composition comprising a target species with a plurality of anisotropic multi-compartment micro-particles. At least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed binding surface capable of binding to the target species, so that the anisotropic multi-compartment micro-particle binds with any target species present in the fluid composition to form a detectable conjugate species.

[0011] In further aspects, the present disclosure provides a separator device that comprises a mixing region for contacting a fluid composition comprising a target species with a plurality of anisotropic multi-compartment micro-particles. At least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed binding surface capable of binding to the target species, so that the anisotropic multi-compartment micro-particle binds with the target species present in the fluid composition to form a conjugate species capable of separation from the fluid composition. The separator device may also comprise a separation region where the conjugate species is removed from the fluid composition that forms a fluid permeate.

[0012] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0013] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0014] FIG. 1A is an illustration of an anisotropic multi-compartment micro-particle comprising two equally sized compartments for use in accordance with certain aspects of the present disclosure;

5 [0015] FIG. 1B is an illustration of an anisotropic multi-compartment micro-particle comprising two different sized compartments for use in accordance with certain aspects of the present disclosure;

[0016] FIG. 1C is an illustration of an anisotropic multi-compartment micro-particle comprising three compartments for use in accordance with certain aspects of the present disclosure;

10 [0017] FIG. 2A is an illustration of anisotropic multi-compartment micro-particles having a spherical shape for use in accordance with certain aspects of the present disclosure;

[0018] FIG. 2B is an illustration of anisotropic multi-compartment micro-particles having a disc shape for use in accordance with certain aspects of the present disclosure;

15 [0019] FIG. 2C is an illustration of anisotropic multi-compartment micro-particles having a cylindrical shape for use in accordance with certain aspects of the present disclosure;

[0020] FIG. 3 is an exemplary schematic of an anisotropic multi-compartment micro-particle having a binding surface with a binding moiety, which is capable of binding with a target species in the form of a cell in accordance with certain principles set forth in the present disclosure;

20 [0021] FIG. 4 is an exemplary schematic of a surface coating comprising a plurality of anisotropic multi-compartment micro-particles capable of binding with a target species present in a surrounding fluid composition in accordance with certain principles set forth in the present disclosure;

25 [0022] FIG. 5A is an exemplary separation device apparatus used for separating a target species from a fluid composition by employing a plurality of anisotropic multi-compartment micro-particles capable of binding with a target species in accordance with certain aspects of the present disclosure;

30 [0023] FIG. 5B is an alternative exemplary embodiment of a separation device apparatus used for separating a target species from a fluid composition by

employing a plurality of anisotropic multi-compartment micro-particles that are capable of binding with a target species in accordance with certain aspects of the present disclosure;

5 [0024] FIG. 6A is an exemplary system for coating a surface of a substrate by employing a surface coating in accordance with certain aspects of the present disclosure. The surface coating comprises a plurality of anisotropic multi-compartment micro-particles capable of binding with a target species. Target species are present in a fluid composition contained in a reservoir;

10 [0025] FIG. 6B is the system of FIG. 6A after the target species has been bound to the plurality of anisotropic multi-compartment micro-particles to form a conjugate species by contacting the plurality of anisotropic multi-compartment micro-particles with the target species in the fluid composition in the reservoir; and

15 [0026] FIG. 7 is an exemplary assay test device employing a plurality of anisotropic multi-compartment micro-particles capable of binding with a target species for analysis of fluid compositions.

[0027] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

20 [0028] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0029] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. Further, the present disclosure contemplates that any particular feature or embodiment can be combined with any other feature or embodiment described herein. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

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[0030] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise.

5 [0031] The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be
10 construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0032] As referred to herein, the word “substantially,” when applied to a characteristic of a composition or method of this disclosure, indicates that there may be
15 variation in the characteristic without having a substantial effect on the chemical or physical attributes of the composition or method.

[0033] Throughout this disclosure, numerical values represent approximate measures or limits to ranges to encompass minor deviations from the given values and
20 embodiments having about the value mentioned as well as those having exactly the value mentioned. All numerical values of parameters (*e.g.*, of quantities or conditions) in this specification, including the appended claims, are to be understood as being modified in all instances by the term “about” whether or not “about” actually appears before the
25 numerical value. “About” indicates that the stated numerical value allows some slight imprecision (with some approach to exactness in the value; approximately or reasonably close to the value; nearly). If the imprecision provided by “about” is not otherwise understood in the art with this ordinary meaning, then “about” as used herein indicates at least variations that may arise from ordinary methods of measuring and using such
30 parameters. If, for some reason, the imprecision provided by “about” is not otherwise understood in the art with this ordinary meaning, then “about” as used herein indicates a possible variation of up to 5% in the value. In addition, disclosure of ranges includes disclosure of all values and further divided ranges within the entire range, including endpoints given for the ranges.

[0034] When an element or layer is referred to as being “on,” “contacting,” “engaged to,” “connected to,” or “coupled to” another element or layer, it may be directly on, engaged, contacting, connected, or coupled to the other element or layer, or intervening elements or layers may be present. Other words used to describe the relationship between elements should be interpreted in a like fashion (*e.g.*, “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0035] Although the terms first, second, third, and the like may be used herein to describe various components, moieties, elements, regions, layers and/or sections, these components, moieties, elements, regions, layers and/or sections are not exclusive and should not be limited by these terms. These terms may be only used to distinguish one component, moiety, element, region, layer or section from another component, moiety, element, region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first component, moiety, element, region, layer or section discussed below could be termed a second component, moiety, element, region, layer or section without departing from the teachings of the example embodiments.

[0036] Spatially relative terms, such as “bottom,” “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0037] In various aspects, the present disclosure provides new methods for detection and/or separation of target species, particularly for biological target species.

Detection or separation of specific target analyte species is important for many different applications. A target analyte is a compound, particle, or other composition of interest to be detected and/or separated from a fluid (*e.g.*, liquid or gas). As used herein, the term “fluid” is intended to broadly encompass gases, liquids, vapors, semi-liquids, and suspensions of solids in liquids or gases. In certain alternative aspects, the present teachings may be employed to detect or separate a target species from a solid phase. Examples of target analytes include, without limitation, cells, drugs, hormones, polypeptides, proteins including immunoglobulins, polysaccharides, nucleic acids, and combinations thereof. For example, as will be discussed in further detail below, the inventive technology can be employed to separate biological target species, like prokaryotic cells, eukaryotic cells, genetic materials, proteins, polypeptides, biomolecules, viruses, saccharides, antigens, and the like from a fluid composition. The techniques of the present disclosure can be used in sensitive bioanalytical assays to detect the presence and to quantify the concentrations of target analytes. In certain aspects, the methods of the present teachings detect the presence and quantify the concentrations of target analytes labeled with specific binding reagents or biomarkers, for example. The techniques of the present disclosure can also be used for separating target analytes from fluid compositions. Therefore, the methods of the present disclosure have vast applicability for numerous applications and can be employed in novel biologic assays and separation devices.

[0038] Thus, in certain aspects, the present teachings are directed to methods for detecting a target species in a fluid composition. As used herein, the term “composition” refers broadly to a substance containing the target species, but which may also comprise additional species, substances, or compounds. Likewise, the term “material” also broadly refers to matter containing target species. In various aspects of the present teachings, a plurality of anisotropic multi-compartment micro-particles is employed to detect and/or separate one or more target species from the fluid composition. Such methods of detection may be used for sensing the presence of a target analyte in sensing applications and sensor devices, as well. At least one distinct compartment of each of the anisotropic multi-compartment micro-particle defines an exposed binding surface that is selected to be capable of binding to the target species. In certain variations, at least one distinct compartment of each of the anisotropic multi-

compartment micro-particle defines an exposed binding surface that comprises a moiety selected for binding to the target species. In other aspects, methods are provided for separating a target species from a fluid composition. The methods of the present disclosure may further be useful in both detecting a target species and separating that target species from a fluid composition.

[0039] Thus, in certain variations, methods of the present disclosure include contacting a fluid composition (potentially comprising one or more target species) with a plurality of anisotropic multi-compartment micro-particles. Such contacting can occur in a detection device, for example, in a contact region, chamber or compartment. At least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed binding surface for binding to the target species. In certain aspects, the exposed binding surface comprises a moiety capable of binding to the target species. In this manner, the anisotropic multi-compartment micro-particle binds with the target species present in the fluid composition to form a conjugate species. Furthermore, in accordance with certain aspects of the present teachings, the conjugate species has at least one property that enhances detection (or separation) of the target species from the fluid composition as compared to the ability to detect (or separate) the target species alone. The presence of conjugate species in the fluid composition is then detected, for example, in the same region or a different region of the detection device. In certain embodiments, the method further includes generating or providing an output from the detection device corresponding to or indicating detection of the presence of the conjugate species. In certain embodiments, such an output signal can be further processed to provide a visually discernable output on a display device, for example.

[0040] In certain aspects, the detecting of the presence of the conjugate species in the fluid composition also comprises detecting a quantity of the conjugate species present in the fluid composition. Thus, providing the output from the detection device further indicates the quantity of the conjugate species present in the fluid composition.

[0041] The increase of at least one property that enhances detection can be an increase in output of a detectable characteristic, such as electromagnetic radiation, magnetism, charge or dipole moment, and the like, that can be used as a detection or diagnostic assay or test. In other aspects, the increase of at least one property that

enhances detection can be an increase in responsiveness to external stimulus, to readily enable detection of the conjugate species. Components that can be included in one or more compartments of the multi-compartment micro-particles that enable such enhanced detection properties, such as those discussed above. For instance, a magnetic cylinder
5 particle is contemplated that comprises two distinct compartments along a main axis, one of the compartments comprises a pH swellable polymer and the other compartment comprises a non-swellable polymer. A change in pH results in bending or distortion of shape of the micro-cylinder, which will alter its responsiveness to a rotational magnetic field, hence giving rise to detectable changes in rotation frequency.

10 [0042] In other aspects, the present disclosure provides a method for separating a target species from a fluid composition. Such a method comprises contacting a fluid composition comprising the target species with a plurality of anisotropic multi-compartment micro-particles. At least one distinct compartment of each of the anisotropic multi-compartment particles defines an exposed binding surface
15 for binding to the target species, so that the anisotropic multi-compartment particle binds with the target species present in the fluid composition to form a conjugate species. In certain variations, an exposed binding surface comprises a moiety for binding to the target species, so that the anisotropic multi-compartment particle binds with the target species present in the fluid composition to form a conjugate species. The conjugate
20 species has at least one property that facilitates separation of the target species from the fluid composition as compared to the target species alone. On this basis, the conjugate species can be readily separated from the fluid composition.

[0043] The increase of at least one property that enhances separation can be an increase in a particle size diameter (as compared to the target species). For example,
25 an increase in an average particle size of the conjugate species as compared to the original target species is optionally at least 100%, optionally at least 200%, optionally at least 500%, optionally at least 1,000% or more of an increase of an average particle size diameter. In this regard, the increase in particle size facilitates separation of the conjugate species from the fluid composition, so that the target species can be removed
30 from the fluid composition.

[0044] In certain aspects, the separating occurs by a process selected from the group consisting of: filtration, centrifugation, ultracentrifugation, settling,

chromatographic methods, precipitation, and combinations thereof. Thus, separation of the target species from the fluid composition can occur by filtration. The filtration may comprise passing the fluid composition having the conjugate species dispersed therein through a filtration membrane to separate the conjugate species from the fluid composition and thus form a fluid permeate after the target species has been removed. In other aspects, the increase of at least one property that enhances detection can be an increase in magnetic properties or magnetization. Thus, the separating can occur by exposing the fluid composition having the conjugate species to a magnetic field so as to remove the conjugate species from the fluid composition. In yet other aspects, at least one property that is enhanced in the conjugate species as compared to the target species by itself is a dielectric moment. In such embodiments, the separating occurs by electrophoresis, which entails exposing the fluid composition to an electrical field to remove the conjugate species from the fluid composition. Accordingly, a plurality of anisotropic multi-compartment micro-particles is employed to detect and/or separate the target species from the fluid composition.

[0045] As used herein, “multi-compartment” means that at least two phases or compartments occupy separate but distinct physical spaces to form the particle. Such compartments can thus be in direct contact with one another. The term “compartment” as used herein, refers to a domain or region of a composition having one average composition, as distinct from another region or domain having a different average composition, which occupies a distinct physical portion of the particle or component.

[0046] In certain preferred aspects, the multi-compartment particles are micro-particles that are anisotropic. For example, in certain variations, a substantially round multi-compartment micro-component may have an anisotropic morphology, where each respective compartment of the multi-compartment component is exposed to an external environment, thus providing a different composition in different directions of the micro-component. The exposure of each respective surface of each compartment desirably provides enhanced environmental interface. As the size of the micro-particle becomes smaller, for example, down to the sub-micron scale, due to the increased surface-to-volume ratio, many of the characteristics of the micro-particles are dominated by the structure and composition of the exposed surface.

[0047] In accordance with various aspects of the present disclosure, anisotropic multi-compartment particles, such as anisotropic multi-compartment micro-particles, are used to detect and/or separate target species from a fluid composition. Such particles may be biphasic or bicompartiment particles having a side-by-side anisotropic phase orientation, which is often referred to as a “Janus particle.” However, the multi-compartment micro-particles for use with the principles of the present disclosure are not limited to only 2 compartments. Thus, in certain variations, the anisotropic multi-compartment micro-particle comprises 2 to 10 distinct compartments. In certain variations, the multi-compartment micro-particle comprises 3 compartments. In various aspects, each respective compartment of the multi-compartment particle has an externally exposed surface capable of interacting with the surrounding environment. Furthermore, distinct exposed surfaces of a multi-compartment micro-particle can be capable of interacting with distinct target species.

[0048] A “micro-particle” is a solid or semi-solid material that can have a variety of shapes or morphologies, however, generally has at least one spatial dimension that is less than or equal to about 1,000 μm (1 mm), optionally less than or equal to about 500 μm , optionally less than or equal to about 250 μm , optionally less than or equal to about 100 μm , optionally less than or equal to about 75 μm , optionally less than or equal to about 50 μm , optionally less than or equal to about 25 μm , optionally less than or equal to about 20 μm , optionally less than or equal to about 10 μm (*i.e.*, 10,000 nm), and in certain aspects, optionally less than or equal to about 5 μm (*i.e.*, 5,000 nm). In certain aspects, a micro-particle as used herein has at least one spatial dimension that is greater than or equal to about 0.5 μm (*i.e.*, 500 nm) and less than or equal to about 100 μm .

[0049] The term “micro-particle” further includes “nano-sized” or “nanometer-sized,” which are generally understood by those of skill in the art to mean less than or equal to about 10 μm (*i.e.*, 10,000 nm), optionally less than or equal to about 2 μm (*i.e.*, less than or equal to about 2,000 nm), optionally less than or equal to about 1 μm (*i.e.*, less than or equal to about 1,000 nm), optionally less than or equal to about 0.5 μm (*i.e.*, 500 nm), and in certain aspects, less than or equal to about 0.2 μm (*i.e.*, 200 nm). In certain aspects, as used herein, a nano-particle has at least one spatial dimension that is greater than or equal to about 10 nm and less than or equal to about 10,000 nm.

[0050] In certain aspects, a particularly suitable anisotropic multi-compartment micro-particle for use in accordance with the present teachings has a particle size (an average diameter for the plurality of micro-particles selected) of greater than or equal to about 10 nm to less than or equal to about 500 μm . In certain variations,
5 the anisotropic multi-compartment micro-particle has an average particle size diameter of greater than or equal to about 5 μm to less than or equal to about 500 μm .

[0051] In certain embodiments, substantially round-shaped micro-particles are selected for use in conjunction with the present methods and devices. "Substantially round-shaped" includes micro-particles having a morphology or shape including
10 spherical, spheroidal, hemispherical, disk, globular, annular, toroidal, cylindrical, rod, discoid, domical, egg-shaped, elliptical, orbled, oval, and the like. In certain preferred variations, the morphology of the anisotropic multi-compartment micro-particle has a shape selected from the group consisting of: spheres, cylinders, rods, disks, toroids, and combinations thereof. Exemplary spherical anisotropic multi-compartment micro-
15 particles are shown in FIG. 2A, anisotropic multi-compartment disks in FIG. 2B, and cylindrical anisotropic multi-compartment micro-particles in FIG. 2C. In certain other aspects, the micro-particles may be other solid micro-particle morphologies, such as rectangles, polygons, cones, pyramids, beads-on-a-string, and/or fibers, by way of non-limiting example. The morphology can be selected to have a predetermined orientation
20 of respective compartments within the micro-particle, so as to provide the anisotropic properties.

[0052] By way of example, the present teachings can employ a multi-compartment micro-particle having a plurality of physically and/or compositionally distinct compartments, such as shown in FIGS. 1A and 1B. In certain aspects, the multi-
25 compartment micro-particles of the present disclosure include multiple distinct compartments, for example three or more distinct compartments. Three or more distinct phases are contemplated by the present teachings, such as in FIG 1C.

[0053] In various aspects, the present disclosure uses multi-compartment particles having a plurality of physically and/or compositionally distinct compartments,
30 such as shown in FIGS. 1A-1C. The multi-compartment particles according to the present teachings include a first compartment and at least one additional compartment that is distinct from the first compartment. In certain aspects, the multi-compartment

particles of the present disclosure include multiple distinct compartments, for example three or more distinct compartments. Each respective compartment occupies a spatially discrete region or compartment of the micro-particle. In certain aspects, each respective compartment of the multi-compartment particle is exposed to an external environment, thus providing exposure of the respective compartment surfaces of the multi-compartment particle to an external environment. The exposure of each respective surface of each compartment provides enhanced environmental interface and optimum diffusion or material transfer, resulting in increased visibility and exposure to surrounding environs.

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10 **[0054]** Configurations such as those shown in FIGS. 1A and 1B have three compartment or phase interfaces. In FIG 1A, a first compartment 20 and a second compartment 22 share a first interface 26, where both the first compartment 20 and second compartment 22 occupy discrete spatial locations within the particle, which may be a micro-particle. First compartment 20 also interacts with an external environmental medium 28 at a second interface 30. Lastly, the second compartment 22 has a third interface 32 with the medium 30. In FIG 1B, a first compartment 20' has a reduced surface area that is exposed to external medium 28 than the second compartment 22'. However, such compartments 20, 22' have a first, second, and third compartment interface 26', 30', 32', like in FIG. 1A. The differences in the relative sizes between compartments in FIGS. 1A and 1B are due to the differences in thermodynamic equilibria present between the materials forming the respective compartments. Thus, as can be appreciated by those of skill in the art, a number of distinct morphologies are possible.

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25 **[0055]** FIG. 1C shows a triphasic micro-particle 34 having three compositionally distinct compartments 36, 37, 38 each respective compartment having an exposed surface to a surrounding medium 35. Interfaces are defined between compartments 36 and 37, 37 and 38, and 36 and 38. Further, each respective compartment interfaces with the surrounding medium 35, thus defining three additional interfaces. In sum, a triphasic three compartment micro-particle 34 includes 6 interfaces.

30 **[0056]** In FIG. 1A, another variation in which the micro-particle is biphasic having two distinct compartments 14, 16 of unequal size (with corresponding chemically distinct sides or surfaces) is illustrated. The differences in the relative sizes between

compartments in FIGS. 1A and 1B are due to the differences in thermodynamic equilibria present between the composite particles in FIG. 1A versus FIG. 1B. In each variation, a number of morphologies are possible and can be useful in the different methods and devices of the present teachings.

5 **[0057]** Multi-compartment micro-particles useful in accordance with the principles of the present teachings can be made of a wide variety of materials, including inorganic and organic materials. However, in certain preferred variations, the multi-compartment micro-particles comprise one or more polymers in each respective compartment. Preferred methods of making such anisotropic multi-compartment micro-
10 particles are by electrified jetting (*e.g.*, electrohydrodynamic jetting), as well as the resultant components made from such processes, are more fully described in detail in Roh et al., “Biphasic Janus Particles With Nanoscale Anisotropy,” *Nature Materials*, Vol. 4, pp. 759-763 (October, 2005), and in U.S. Patent No. 7,767,010 issued on August 3, 2010, and in U.S. Patent Application No. 11/763,842 filed on June 15, 2007, which
15 published as U.S. Pub. No. 2007/0237800, all of which are to Lahann et al. The contents of each of these respective references, as well as any additional references discussed herein, are hereby incorporated by reference in their respective entireties.

[0058] In certain aspects, the plurality of anisotropic multi-compartment micro-particles is formed by an electrified jetting process so that the anisotropic multi-
20 compartment micro-particles have a substantially round shape. In other aspects, the plurality of anisotropic multi-compartment micro-particles is formed by an electrified jetting process so that the anisotropic multi-compartment micro-particles have a shape selected from the group consisting of: spheres, cylinders, rods, disks, toroids, and combinations thereof.

25 **[0059]** For example, in certain aspects, the micro-particles can be formed in an electrified jetting process that includes forming a composite stream by contacting a portion of a first liquid stream with a portion of a second liquid stream. At least a portion of the composite stream is exposed to an electric force field sufficient to form a solid micro-component having distinct compartments with a predetermined morphology,
30 based upon the jetting conditions employed. Each liquid stream that is jetted in such processes comprises a material optionally selected from liquid solutions, curable polymer precursors, polymer solutions, and polymer melts. Thus, each respective compartment of

the micro-particle is formed from material from the respective jetted liquid streams. Specifically, each compartment optionally contains polymers or polymer precursors (which upon curing form polymers), such as biodegradable or non-biodegradable polymers, biocompatible polymers, or natural polymers. Such polymers may be further
5 cross-linked and cured after jetting.

[0060] In certain embodiments, at least one compartment of the multi-compartment micro-component comprises at least one polymer. In certain aspects, multiple compartments of the multi-compartment micro-component each comprise one or more polymers. The polymers can also be modified by chemical or physical methods,
10 such as cross-linking, heat treatment, photochemical treatment, and/or changes in the chemical or physical environment. Cross-linking, for example, can be thermally induced or actinic radiation induced (*e.g.*, photochemically induced). Moreover, the cross-linking may also include immobilization of active components included, which will be described in greater detail below. In certain variations, the polymer modification occurs in a select
15 portion or region of one or more of the multiple compartments, or such polymer modification can occur to different degrees, potentially resulting in different materials or materials responses, as appreciated by those of skill in the art.

[0061] Suitable non-limiting polymers for use in the multi-compartment micro-component compositions include sodium polystyrene sulfonate (PSS), polyethers,
20 such as a polyethylene oxide (PEO), polyoxyethylene glycol or polyethylene glycol (PEG), polyethylene imine (PEI), a biodegradable polymer such as a polylactic acid, polycaprolactone, polyglycolic acid, poly(lactide-co-glycolide) polymer (PLGA), polyvinylpyrrolidone, and copolymers, derivatives, and mixtures thereof. Other polymers include those well known to those of skill in the art. Specifically, at least one
25 compartment can be designed to have one or more of the following properties based upon material selection: hydrophobic, positively-charged (cationic), negatively-charged (anionic), polyethylene glycol (PEG)-ylated, covered with a zwitterion, hydrophobic, superhydrophobic (for example having water contact angles in excess of 150°), hydrophilic, superhydrophilic (for example, where the water contact angle is near or at
30 0°), olephobic/lipophobic, olephilic/lipophilic, and/or nanostructured, among others. In other aspects, one or more polymers or materials used within a compartment may be functionalized to subsequently undergo reaction with various moieties or substances after

formation of the multi-compartment micro-component, to provide desired surface properties or to contain various moieties presented on the compartment surface, as recognized by those of skill in the art.

[0062] Water-soluble and/or hydrophilic polymers that can be used include
5 cellulose ether polymers, including those selected from the group consisting of hydroxyl alkyl cellulose, including hydroxypropyl methyl cellulose (HPMC), hydroxypropyl cellulose (HPC), hydroxyethyl cellulose (HEC), methyl cellulose (MC), carboxymethyl cellulose (CMC), and mixtures thereof. Other polymers among those useful herein include polyvinylpyrrolidone, vinyl acetate, polyvinylpyrrolidone-vinyl acetate
10 copolymers, polyvinyl alcohol (PVA), acrylates and polyacrylic acid (PAA), including polyacrylate polymer, vinylcaprolactam/sodium acrylate polymers, methacrylates, poly(acryl amide-co-acrylic acid) (PAAm-co-AA), vinyl acetate and crotonic acid copolymers, polyacrylamide, polyethylene phosphonate, polybutene phosphonate, polystyrene, polyvinylphosphonates, polyalkylenes, and carboxy vinyl polymer. The
15 micro-component compositions may comprise derivatives, copolymers, and further combinations of such polymers, as well.

[0063] Other polymers or water-soluble fillers among those useful herein include, without limitation, sodium alginate, carrageenan, xanthan gum, gum acacia, Arabic gum, guar gum, pullulan, agar, chitin, chitosan, pectin, karaya gum, locust bean
20 gum, various polysaccharides; starches such as maltodextrin, amylose, corn starch, potato starch, rice starch, tapioca starch, pea starch, sweet potato starch, barley starch, wheat starch, modified starch (*e.g.*, hydroxypropylated high amylose starch), dextrin, levan, elsinan and gluten; and proteins such as collagen, whey protein isolate, casein, milk protein, soy protein, keratin, and gelatin.

[0064] Further, suitable non-limiting examples of water insoluble or hydrophobic polymers include cellulose acetate, cellulose nitrate, ethylene-vinyl acetate
25 copolymers, vinyl acetate homopolymer, ethyl cellulose, butyl cellulose, isopropyl cellulose, shellac, hydrophobic silicone polymer (*e.g.*, dimethylsilicone), polymethyl methacrylate (PMMA), cellulose acetate phthalate and natural or synthetic rubber;
30 siloxanes, such as polydimethylsiloxane (PMDS), polymers insoluble in organic solvents, such as cellulose, polyethylene, polypropylene, polyesters, polyurethane and nylon, including copolymers, derivatives, and combinations thereof. These polymers

may be cross-linked after formation by application of heat, actinic radiation or other methods of curing and treating polymers known to those of skill in the art.

[0065] In various aspects, at least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed surface that is reactive with and serves to bind the target species. In certain aspects, at least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed surface that comprises a moiety for binding to the target species. By “binding” it is meant that the target species is reacted with, has an affinity to, or is otherwise associated with the surface (for example, with the moiety on the surface) so that a free target species is removed from the fluid composition by being preferentially associated with the binding surface. In certain variations, the binding of the target species forms a conjugate species with the moiety and thus the entire micro-particle, so that a free target species is removed from the fluid composition by being bound to the moiety. In certain preferred aspects, the binding of the target species to the moiety occurs by a chemical reaction. The binding may be reversible in certain alternative aspects, discussed in greater detail below. Furthermore, multiple distinct compartments of each of the anisotropic multi-compartment micro-particles may be capable of binding with distinct target species, so that the micro-particle can bind with multiple distinct target species.

[0066] Thus, in certain aspects, the exposed surface that comprises the moiety for binding to the target species is a first exposed binding surface (a binding surface). Another distinct compartment of the anisotropic multi-compartment micro-particle defines a second distinct exposed surface that does not bind with the target species (a non-binding surface). Notably, the present teachings further contemplate different exposed surfaces of the multi-compartment micro-particle as being capable of binding with distinct target species, so that a first exposed binding surface may bind to a first target species and a second exposed surface is non-binding with respect to the first target species, while the second exposed surface may bind to a second distinct target species (and thus, the first binding surface does not bind with the second distinct target species). In certain variations, the first exposed surface has a first surface area that is greater than a second surface area of the second exposed surface. For example, in certain embodiments, the first exposed surface has a first surface area that is at least 50 times greater than a second surface area of the second exposed surface. In other variations, the

first exposed surface has a first surface area that is at least five times smaller than a second surface area of the second exposed surface.

[0067] The reactive moiety may be a chemical group, a component, a cell, or other material that is presented along the exposed surface of one or more of the compartments of the multi-compartment micro-particle. Such a moiety can be generally incorporated into the material that forms the compartment, or can be formed by treating the surface of the compartment after formation of the particle, or may itself be reacted with a material on the surface of the compartment. Hence, an exposed surface of a compartment can be designed to be a binding surface having the predetermined properties required to bind a target species to the surface by providing such materials within the material forming the compartment, or by subsequent treating, reacting, or coating of the exposed compartment surface after formation of the micro-particle to achieve such properties. In certain aspects, at least one compartment optionally comprises a surface moiety (*e.g.*, each phase's surface can be tagged with a different targeting moiety or active agent) or each compartment can optionally have different surface properties. Specifically, at least one compartment can have an exposed surface selected to be a binding surface that is hydrophilic, hydrophobic, positively charged (cationic), negatively charged (anionic), surface active agent modified (*e.g.*, PEG-ylated or covered with a zwitterion), superhydrophobic, superhydrophilic, oleophobic, oleophilic, and/or nanostructured.

[0068] In accordance with the present teachings, multi-compartment micro-particles can include two compartments having the same property, such as both phases being hydrophilic. A multi-compartment micro-particle can be designed to have such properties by providing such materials within the material forming the phase, or may be provided by subsequent treating, reacting, or coating of the exposed compartment surface after formation of the multi-compartment micro-particle to achieve such properties.

[0069] Polymers within a selected compartment can further be modified to interact and/or react with certain target species. For example, as discussed above, reactive groups on a polymer in a first compartment may be cationic and the target species is anionic, so that the target species will be attracted to the exposed surface of the first compartment. In other embodiments, the functional groups on the polymer may participate in a reaction with a functional group present on a moiety, such that they react with and are bonded to the surface of the compartment. The moiety can thus be presented on the exposed surface for reaction with a target species. For example, reactive groups on a polymer in a first phase or compartment may be cationic and the target species is anionic and will be attracted to the exposed surface of the first compartment. In other variations, reactive groups on a polymer in a first phase or compartment may be cationic and the target species may likewise be cationic. A desired moiety for the surface is anionic and will be attracted to the cationic exposed surface of the first compartment. Subsequently, a cationic target species will thus be attracted to the anionic surface moiety disposed along the cationic exposed surface of the first compartment. For example, if a first compartment of the multi-compartment micro-particle comprises a polymer with a $-CHO$ functional group at the surface and the moiety to be attached to the first compartment has a $-CH_2NH_2$ functional group, such groups have an affinity to form a $-C=N$ covalent bond; thus, the surface of the first compartment has an affixed moiety presented at the surface.

[0070] Moreover, in certain embodiments, each compartment can comprise a different moiety (*e.g.*, each phase can be tagged with a different targeting moiety or active agent) or can optionally have different surface properties. Specifically, at least one compartment can be selected to be hydrophilic, hydrophobic, positively charged (cationic), negatively charged (anionic), surface active agent modified (*e.g.*, PEG-ylated or covered with a zwitterion), superhydrophobic, superhydrophilic, oleophobic, oleophilic, and/or nanostructured, as described above.

[0071] Notably, other compartments of the anisotropic multi-compartment micro-particles can be reactive with other surfaces or distinct target species. In certain variations, a second distinct compartment of the multi-compartment micro-particle may be reactive with or attracted to a surface to be coated, so as to self-assemble and form a surface coating on the surface. The anisotropic morphology of the multi-compartment

micro-particle enables one or more other compartments of the micro-particle to be exposed to the external environment for interaction with target species, while being anchored to the surface as a coating. In various aspects, one or more exposed compartment surfaces comprise a moiety for binding with a target species, such as those described in U.S. Patent Application Serial No. 11/763,842.

[0072] The following is a list of non-limiting examples of suitable binding moieties for use with the multi-compartment micro-particles. Proteins, such as heat shock protein HSP70 for dendritic cells and folic acid to target cancer cells, are suitable moieties. Polysaccharides or sugars, such as silylic acid for targeting leucocytes, targeting toxins such as saporin, antibodies, including CD 2, CD 3, CD 28, T-cells, and other suitable antibodies are listed in a Table entitled Anti-HUMAN CD CLUSTERED (CD) ANTIBODIES at <http://www.researchd.com/rdicdabs/cdindex.htm> (October 17, 2011), expressly incorporated by reference herein. Other binding moieties include aptamers, which are small oligonucleotides that specifically bind to certain target molecules, for example, Aptamer O-7 which binds to osteoblasts; Aptamer A-10 which binds to prostate cancer cells; and Aptamer TTA1, which binds to breast cancer cells. Other exemplary binding moieties include peptides, such as CGLIIQKNEC (CLT1) and CNAGESKNC (CLT2) for binding to clots. Various peptides are well known in the art for binding to cells from the brain, kidneys, lungs, skin, pancreas, intestine, uterus, adrenal gland, and prostate, including those described in Pasqualini et al., "Searching for a molecular address in the brain," *Mol. Psychiatry* 1(6) (1996) pp. 421-2 and Rajotte, et al., "Molecular heterogeneity of the vascular endothelium revealed by in vivo phage display," *J. Clin. Invest.* 102(2) (1998) pp. 430-7, for example. Other binding moieties may include viruses, phages, bacteria or cells. Other binding biological moieties known or to be developed in the art are contemplated by the present disclosure.

[0073] In certain aspects, the materials selected for use as a moiety within the micro-components of the present disclosure can be designed to reversibly bind a target species, so that in the presence of an external stimulus, the target species is released from the moiety. Exemplary stimuli to which the moieties of the micro-particles can be designed to respond include light, change in pH, temperature, pressure, humidity, light, magnetic fields, electrical fields, other applied energy fields, or various chemicals stemming from either the human body or the environment, as described below. One

example is where the target species are released from a conjugate species upon exposure to light, such as UV light of a certain wavelength range. This approach takes advantage of typical photo-cleavable groups, well known to those skilled in the art.

5 **[0074]** In certain aspects, at least one of the compartments of the micro-component may further contain an additional additive or component, for example colorants, dyes, traditional diagnostic and detection agents, magnetic particles, inorganic nanocrystals, quantum dots, biomolecules, cross-linkers, pharmaceutical compounds, molecular probes, molecules that enable drug delivery (*e.g.*, targeted or untargeted), and the like. In other aspects, multiple compartments may contain the same polymer, but
10 differ in the additives present in each respective compartment.

[0075] Because the multi-compartment micro-particles can be employed for detection of the presence of certain target species, it can be desirable to include one or more colorants in compartment(s) to facilitate visible detection. Suitable colorant materials for use in accordance with the present teachings include, but are not limited to,
15 dyes, pigments, and polymers. A “pigment,” is generally an inorganic or organic, colored, white or black material that is usually substantially insoluble in solvents. A “dye,” unlike a pigment, is generally soluble in a solvent or carrier. Pigments may be selected to have a particle size suitable for an application, for example, a maximum particle size that is small enough to avoid clogging of nozzles or capillaries during
20 formation and of a smaller particle size than the micro-component dimensions. In certain aspects, the pigments have minimal deviation in particle size, *i.e.* have a narrow particle size distribution. Other suitable colorants include polymers, which may also form a structural component material of the micro-component. Furthermore, pluralities of distinct colorants can be used.

25 **[0076]** In one variation, one or more quantum dots, which have specific electronic, magnetic, optical or biomedical properties, are incorporated into only one side or compartment of the micro-particle. Quantum dots are emerging new materials for biological labeling and are rapidly substituting traditional organic colorants and fluorescent proteins due to their unique characteristics such as high luminescence and
30 long stability. These quantum dots can be encapsulated in or selectively attached to the multi-compartment component. Detection can be accomplished by combining the multi-compartment micro-particle and an appropriate physical mechanism (*e.g.* fluorescent

resonance energy-transfer or “FRET”) for detecting the presence of the target species with the multi-compartment micro-particle as a conjugate species. For sensors or probes based on FRET, size control and interface design between the donor and acceptor considering the Foster distance are important design criteria.

5 **[0077]** In other aspects to facilitate detection or separation, one of the compartments of the micro-components may contain a redox-active material, a conducting material, a charged material, or a material that is otherwise reactive to an external energy source (for example, an energy field that is controllable, such as magnetic fields, electric fields, heat or electromagnetic energy, pressure, sonication, and
10 the like). In this way, the target species bound to the multi-compartment micro-particle (as a conjugate species) can be isolated from the fluid composition in the presence of the external field. Further, in certain aspects, the micro-component may contain materials that enable the generation of an electrical potential in response to application of energy or radiation, such as a light pulse, for example, or an electrical potential comparable to a
15 typical cell potential, which can be used for detecting the presence of target species. The micro-component may likewise have a preferential alignment towards a cell, so that when a cell potential is applied, detection or separation occurs.

[0078] Therefore, one or more compartments of the micro-particle can be responsive to an external stimulus, such that conjugate species comprising the micro-
20 particle and target species may be readily detected or separated from the fluid composition. The external stimulus can be selected from the group consisting of pH, humidity, pressure, light, temperature, applied energy fields, electrical fields, magnetic fields, and combinations thereof. As discussed below, micro-particles comprising materials responsive to an external stimulus can be used as a basis for separating the
25 conjugate species (and thus the target species) from the composition. Thus, in certain aspects, one or more compartments may comprise polymers or incorporate other components that respond upon exposure to an external stimulus, such as polymers or additives that respond to a change in pH, temperature, pressure, humidity; dyes or other additives that change emission properties upon exposure to external UV radiation or
30 light; particles or additives that are magnetic or conductive which respond to external energy fields, such as magnetic fields, and electrical fields; and the like.

[0079] Where the micro-components are used in such applications, the micro-components are formed with different compartments having charged components or a distribution of components responsive to an external force field. Where the micro-components are used in such applications, the micro-components are formed with
5 different compartments having charged components or a distribution of magnetic or other responsive elements. In another aspect, the present teachings contemplate using light to activate the dipole moment of the micro-component by inducing temporary charge transport from one compartment of the micro-component to another compartment.

10 [0080] In certain embodiments, one or more compartments of the micro-particle can comprise a colorant, a fluorescence dye, an antibody disposed on an exposed compartment surface, or an environmentally responsive compartment surface, and the like.

[0081] By way of example, useful nano-crystals or other micro-component
15 additives for incorporating into one or more compartments of the micro-particle generally have a particle size of less than about 50 nm, optionally less than about 20 nm, and in some aspects, less than 10 nm. Useful non-limiting additive ingredients include colorants and dyes, magnesium oxide, and metal-based nano-particles, comprising gold, silver, and the like. Suitable other active ingredient nano-crystals include magnetite
20 (Fe_3O_4). Quantum dots are optically active nano-structures, for example, cadmium tellurium (CdTe).

[0082] In other variations, additional ingredients that can be used in the multi-compartment micro-particles are used for diagnostic or detection purposes, such as
25 in analytical assays, diagnostic medical imaging procedures (for example, radiographic imaging (x-ray), fluorescence spectroscopy, Forster/fluorescent resonance energy-transfer (FRET), computed tomography (CT scan), magnetic resonance imaging (MRI), positron emission tomography (PET), other nuclear imaging), and the like. Diagnostic active ingredients for use with diagnostic imaging include colorants, dyes, and/or contrast agents, such as barium sulfate for use with MRI, for example, or fluorescein
30 isothiocyanate (FITC).

[0083] One or more compartments of the micro-particles optionally comprise additives that have polarity or charge (to form an induced charge-charge/dipole moment).

In certain aspects, a first compartment may have an additive or polymer with a first charge and a second compartment may have an additive or polymer with a second charge opposite to the first charge, so that the orientation of molecules can be controlled in multiple directions, therefore providing control over multiple dimensions. Another suitable embodiment employs amphiphilicity, which can be provided by surface modification of exposed compartments or inclusion of appropriate components in each respective compartment to provide a hydrophobic-hydrophilic dipole in respective distinct compartments to detection and/or separation.

[0084] In certain aspects, at least one of the compartments of the micro-component optionally further contains an additional additive or component, for example biomolecules, cross-linkers, conventional additives, pharmaceutical compounds, molecular probes, active ingredients and drugs, and molecules that enable drug delivery and/or bioavailability. In other aspects, multiple compartments may contain the same polymer, but differ in the additives present in each respective compartment.

[0085] In certain aspects, a variety of low molecular weight molecules can further be included in one or more compartments of the multi-compartment micro-components depending on the application, particularly those having a molecular weight of less than about 10,000 g/mol, optionally less than about 1,000 g/mol, and optionally less than about 500 g/mol. Such molecules include pharmaceutical therapeutic drugs, which by way of non-limiting example include chemotherapeutic drugs, for example, doxorubicin (molecular mass of about 543.5 g/mol); paclitaxel or TaxolTM (molecular mass of about 853.9 g/mol), cholesterol lowering drugs, lovastatin (molecular mass of about 404.5 g/mol), and NSAID analgesic ibuprofen (molecular mass of 206.3 g/mol).

[0086] In certain variations, methods of the present disclosure include those used to detect the presence of one or more target analytes or species in a fluid composition. For example, a schematic is shown in FIG. 3. A plurality of multi-compartment micro-particles 60 are dispersed in a fluid composition 50. Each multi-compartment micro-particle 60 comprises a first compartment 52 with an exposed surface and a second distinct compartment 54 also having an exposed surface. In one example such as that shown in FIG. 3, there may be two distinct moieties on the respective compartments of the multi-compartment micro-particles 60. Thus a first moiety 62 is disposed along an exposed surface of first compartment 52, while a second

distinct moiety 56 is disposed on the exposed surface of the second compartment 54. As shown, the first moiety 62 binds with a plurality of receptors or surface ligands 64 on a target species cell 65 to form a conjugate species comprising both the cell 65 and the multi-component micro-particle 60. Thus, target species cell 65 can be any variety of cells, such as an immune system cell like a leukocyte or T-cell. The second moiety 56 may bind with a different target species. For example, the second binding moiety 318 may be compatible with a second target cell (not shown) or may provide a change in optical properties to use in conjunction with diagnostic imaging, such as a diagnostic species, like an immunoassay species, an immunoradiometric species, or specifically fluorescein isothiocyanate (FITC) antigen species. The first moiety 62 on the surface of the first compartment 52 of the multi-compartment micro-particle 60 thus binds to the primary target cell 65 with high selectivity, while the other second compartment 54 binds selectively with a distinct target species. Suitable moieties for binding with targets associated include all those previously described.

15 **[0087]** In various aspects, the use of multi-compartment micro-components of the present disclosure provides a variety of advantages. For example, the multi-compartment micro-particles 60 are complex and directional due to the anisotropic design. Conventional nano-scale systems are isotropic and do not provide directional targeting. Thus, the multi-compartment micro-particles 60 provide directed targeting based on the orientated interactions with the surrounding environment, as where conventional systems lack such directional targeting. Furthermore, the multi-compartment micro-particles 60 have only certain ligands or moieties (for example cancer ligands) exposed for selective binding with target species; thus, there is minimal risk for cross-linking or adverse interaction with the surrounding environment. Conventional delivery systems may use certain ligands that are permanently exposed, but the extended exposure of the ligands increases the potential for interaction with multiple undesirable species in addition to the target species or analyte. Further, multi-compartment micro-particles 60 provide functional imaging due to two-dimensional analysis, as there is a potential to differentiate specific and non-specific events, in contrast to previous systems, where only one-dimensional imaging was possible due to contrast agents lacking the ability to undergo specific and non-specific binding.

[0088] Therefore, in accordance with various aspects of the present disclosure, methods include contacting a fluid composition (potentially comprising the target species) with a plurality of anisotropic multi-compartment micro-particles. Such contacting can occur in a detection device, for example, in a region, a chamber or other device compartment. Thus, at least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed binding surface capable of binding to the target species, so that the anisotropic multi-compartment micro-particle binds with the target species present in the fluid composition to form a conjugate species. In certain aspects, at least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed surface that optionally comprises a moiety for binding to the target species, so that the anisotropic multi-compartment micro-particle binds with the target species present in the fluid composition to form a conjugate species. In certain variations, the target species is a biological target selected from the group consisting of: prokaryotic cells, eukaryotic cells, genetic materials, proteins, polypeptides, biomolecules, viruses, saccharides, antigens, and combinations thereof. Furthermore, in accordance with certain aspects of the present teachings, the conjugate species has at least one property that enhances detection of the target species from the fluid composition as compared to the target species alone. The presence of conjugate species in the fluid composition is then readily detected, for example, in the same region or a different region of the detection device. In certain embodiments, the method further includes generating or providing an output from the detection device indicating detection of the presence of the conjugate species.

[0089] In certain aspects, the detecting of the presence of the conjugate species in the fluid composition also comprises detecting a quantity of the conjugate species present in the fluid composition. Thus, providing the output from the detection device further indicates the quantity of the conjugate species present in the fluid composition.

[0090] In certain variations, the plurality of multi-compartment micro-particle components can self-assemble to form a surface coating by interaction with a substrate surface (for example, certain exposed surfaces of the compartments of the micro-particle can have a reactive group, charge, or other responsive characteristic that is attracted and bound to a substrate. In other variations, the multi-compartment micro-

particle components can be provided in a coating and thus dispersed in a binder material to form a coating, such as binder materials selected from the group consisting of polymeric materials, organic materials (such as materials derived from plants or animals), inorganic materials, and the like.

5 **[0091]** An alternative embodiment of a detection component 200 for a detector device is shown in FIG. 4. A fluid composition 202 that potentially comprises target species 212 is provided in an external surrounding environment. A surface of a substrate 204 has a plurality of anisotropic substantially round multi-compartment micro-particles 206 self-assembled thereon to form a coating. The plurality of multi-compartment micro-
10 particles 206 on substrate 204 is contacted with the fluid composition 212. Such contacting can occur in a detection device, for example, in a contact region, chamber or compartment, as are well known in the art.

[0092] Each multi-compartment micro-particle 206 comprises a first compartment 208 and a second distinct compartment 210. The first compartment 208
15 interfaces with the surface of substrate 204 to bind the multi-compartment micro-particle 206 thereon. The second compartment 210 is a reactive binding surface (*e.g.*, having a moiety or plurality of binding moieties) that is capable of binding with target species 212. A conjugate species 220 is formed when a target species 212 is associated and bound to second compartment 210 of the multi-compartment micro-particle 206.
20 Furthermore, in accordance with certain aspects of the present teachings, the conjugate species 220 has at least one property that enhances detection of the target species 212. A substrate surface 204 coated with multi-compartment micro-particles 206 as in FIG. 4, can enable detection or separation of target species 212 from fluid composition 202.

[0093] The increase of at least one property that enhances detection can be an
25 increase in output of a detectable characteristic, such as electromagnetic radiation, magnetism, charge or dipole moment, and the like that can be used as a detection or diagnostic assay or test. In other aspects, the increase of at least one property that enhances detection can be an increase in responsive to external stimulus, to readily enable detection of the conjugate species. Components that can be included in one or
30 more compartments of the multi-compartment micro-particles that enable such enhanced detection properties were discussed above. For example, the presence of conjugate species 220 in the fluid composition 202 can be detected in the same region of a

detection device. In certain embodiments, an output from the detection device indicates detection of the presence of the conjugate species. Such an output may be generation of a signal, electromagnetic wave, or the like. Thus, the methods of the present teachings for detecting the presence of a target species can be used in sensor devices.

5 **[0094]** In certain aspects, the detecting of the presence of the conjugate species in the fluid composition also comprises detecting a quantity of the conjugate species present in the fluid composition. For example, target analyte species may be labeled with specific binding reagents or biomarkers that provide the capability for both detection and quantification, for example. Thus, providing the output from the detection
10 device further indicates the quantity of the conjugate species present in the fluid composition.

[0095] An exemplary analytical assay device 250 is shown in FIG. 7, which can be used to detect the presence and to quantify the concentrations of target analytes. A matrix of wells 252 or other compartments are formed in a substrate 254. As shown,
15 the wells have a plurality of anisotropic multi-compartment micro-particles 260 disposed therein. Such anisotropic multi-compartment micro-particles 260 may be disposed in the wells 252, and/or may be formed as a coating on the surfaces of the wells (not shown). Each anisotropic multi-compartment micro-particle 260 has a first compartment 264 and a second compartment 266, each respectively having an exposed surface region. The first
20 compartment 264 is capable of reacting with a pre-determined target species. A fluid composition 270 potentially including a target species (not shown) is introduced via a pipette 272 into select wells 252. Thus, the fluid composition 270 is contacted with the anisotropic multi-compartment micro-particles 260 in the well 252. If the desired target species is present in the fluid composition, it will bind to the reactive surface 260 to form
25 a detectable conjugate species (not shown in FIG. 7). It is noted that the anisotropic multi-compartment micro-particles 260 may comprise multiple distinct compartments that are reactive with a plurality of distinct target species, so that detection and/or quantification of a variety of different target analyte species in the assay device 250 is contemplated.

30 **[0096]** Thus, an analytical assay, such as the exemplary assay 250 in FIG. 7, can involve at least one anisotropic particle binding to at least one target species analyte so that a specific property of the conjugate species (comprising the micro-particle and the

target species) is increased. Furthermore, such a conjugate species facilitates subsequent separation of the analyte/particle conjugate species based on that specific properties imparted to the analyte/particle conjugate species via the micro-particle properties (discussed previously above).

5 **[0097]** In other aspects, the present disclosure provides a method for separating a target species from a fluid composition. While such separating may be done with a configuration like that shown in FIG. 4, other alternative separator configurations are shown in FIGS. 5A-5B. Such a method comprises contacting a fluid composition comprising the target species with a plurality of anisotropic multi-compartment micro-
10 particles. FIG. 5A shows an exemplary schematic of one embodiment of a separation apparatus 100. Separation apparatus 100 feeds a fluid composition 101 from a tube or conduit 102 into a feeding chamber 110 at a constant rate. The fluid composition 100 comprises a plurality of target species 114 to be separated therefrom.

[0098] Chamber 106 comprises a plurality of anisotropic multi-compartment
15 particles 112 (that can be separately fed to the feeding chamber via a delivery system that is not shown for continuous processes). When the fluid composition 101 is combined with the anisotropic multi-compartment particles 112, a mixture 104 is formed and contained in chamber 106. At least one distinct compartment of each of the anisotropic multi-compartment particles 112 defines an exposed binding surface that comprises a
20 moiety for binding to the target species 114 as described previously above, so that the anisotropic multi-compartment particle 112 binds with the target species 114 present in the fluid composition to form a conjugate species 116. In such an embodiment, the conjugate species 116 has at least one property that facilitates separation of the target species 112 from the fluid composition 101. In this context, the property is the size of
25 the conjugate species 116, which is significantly larger than the target species 114 alone.

[0099] The increase of at least one property that enhances separation can be an increase in a particle size diameter (as compared to the target species). For example, an increase in an average particle size of the conjugate species as compared to the original target species is optionally at least 100%, optionally at least 200%, optionally at
30 least 500%, optionally at least 1,000% or more of an increase of an average particle size diameter. In this regard, the increase in particle size facilitates separation of the conjugate species from the fluid composition, so that the target species can be removed.

[00100] In certain aspects, the separating occurs by a process selected from the group consisting of: filtration, centrifugation, ultracentrifugation, settling, chromatographic methods, precipitation, and combinations thereof. Thus, separation of the target species from the fluid composition can occur by filtration, which comprises
5 passing the fluid composition having the conjugate species dispersed therein through a filtration membrane to separate the conjugate species from a fluid permeate. Suitable filtration membranes can be selected from the group consisting of: a nanoscopic filtration membrane, a mesoscopic filtration membrane, a microscopic filtration membrane, and combinations thereof.

10 [00101] Such a filtration membrane may be highly porous (*e.g.*, of greater than about 1% to less than or equal to about 99%, optionally having a porosity of greater than about 10% to less than or equal to about 95%), having a plurality of pores formed within a body of the material. The plurality of pores includes a plurality of internal pores and
15 external pores that are open to one another and form continuous flow paths or channels through the substrate body extending from a first external surface to a second external surface. As used herein, the terms “pore” and “pores” refer to pores of various sizes, including so-called “macropores” (pores greater than 50 nm diameter), “mesopores” (pores having diameter between 2 nm and 50 nm), “micropores” (pores having diameter of less than 2 nm) unless otherwise indicated, and “nanopores” (generally overlapping
20 with microporous, mesoporous, and macroporous categories having pores with diameters between 2 nm and 100 nm), where the pore size refers to an average or median value, including both the internal and external pore diameter sizes. In various aspects, the filtration material comprises a plurality of pores having an average pore size diameter of greater than or equal to about 10 nm to less than or equal to about 1 mm, optionally
25 greater than or equal to about 20 nm to less than or equal to about 10 μm , optionally greater than or equal to about 30 nm to less than or equal to about 5 μm , optionally greater than or equal to about 40 nm to less than or equal to about 1 μm . In certain variations, an average pore size diameter of the plurality of pores in the filtration material is selected to be greater than or equal to about 10 nm to less than or equal to about 1 mm,
30 optionally greater than or equal to about 50 nm to less than or equal to about 500 nm. Thus, in certain variations, the filtration membrane for separations is selected from the

group consisting of: a nanoscopic filtration membrane, a mesoscopic filtration membrane, a microscopic filtration membrane, and combinations thereof.

[00102] A separator device for conducting such filtration separation processes may have a configuration so that the fluid composition having the conjugate species dispersed therein is gravity fed towards a filtration membrane. The first porous filtration material is operable to continuously separate the conjugate species from the fluid composition permeate.

[00103] On this principle, the conjugate species 116 in FIG. 5A is readily separated from the fluid composition 101 as follows. The mixture of conjugate species 116 and the fluid composition 101 flows into a holding chamber 120 that collects the conjugate species 116. An opening in the holding chamber 120 has a filtration membrane 122 disposed therein. Thus, the fluid composition 101 passes through the filtration membrane 122, so that a fluid permeate 124 is permitted to pass through into permeate retention chamber 126, while the conjugate species 116 is retained above the filtration membrane 122. In this way, the conjugate species 116 is separated from the fluid composition 101.

[00104] In other aspects, the increase of at least one property that enhances detection can be an increase in magnetic properties or magnetization. Thus, the separating can occur by exposing the fluid composition having the conjugate species to a magnetic field so as to remove the conjugate species from the fluid composition.

[00105] FIG. 5B shows an alternative embodiment of a separator device like that in FIG. 5A. To the extent that the components are common to both, they will not be discussed herein. In the separation device of FIG. 5B, conjugate species 116 are formed in the same manner as described in FIG. 5A and mixture 104A is contained in chamber 106. However, the property of conjugate species 116A that facilitates separation of the target species 112 from the fluid composition 101 is magnetism because at least one compartment of the plurality of multi-compartment micro-particles 112A includes a magnetic material. Thus, holding chamber 120A has the capability to induce an external force field, such as a magnetic force field that can be selectively induced or a permanent magnet. Other similar force fields can be employed for separation. Thus, conjugate species 116A is exposed to the magnetic field in holding chamber 120A, the conjugate

species 116A is retained therein, while a separated fluid permeate 124 is permitted to pass through into permeate retention chamber 126.

[00106] It should be noted that separation devices may incorporate other conventional components or have various other configurations and are not limited
5 exclusively to the exemplary designs discussed above, as appreciated by those of skill in the art.

[00107] In other aspects, at least one property that is enhanced in the conjugate species as compared to the target species by itself is a dielectric moment. In such
10 embodiments, the separating occurs by electrophoresis, which entails exposing the fluid composition to an electrical field to remove the conjugate species from the fluid composition.

[00108] Thus, the present disclosure provides methods of separating a target species from a mixture of a fluid composition with the target species. The fluid composition comprises a target species present at an initial amount. The methods
15 comprise contacting the mixture of the fluid composition and target species with the multi-component micro-particle, for example, by introducing a plurality of multi-component micro-particles into the fluid composition or by passing the fluid composition by or over a plurality of multi-component micro-particles. The contacting facilitates binding of the target species with a moiety on the multi-component micro-particle so as
20 to form a conjugate species. The conjugate species has one or more properties that enable separation, isolation, and/or removal from the remaining fluid composition. For example, such contact can serve to separate greater than or equal to about 75 weight % of the initial amount of the target species from the fluid composition, optionally greater than or equal to about 80 weight %, optionally greater than or equal to about 85 weight
25 %, optionally greater than or equal to about 90 weight %, optionally greater than or equal to about 95 weight %, optionally greater than or equal to about 97 weight %, optionally greater than or equal to about 98 weight %, optionally greater than or equal to about 99 weight %, and in certain aspects, optionally greater than or equal to about 99.5 weight % of the initial amount of the target species from the fluid composition. In certain
30 variations, the contacting separates greater than or equal to about 90 weight % up to 100 weight % of the initial amount of the target species from the fluid composition. Further, such methods can be conducted as continuous processes and may be gravity-assisted.

[00109] In other variations, the present disclosure provides a separator device for conducting such separations processes. In certain variations, an efficiency of separation using the inventive materials as a separator technology is greater than or equal to about 85%, optionally greater than or equal to about 90%, optionally greater than or equal to about 95%, optionally greater than or equal to about 97%, optionally greater than or equal to about 99%, optionally greater than or equal to about 99.5%, and in certain preferred aspects, optionally greater than or equal to about 99.9% for fluid compositions comprising the target species.

[00110] In yet other variations, the binding of the anisotropic multi-compartment micro-particles with the target species is reversible. After the separating, the conjugate species is subjected to conditions so as to release the target species from the anisotropic multi-compartment micro-particles. In this manner, the target species can be isolated and recovered after the separating process. As discussed above, the conditions that the conjugate species is subjected to for releasing the target species (and reverse the binding of the surface or moiety of one or more compartments with the target species) can be selected from the group consisting of: a change in pH, a change in temperature, exposure to a second distinct stimulus, and combinations thereof. In variations where binding of the target species to the moiety of the multi-compartment micro-particles is reversible and the conjugate species is disassociated under certain conditions, a second additional porous separator filtration membrane may optionally be present and configured in the separation device to continuously remove the target species or micro-particles after reversing the binding of the target species from the moiety.

[00111] Thus, in certain aspects, the present teachings provide both methods of separation, as well as separator devices. For example, in certain aspects, a separator device comprises a mixing region for contacting a fluid composition comprising a target species with a plurality of anisotropic multi-compartment micro-particles. At least one distinct compartment of each of the anisotropic multi-compartment particles defines an exposed binding surface that comprises a moiety for binding to the target species, so that the anisotropic multi-compartment particle binds with the target species present in the fluid composition to form a conjugate species capable of separation from the fluid composition. The separator device further

comprises a separation region where the conjugate species is removed from the fluid composition that forms a fluid permeate.

[00112] In other aspects, the present disclosure provides a method for applying a target species to a surface coating. The method can comprise contacting a surface
5 coating comprising a plurality of anisotropic multi-compartment micro-particles to a fluid composition comprising the target species. At least one distinct compartment of the anisotropic multi-compartment particles defines an exposed binding surface that comprises a moiety for binding to the target species, so that after contacting the surface coating to the fluid composition, at least a portion of the target species present in the
10 fluid composition are bound to the surface coating.

[00113] FIGS. 6A-6B show yet another embodiment of the present disclosure. A substrate 300 (for example, a medical device) has a surface 302 that has a coating comprising a plurality of anisotropic multi-compartment micro-particles 304. Each multi-compartment micro-particle 304 has a first compartment 306 that interacts and
15 binds the plurality of micro-particles 304 to surface 302 (alternatively, any well-known binder may be employed to form a surface coating with the plurality of micro-particles 34). A second compartment 308 has an exposed binding surface (*e.g.*, with a surface moiety not shown) for reacting with a target species. The surface 302 can be contacted with a fluid composition 312 contained in a reservoir 314, by dipping 310 the surface
20 302 therein. The fluid composition 312 comprises target species 316.

[00114] When the substrate 300 and surface coating 302 are removed from the reservoir at 320, the target species 316 has reacted with the exposed binding surface 308 of the plurality of multi-compartment micro-particles 304 on surface 302. Thus a conjugate species 322 comprising the target species 316 and the multi-compartment
25 micro-particle 304 is formed along one or more regions of the surface coating surface 302.

[00115] In certain aspects, after the contacting of the surface 302 with the fluid composition 312, greater than or equal to about 50 weight % of an initial amount of target species 316 in the fluid composition in the reservoir 314 is transferred to the
30 surface coating 302; optionally greater than or equal to about 70 weight %; optionally greater than or equal to about 95 weight %; and in certain variations, greater than or

equal to about 99 weight % of an initial amount of target species 316 in the fluid composition in the reservoir 314 is transferred to the surface coating 302.

[00116] Thus, in certain aspects, the surface coating can be formed on a medical device and the target species is a biological target that is irreversibly removed from the fluid composition in the reservoir. Irreversibly removing the target species from the fluid composition in the reservoir can occur by a process selected from the group consisting of: removal using a membrane, removal using a magnetic field, and removal using a chromatographic process. In certain embodiments, the surface coating is disposed on a medical device and the target species is an inorganic particle, a biological target, or an organism. In certain variations, the surface coating can be disposed on a medical device selected from the group consisting of: a vasculature access device, a catheter, a cardiac catheter, an extracorporeal implant, an intracorporeal implant, a ventricular access device, a catheter, a dialysis catheter, and combinations thereof.

[00117] In certain variations, the binding of the anisotropic multi-compartment micro-particle with the target species on the surface coating can be reversible and after the contacting, the surface coating is subjected to conditions so as to release the target species from the anisotropic multi-compartment micro-particle. Such conditions (to which the surface coating is subjected) can be selected from the group consisting of: a change in pH, a change in temperature, exposure to light, exposure to a second stimulus, and combinations thereof.

[00118] Such coatings, where the biological targets are bound to the micro-particles under one set of environmental conditions, can then be exposed to a second distinct set of environmental conditions, so that at least a part of the biological targets are released from the particles. In yet other aspects, the surface coating having the target species and the anisotropic multi-compartment micro-particles can be incorporated into a nano-membrane.

[00119] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same

may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

What is claimed is:

1. A method for detecting a target species in a fluid composition,
5 comprising:
contacting a fluid composition comprising the target species with a
plurality of anisotropic multi-compartment micro-particles in a detection device, wherein
at least one distinct compartment of each of the anisotropic multi-compartment micro-
particles defines an exposed surface for binding to the target species, so that the
10 anisotropic multi-compartment micro-particle binds with the target species present in the
fluid composition to form a conjugate species, wherein the conjugate species has at least
one property that enhances detection of the target species from the fluid composition as
compared to the target species alone;
detecting the presence of the conjugate species in the fluid composition;
15 and
providing an output from the detection device corresponding to the
presence of the conjugate species.
2. The method of claim 1, wherein the exposed surface for binding to the
20 target species comprises a moiety that is capable of binding to the target species and
another distinct compartment of the anisotropic multi-compartment micro-particle
defines a second distinct exposed surface that does not bind with the target species.
3. The method of claim 2, wherein the first exposed surface has a first
25 surface area that is greater than a second surface area of the second exposed surface.
4. The method of claim 3, wherein the first exposed surface has a first
surface area that is at least 50 times greater than a second surface area of the second
exposed surface.

30

5. The method of claim 2, wherein the first exposed surface has a first surface area that is at least five times smaller than a second surface area of the second exposed surface.

5 6. The method of claim 1, wherein the detecting the presence of the conjugate species further comprises detecting a quantity of the conjugate species present in the fluid composition and the providing of the output from the detection device indicates the quantity of the conjugate species present in the fluid composition.

10 7. The method of claim 1, wherein the plurality of anisotropic multi-compartment micro-particles is formed by an electrified jetting process so that the anisotropic multi-compartment micro-particles have a shape selected from the group consisting of: spheres, cylinders, rods, disks, toroids, and combinations thereof.

15 8. The method of claim 1, wherein an average particle diameter of the plurality of anisotropic multi-compartment micro-particles is greater than or equal to about 10 nm to less than or equal to about 500 μm .

20 9. The method of claim 1, wherein an average particle diameter of the plurality of anisotropic multi-compartment micro-particles is greater than or equal to about 5 μm to less than or equal to about 500 μm .

10. The method of claim 1, wherein each of the plurality of anisotropic multi-compartment micro-particles comprises 2 to 10 distinct compartments.

25

11. The method of claim 1, wherein the target species is a biological target selected from the group consisting of: prokaryotic cells, eukaryotic cells, genetic materials, proteins, polypeptides, biomolecules, viruses, saccharides, antigens, and combinations thereof.

30

12. A method for separating a target species from a fluid composition, comprising:

5 contacting a fluid composition comprising the target species with a plurality of anisotropic multi-compartment micro-particles, wherein at least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed binding surface for binding to the target species, so that the anisotropic multi-compartment micro-particle binds with the target species present in the fluid composition to form a conjugate species, wherein the conjugate species has at least one property that facilitates separation of the target species from the fluid composition as compared to the target species alone; and

10 separating the conjugate species from the fluid composition.

13. The method of Claim 12, wherein the at least one property is an increase in particle size diameter by at least 100% and the separating occurs by a process selected from the group consisting of: filtration, centrifugation, ultracentrifugation, settling, chromatographic methods, precipitation, and combinations thereof.

15

14. The method of Claim 13, wherein the separating occurs by filtration, wherein the separating comprises passing the fluid composition having the conjugate species dispersed therein through a filtration membrane to separate the conjugate species from the fluid permeate.

20

15. The method of Claim 14, wherein the filtration membrane is selected from the group consisting of: a nanoscopic filtration membrane, a mesoscopic filtration membrane, a microscopic filtration membrane, and combinations thereof.

25

16. The method of Claim 12, wherein the at least one property is magnetization and the separating occurs by exposing the fluid composition having the conjugate species to a magnetic field so as to remove the conjugate species from the fluid composition.

30

17. The method of Claim 12, wherein the at least one property is a dielectric moment and the separating occurs by electrophoresis that comprises exposing the fluid composition to an electrical field so as to remove the conjugate species from the fluid composition.

5

18. The method of Claim 12, wherein the binding of the anisotropic multi-compartment micro-particles with the target species is reversible in the presence of an external stimulus and after the separating, the conjugate species is subjected to the external stimulus so as to release the target species from the anisotropic multi-compartment micro-particles.

10

19. The method of Claim 18, wherein the external stimulus to which the conjugate species is subjected is selected from the group consisting of: a change in pH, a change in temperature, exposure to light, and exposure to a second stimulus.

15

20. The method of Claim 12, wherein after the separating, greater than or equal to about 75 weight % of an initial amount of the target species is separated from the fluid composition.

20

21. The method of Claim 12, wherein after the separating, greater than or equal to about 95 weight % of an initial amount of the target species is separated from the fluid composition.

25

22. The method of Claim 12, wherein after the separating, greater than or equal to about 99 weight % of an initial amount of the target species is separated from the fluid composition.

23. A method for applying a target species to a surface coating, comprising:
contacting a surface coating comprising a plurality of anisotropic multi-
compartment micro-particles with a fluid composition comprising the target species
5 contained in a reservoir, wherein at least one distinct compartment of the anisotropic
multi-compartment micro-particles defines an exposed surface that comprises a binding
surface to bind with the target species, so that after contacting the surface coating with
the fluid composition, at least a portion of the target species present in the fluid
composition forms a conjugate species with the anisotropic multi-compartment micro-
10 particles disposed along one or more regions of the surface coating.

24. The method of Claim 23, wherein after the contacting, greater than or
equal to about 50 weight % of an initial amount of the target species in the fluid
composition in the reservoir is transferred to the surface coating.

15

25. The method of Claim 23, wherein after the contacting, greater than or
equal to about 70 weight % of an initial amount of the target species in the fluid
composition in the reservoir is transferred to the surface coating.

26. The method of Claim 23, wherein after the contacting, greater than or
equal to about 95 weight % of an initial amount of the target species in the fluid
composition in the reservoir is transferred to the surface coating.

20

27. The method of Claim 23, wherein after the contacting, greater than or
equal to about 99 weight % of an initial amount of the target species in the fluid
composition in the reservoir is transferred to the surface coating.

25

28. The method of Claim 23, wherein the surface coating is disposed on a
medical device and the target species is a biological target that is irreversibly removed
30 from the fluid composition in the reservoir.

30

29. The method of Claim 28, wherein the irreversibly removing the target species from the fluid composition in the reservoir occurs by a process selected from the group consisting of: removal using a membrane, removal using a magnetic field, removal using a chromatographic process, and combinations thereof.

5

30. The method of Claim 23, wherein the binding of the anisotropic multi-compartment micro-particle with the target species on the surface coating is reversible and after the contacting, the surface coating is subjected to conditions so as to release the target species from the anisotropic multi-compartment micro-particle.

10

31. The method of Claim 30, wherein the conditions to which the surface coating is subjected are selected from the group consisting of: a change in pH, a change in temperature, exposure to light, and exposure to a second stimulus.

15

32. The method of claim 23, wherein the surface coating is disposed on a medical device and the target species is selected from the group consisting of: an inorganic particle, a biological target, and an organism.

20

33. The method of claim 23, wherein the surface coating is disposed on a medical device selected from the group consisting of: a vasculature access device, a catheter, a cardiac catheter, an extracorporeal implant, an intracorporeal implant, a ventricular access device, and a dialysis catheter.

25

34. The method of claim 23, wherein the surface coating having the target species and the anisotropic multi-compartment micro-particles is incorporated into a nanomembrane.

30

35. An analytical assay device comprising:
a region for contacting a fluid composition comprising a target species with a plurality of anisotropic multi-compartment micro-particles, wherein at least one distinct compartment of each of the anisotropic multi-compartment micro-particles defines an exposed binding surface capable of binding to the target species, so that the

anisotropic multi-compartment micro-particle binds with any target species present in the fluid composition to form a detectable conjugate species.

36. The analytical assay device of claim 35, wherein the exposed binding
5 surface comprises a moiety that is capable of binding to the target species.

37. A separator device comprising:
a mixing region for contacting a fluid composition comprising a target
species with a plurality of anisotropic multi-compartment micro-particles, wherein at
10 least one distinct compartment of each of the anisotropic multi-compartment micro-
particles defines an exposed binding surface capable of binding to the target species, so
that the anisotropic multi-compartment micro-particle binds with the target species
present in the fluid composition to form a conjugate species capable of separation from
the fluid composition; and
15 a separation region where the conjugate species is removed from the fluid
composition that forms a fluid permeate.

38. The separator device of claim 37, wherein the exposed binding surface
comprises a moiety that is capable of binding to the target species.
20

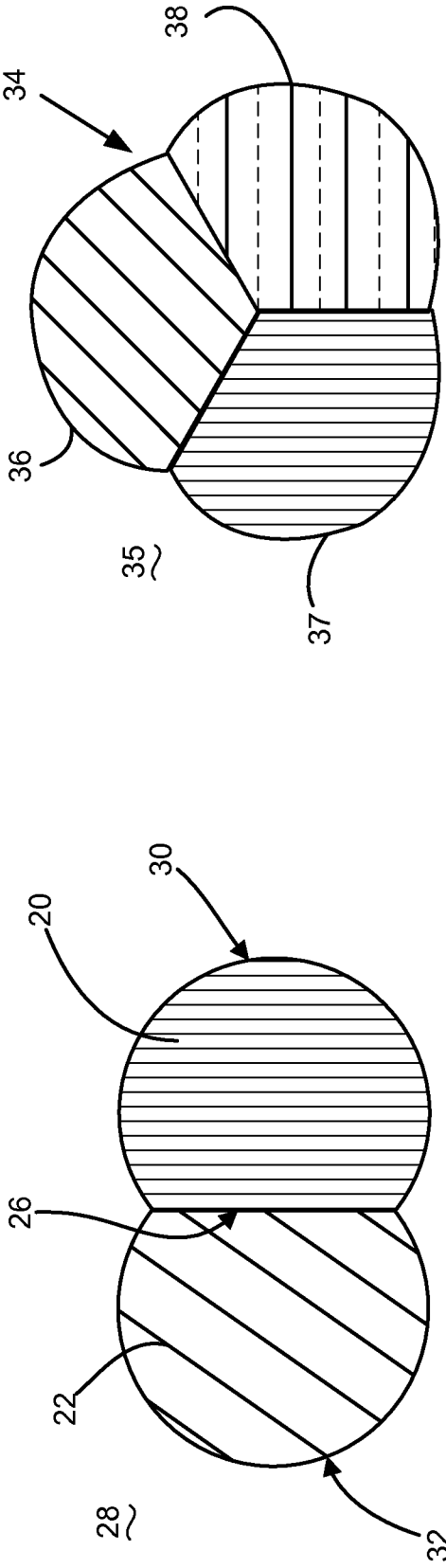


FIG. 1C

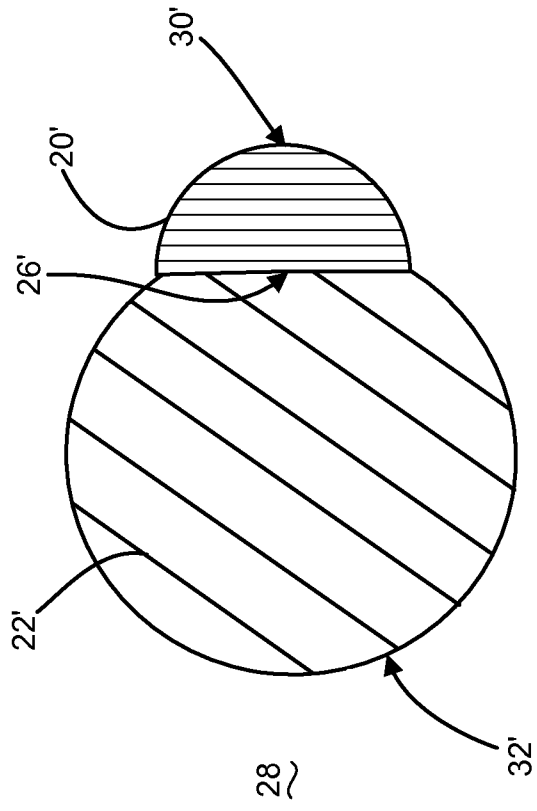


FIG. 1B

SPHERES

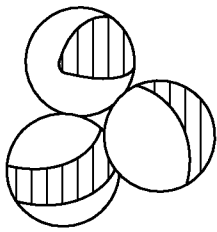


FIG. 2A

CYLINDERS

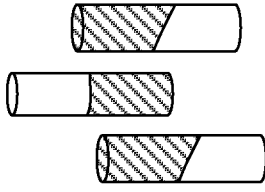


FIG. 2C

DISCS

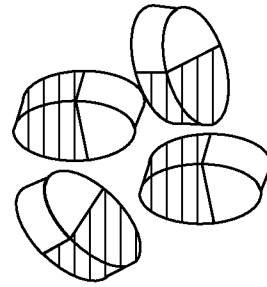


FIG. 2B

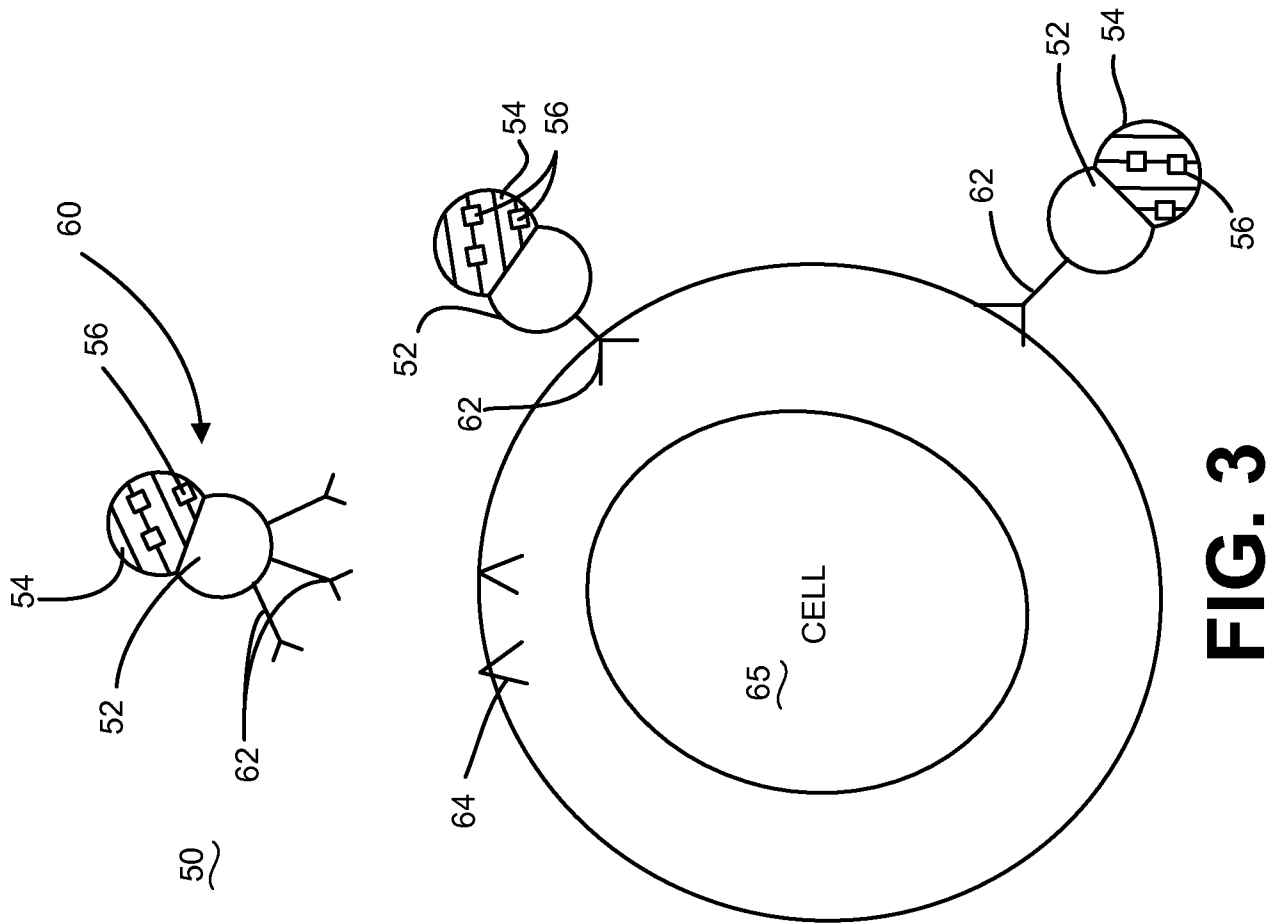


FIG. 3

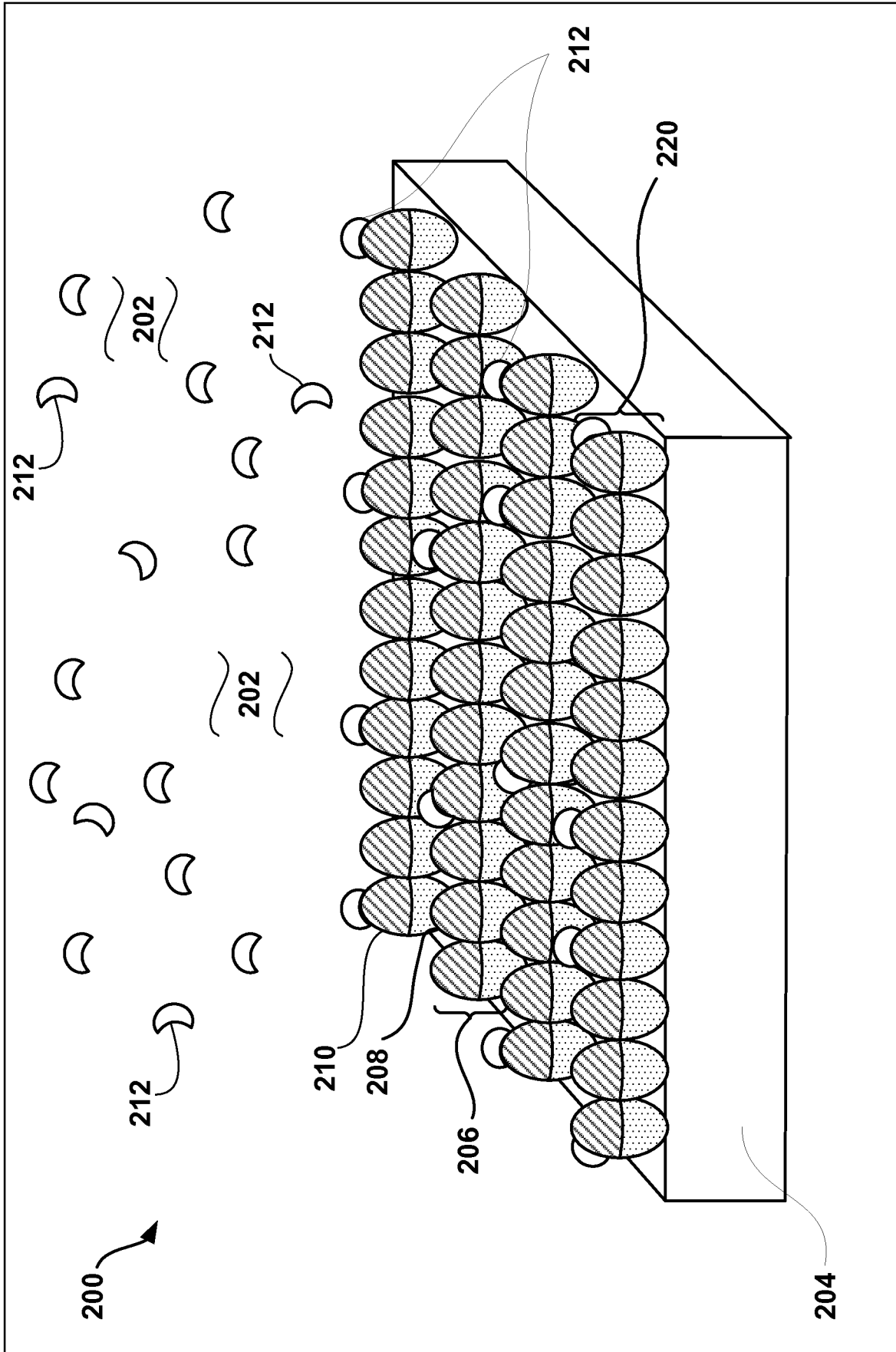


FIG. 4

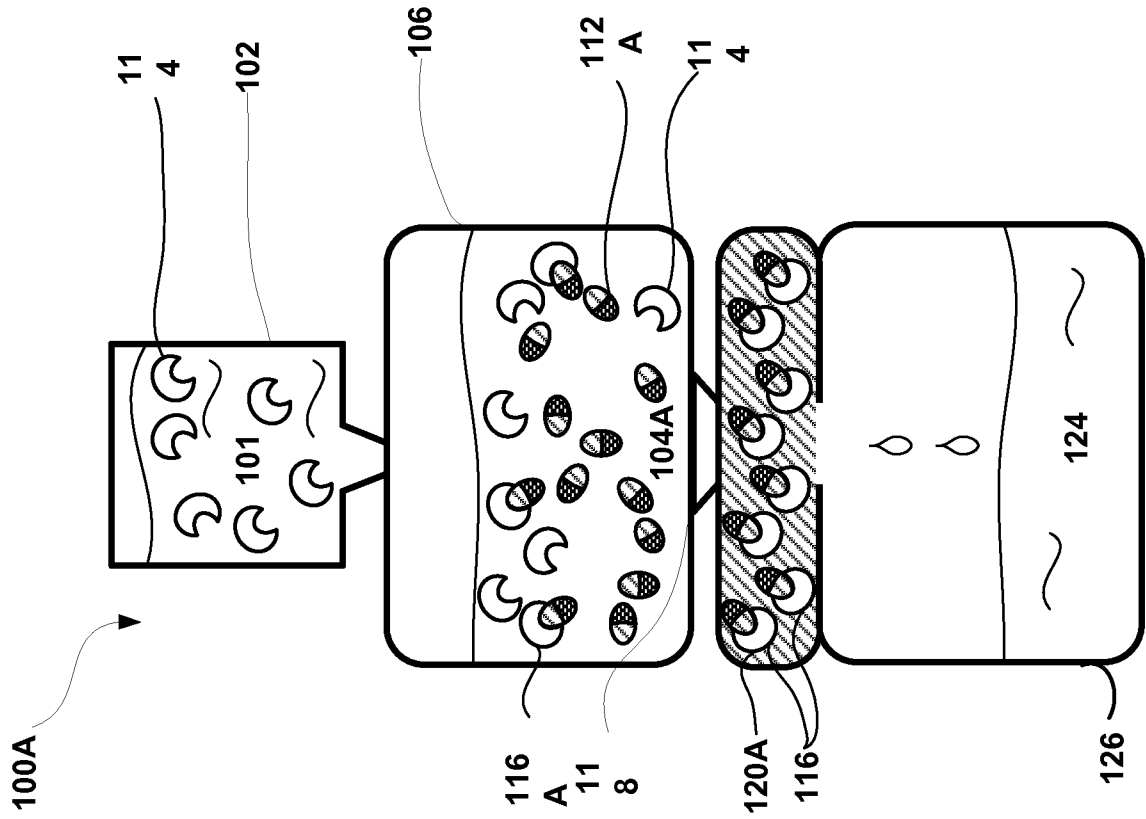


FIG. 5B

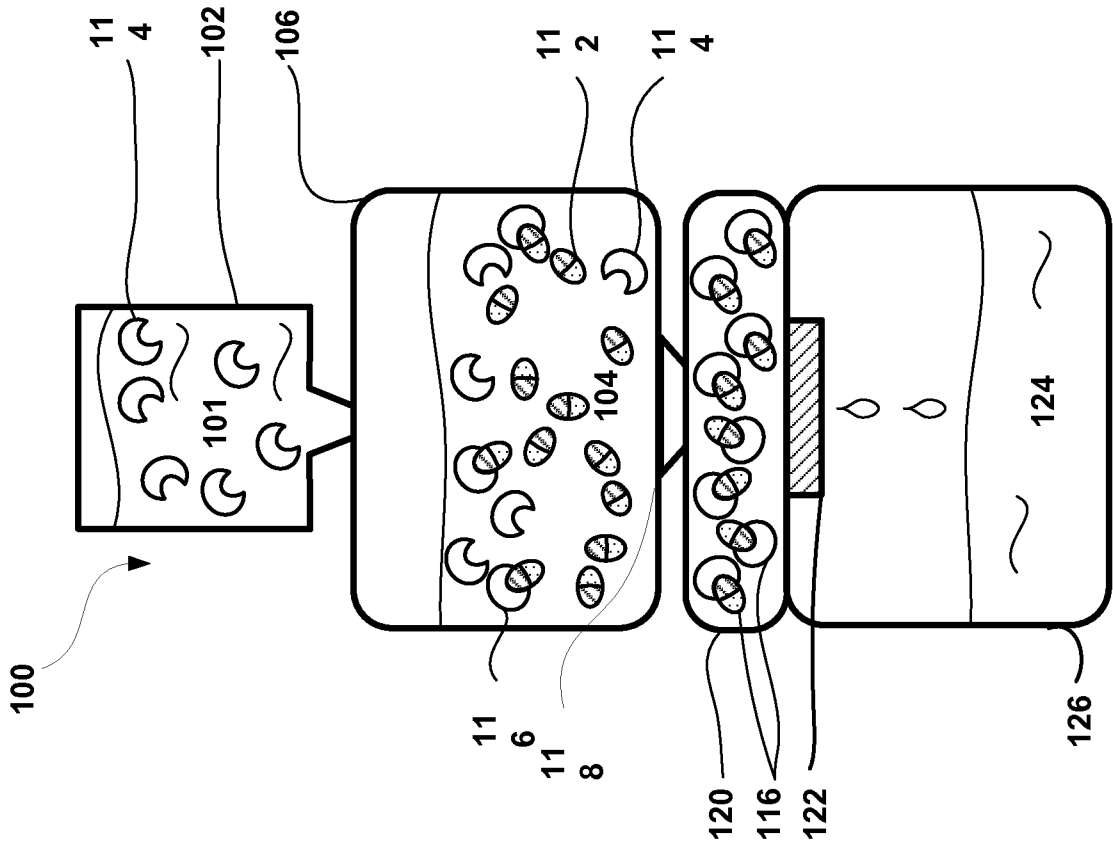


FIG. 5A

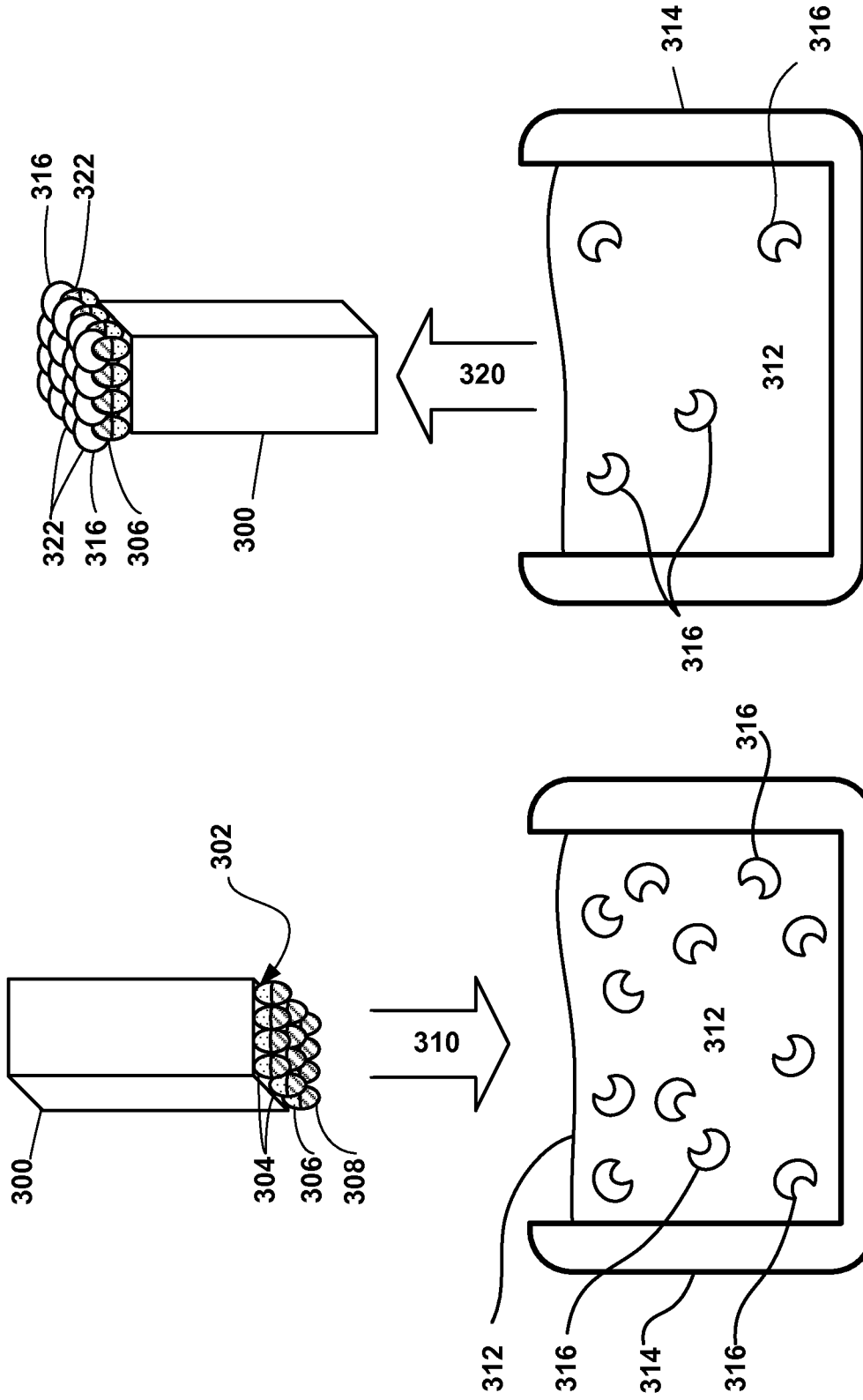


FIG. 6B

FIG. 6A

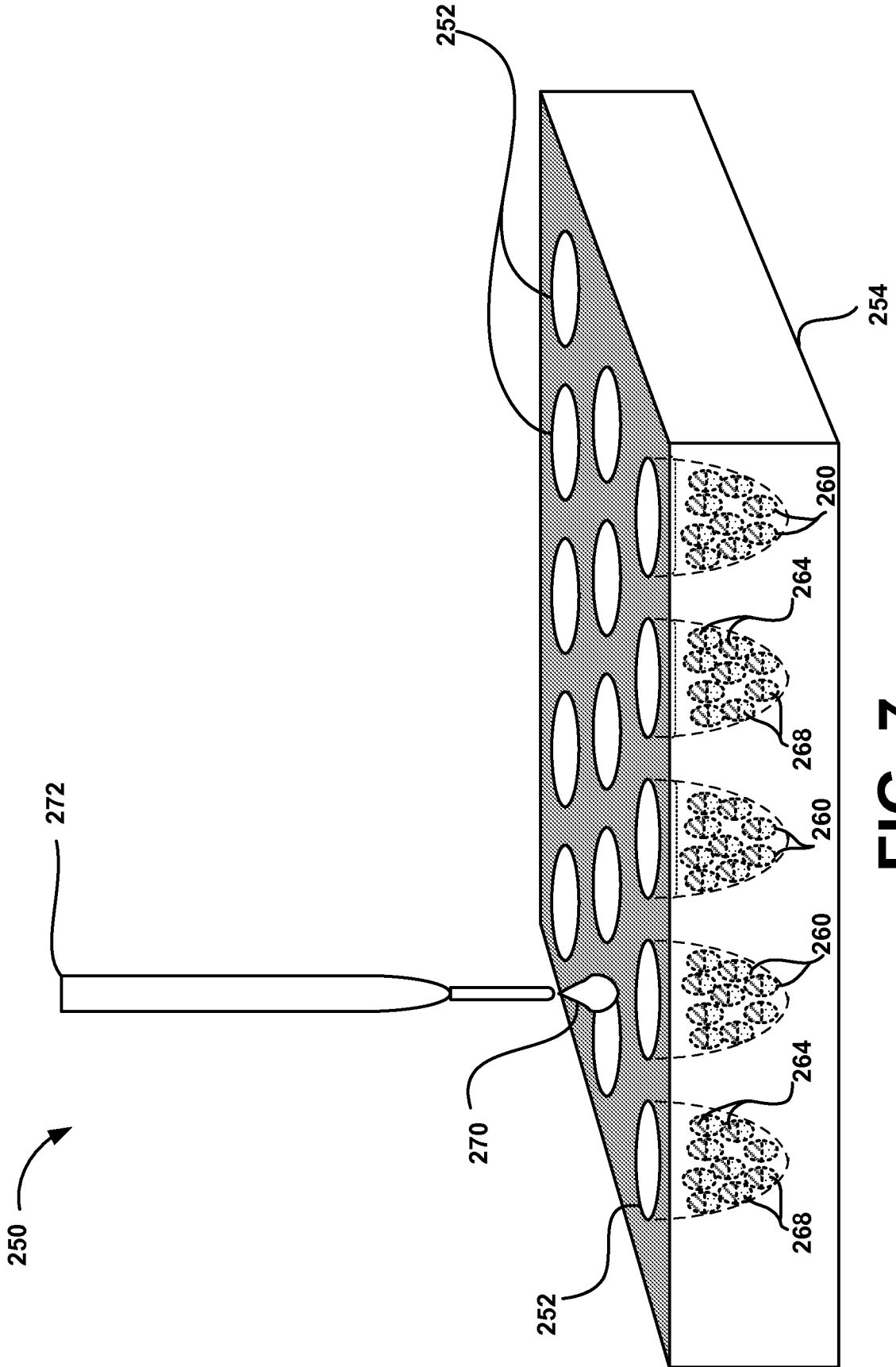




FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/060578

A. CLASSIFICATION OF SUBJECT MATTER		
<i>G01N 33/50(2006.01)i, G01N 27/26(2006.01)i</i>		
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) G01N 33/50; G01N 33/546; A61B 5/1459; A61K 49/00; A61B 5/145; H01L 51/00; C25D 5/02; G01N 33/53; C12Q 1/68; A61B 5/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & keywords: anisotropic multi-compartment micro-particle, conjugate, detection, enhancement		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2006-073439 A2 (NANOPLEX TECHNOLOGIES, INC.) 13 July 2006 See abstract and claims 29-37.	1-38
A	US 2010-0069726 A1 (LEVINSON, D. A.) 18 March 2010 See abstract and claim 83.	1-38
A	US 2007-0007512 A1 (DIMITRIJEVIC et al.) 11 January 2007 See abstract and claims 1-3.	1-38
A	EP 0503454 A1 (F. HOFFMANN-LA ROCHE AG) 16 September 1992 See abstract and claim 1.	1-38
A	US 2009-0131773 A1 (STRUVE et al.) 21 May 2009 See abstract and claims 1, 21.	1-38
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> 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 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 27 March 2013 (27.03.2013)		Date of mailing of the international search report 28 March 2013 (28.03.2013)
Name and mailing address of the ISA/KR  Korean Intellectual Property Office 189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. 82-42-472-7140		Authorized officer CHANG, Bong Ho Telephone No. 82-42-481-3353 

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/060578

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