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(54) Title: MINERAL SEPARATION USING FUNCTIONALIZED MEMBRANES

Figure 1

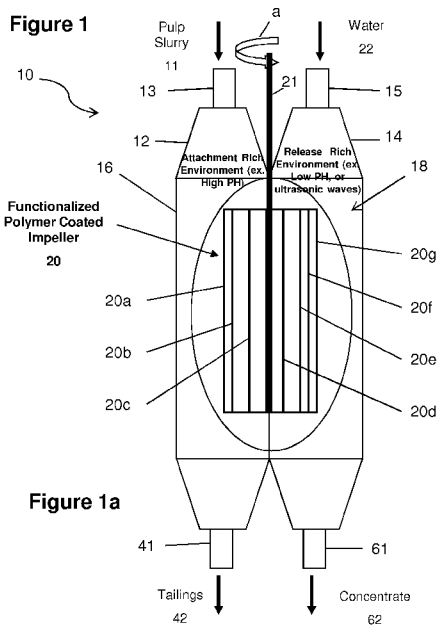

Figure 1a

(57) Abstract: A machine or apparatus featuring a first processor and a second processor. The first processor is configured to receive a mixture of fluid, valuable material and unwanted material and a functionalized polymer coated member configured to attach to the valuable material in an attachment rich environment, and provide an enriched functionalized polymer coated member having the valuable material attached thereto. The second processor is configured to receive a fluid and the enriched functionalized polymer coated member in a release rich environment to release the valuable material, and provide the valuable material released from the enriched functionalized polymer coated member.

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MINERAL SEPARATION USING FUNCTIONALIZED MEMBRANES

Cross-Reference to Related Patent Applications

The present application claims the benefit of U.S. Provisional Patent Application No. 61/489,893, filed 25 May 2011, and U.S. Provisional Patent Application No. 61/533,544, filed 12 September 2011, which are both incorporated by reference herein in their entirety.

This application is also related to the following eight PCT applications, which are all concurrently filed on 25 May 2012, which all claim the benefit of the aforementioned U.S. Provisional Patent Application No. 61/489,893, filed 25 May 2011, and the aforementioned U.S. Provisional Patent Application No. 61/533,544, filed 12 September 2011, and which are all incorporated by reference in their entirety so as to include the subject matter of each other, as follows:

PCT application no. _____ (Atty docket no. 712-002.356-1), entitled "Flotation separation using lightweight synthetic bubbles and beads;"

PCT application no. _____ (Atty docket no. 712-002.359-2), entitled "Mineral separation using sized, weighted and magnetized beads;"

PCT application no. _____ (Atty docket no. 712-002.382), entitled "Synthetic bubbles/beads functionalized with molecules for attracting or attaching to mineral particles of interest;"

PCT application no. _____ (Atty docket no. 712-002.383), entitled "Method and system for releasing mineral from synthetic bubbles and beads;"

PCT application no. _____ (Atty docket no. 712-002.384), entitled "Synthetic bubbles and beads having hydrophobic surface;"

PCT application no. _____ (Atty docket no. 712-002.385), entitled "Mineral separation using functionalized filters and membranes;"

PCT application no. _____ (Atty docket no. 712-002.386), entitled "Mineral recovery in tailings using functionalized polymers;" and

PCT application no. _____ (Atty docket no. 712-002.387), entitled "Techniques for transporting synthetic beads or bubbles In a flotation cell or column."

Background of the Invention

1. Technical Field

This invention relates generally to a method and apparatus for separating valuable material from unwanted material in a mixture, such as a pulp slurry.

2. Description of Related Art

In many industrial processes, flotation is used to separate valuable or desired material from unwanted material. By way of example, in this process a mixture of water, valuable material, unwanted material, chemicals and air is placed into a flotation cell. The chemicals are used to make the desired material hydrophobic, as well as to aid the formation of bubbles and the stability of the froth, and the air is used to carry the material to the surface of the flotation cell. When the hydrophobic material and the air bubbles collide they become attached to each other. The bubble rises to the surface carrying the desired material with it.

The performance of the flotation cell is dependent on the bubble surface area flux in the collection zone of the cell. The bubble surface area flux is dependent on the size of the bubbles and the air injection rate. Controlling the bubble surface area

flux has traditionally been very difficult. This is a multivariable control problem and there are no dependable real time feedback mechanisms to use for control.

There is a need in the industry to provide a better way to separate valuable material from unwanted material, e.g., including in such a flotation cell, so as to eliminate problems associated with using air bubbles in such a separation process.

Summary of the Invention

The present invention provides mineral separation techniques using functionalized membranes.

The present invention consists of a new machine and process for recovering valuable materials or minerals from mineral rich pulp slurry. This slurry could be any type of slurry being air conveyed ground minerals or an aqueous mixture for example. This mineral rich slurry may be put into contact with a functionalized polymer surface which has been engineered to attract or attach to the mineral of interest. The functionalized polymer surface may take the form of a synthetic bubble or bead, consistent with that set forth in the aforementioned PCT application no. _____ (Atty docket nos. 712-2.359-2 and 712-2. 382), both filed 25 May 2012, claiming benefit to the aforementioned U.S. Provisional Patent Application No. 61/489,893, as well as a membrane or membrane structure that may take the form of an impeller, a conveyor belt, a filter assembly, or a flat plate, consistent with that set forth in the aforementioned U.S. Provisional Patent Application No. 61/533,544.

The unwanted material may be washed away and only the desirable material or mineral is left on the functionalized polymer surface, or the membrane structure containing the functionalized polymer surface may be separated from the unwanted material. Such separation can take place via techniques related to flotation, size

separation, gravimetric separation, and/or magnetic separation. The enriched surface is then treated so that the mineral is released and collected. The polymer surface can then be reused.

According to some embodiments of the present invention, the machine or apparatus will be configured with two chambers, tanks, cells or columns. One chamber, tank, cell or column has an environment conducive to attachment of a valuable material or mineral or particle of interest and the other chamber, tank, cell or column has an environment conducive for release of the valuable material or mineral or particle of interest. An impeller may be coated with a functionalized polymer and configured to rotate slowly inside the two chambers, tanks, cells or columns. As an impeller blade moves into an attachment zone in the one chamber, tank, cell or column, it collects the valuable material or mineral or particle of interest. As the enriched blade moves to a release zone in the other chamber, tank, cell or column, the valuable material or mineral or particle of interest are released.

According to some embodiments of the present invention, a functionalized polymer conveyor belt may be configured to run between the two chambers, tanks, cells or columns, whereby it collects and releases the valuable material or mineral or particle of interest.

According to some embodiments of the present invention, a functionalized polymer collection filter may be placed into each chamber, tank, cell or column to collect and release the valuable material or mineral or particle of interest. This is a batch type process.

Embodiment of Mineral Separation Apparatus

In its broadest sense, the present invention may take the form of a machine, system or apparatus featuring a first processor and a second processor. The first processor may be configured to receive a mixture of fluid, valuable material and unwanted material and a functionalized polymer coated member configured to attach to the valuable material in an attachment rich environment, and provide an enriched functionalized polymer coated member having the valuable material attached thereto. The second processor may be configured to receive a fluid and the enriched functionalized polymer coated member in a release rich environment to release the valuable material, and provide the valuable material released from the enriched functionalized polymer coated member to the release rich environment.

The apparatus may be configured to include one or more of the following features:

The first processor may take the form of a first chamber, tank, cell or column, and the second processor may take the form of a second chamber, tank, cell or column.

The first chamber, tank or column may be configured to receive a pulp slurry having water, the valuable material and the unwanted material in the attachment rich environment, which has a high pH, conducive to attachment of the valuable material.

The second chamber, tank or column may be configured to receive water in the release rich environment, which may have a low pH or receive ultrasonic waves conducive to release of the valuable material.

Although the invention is described as having a high pH in an attachment environment and a low pH in a release environment, the present invention will work equally as well where the pH of the attachment environment is selected to optimize

the attachment of desired materials, such as a low, high or neutral pH, and the pH of the release environment is selected to be a different pH than the attachment environment and selected to optimize the release of the desired material.

The functionalized polymer coated member may take the form of a functionalized polymer coated impeller having at least one impeller blade configured to rotate slowly inside the first processor and the second processor. The first processor may be configured to receive the at least one impeller blade in an attachment zone, and provide at least one enriched impeller blade having the valuable material attached thereto in the attachment zone. The second processor may be configured to receive the at least one enriched impeller blade in a release zone and to provide the valuable material released from the at least one enriched impeller blade. The first processor may be configured with a first transition zone to provide drainage of tailings, and the second processor may be configured with a second transition zone to provide drainage of concentrate.

As used herein with respect to functionalized polymer, the term “enriched” is intended to refer to a functionalized material that has been exposed to a material of interest, and wherein the material of interest has been attached, attracted, connected or otherwise collected by the functionalized material prior to release.

The functionalized polymer coated member may take the form of a functionalized polymer coated conveyor belt configured to run between the first processor and the second processor. The first processor may be configured to receive the functionalized polymer coated conveyor belt and provide an enriched functionalized polymer coated conveyor belt having the valuable material attached thereto. The second processor may be configured to receive the enriched functionalized polymer coated conveyor belt and provide the valuable material

released from the enriched functionalized polymer coated conveyor belt. The functionalized polymer coated conveyor belt may be made of a mesh material.

The functionalized polymer coated member may take the form of a functionalized polymer coated collection filter configured to move between the first processor and the second processor as part of a batch type process. The first processor may be configured to receive the functionalized polymer coated collection filter and to provide an enriched functionalized polymer coated collection filter having the valuable material attached thereto. The second processor device may be configured to receive the enriched functionalized polymer coated collection filter and provide the valuable material released from the enriched functionalized polymer coated collection filter.

The first processor may be configured to provide tailings containing the unwanted material, and the second processor may be configured to provide a concentrate containing the valuable material.

The functionalized polymer coated member may take the form of a membrane or a thin soft pliable sheet or layer.

According to some embodiment, the present invention may also take the form of apparatus featuring first means that may be configured to receive a mixture of fluid, valuable material and unwanted material and a functionalized polymer coated member configured to attach to the valuable material in an attachment rich environment, and provide an enriched functionalized polymer coated member having the valuable material attached thereto; and second means that may be configured to receive a fluid and the enriched functionalized polymer coated member in a release rich environment to release the valuable material, and provide the valuable material

released from the enriched functionalized polymer coated member to the release rich environment.

According to some embodiments of the present invention, the first means may be configured to receive a pulp slurry having water, the valuable material and the unwanted material in the attachment rich environment, which has a high pH, conducive to attachment of the valuable material; and the second means may be configured to receive water in the release rich environment, which has a low pH or receives ultrasonic waves conducive to release of the valuable material.

According to some embodiments of the present invention, the functionalized polymer coated member may take the form of one of the following:

a functionalized polymer coated impeller having at least one impeller blade configured to rotate slowly inside the first means and the second means;

a functionalized polymer coated conveyor belt configured to run between the first means and the second means; or

a functionalized polymer coated collection filter configured to move between the first means and the second means as part of a batch type process.

Embodiments of Mineral Separation Processes or Methods

According to some embodiment, the present invention may also take the form of a process or method featuring receiving in a first processor a mixture of fluid, valuable material and unwanted material and a functionalized polymer coated member configured to attach to the valuable material in an attachment rich environment, and providing from the first processor an enriched functionalized polymer coated member having the valuable material attached thereto; and receiving in a second processor a fluid and the enriched functionalized polymer coated

member in a release rich environment to release the valuable material, and providing the valuable material released from the enriched functionalized polymer coated member to the release rich environment.

According to some embodiments of the present invention, the method may include being implemented consistent with one or more of the features set forth herein.

The Synthetic Functionalized Polymer Coated Member Chemistry

According to some embodiments of the present invention, the functionalized polymer coated member may take the form of a solid-phase body comprising a surface in combination with a plurality of molecules attached to the surface, the molecules comprising a functional group selected for attracting or attaching to one or more mineral particles of interest to the molecules. The term "polymer" in this specification is understood to mean a large molecule made of many units of the same or similar structure linked together.

According to some embodiments of the present invention, the solid-phase body may be made of a synthetic material comprising the molecules. By way of example, the synthetic material may be selected from a group consisting of, but not limited to, polyamides (nylon), polyesters, polyurethanes, phenol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, polyacetal, polyethylene, polyisobutylene, polyacrylonitrile, poly(vinyl chloride), polystyrene, poly(methyl methacrylates), poly(vinyl acetate), poly(vinylidene chloride), polyisoprene, polybutadiene, polyacrylates, poly(carbonate), phenolic resin and polydimethylsiloxane.

According to some embodiments of the present invention, the solid-phase body may include an inner material and a shell providing the surface, the shell being made of a synthetic material comprising the molecules.

According to some embodiments of the present invention, the functional group may have an ionic group, which may be either anionic or cationic, for attracting or attaching the mineral particles to the surface.

According to some embodiments of the present invention, the functional group may take the form of a collector having a non-ionizing bond having a neutral or ionic functional group, or having an ionizing bond.

According to some embodiments of the present invention, the ionizing bond may be an anionic bond or a cationic bond. The anionic functional group may be comprised of an oxyhydryl, including carboxylic, sulfates and sulfonates, and sulfhydral bond.

Hydrophobicity

According to some embodiments of the present invention, the surface of the polymer coated member may be functionalized to be hydrophobic so as to provide a bonding between the surface and a mineral particle associated with one or more hydrophobic molecules.

Furthermore, the polymer can be naturally hydrophobic or functionalized to be hydrophobic. Some polymers having a long hydrocarbon chain or silicon-oxygen backbone, for example, tend to be hydrophobic. Hydrophobic polymers include polystyrene, poly(d,l-lactide), poly(dimethylsiloxane), polypropylene, polyacrylic, polyethylene, etc. The mineral particle of interest or the valuable material associated with one or more hydrophobic molecules is referred to as a wetted mineral particle.

When the pulp slurry contains a plurality of collectors or collector molecules, some of the mineral particles will become wetted mineral particles if the collectors are attached to mineral particles. Xanthates can be used in the pulp slurry as the collectors. The functionalized polymer coated member can be coated with hydrophobic silicone polymer including polysiloxanates so that the functionalized polymer coated member become hydrophobic. The functionalized polymer coated member can be made of hydrophobic polymers, such as polystyrene and polypropylene to provide the desired hydrophobicity.

Combined Collector/Hydrophobic Functionalized Polymer Coated Member

According to some embodiments of the present invention, only a part of the surface of the functionalized polymer coated member may be configured to have the molecules attached thereto, wherein the molecules comprise collectors.

According to some embodiments of the present invention, a part of the surface of the functionalized polymer coated member may be configured to have the molecules attached thereto, wherein the molecules comprise collectors, and another part of the surface of the functionalized polymer coated member may be configured to be hydrophobic.

According to some embodiments of the present invention, a part of the surface of the functionalized polymer coated member may be configured to be hydrophobic.

Brief Description of the Drawing

Referring now to the drawing, which are not necessarily drawn to scale, the foregoing and other features and advantages of the present invention will be more

fully understood from the following detailed description of illustrative embodiments, taken in conjunction with the accompanying drawing in which like elements are numbered alike:

Figure 1 includes Figure 1a is a side partial cutaway view in diagram form of a separation processor configured with two chambers, tanks or columns having a functionalized polymer coated impeller arranged therein according to some embodiments of the present invention, and includes Figure 1b is a top partial cross-sectional view in diagram form of a functionalized polymer coated impeller moving in an attachment rich environment contained in an attachment chamber, tank or column and also moving in a release rich environment contained in a release chamber, tank or column according to some embodiments of the present invention.

Figure 2 is diagram of a separation processor configured with two chambers, tanks or columns having a functionalized polymer coated conveyor belt arranged therein according to some embodiments of the present invention.

Figure 3 is diagram of a separation processor configured with a functionalized polymer coated filter assembly for moving between two chambers, tanks or columns in a semi-continuous batch process according to some embodiments of the present invention.

Figure 4a shows at least part of a generalized a solid-phase body, e.g., a functionalized polymer coated member, according to some embodiments of the present invention.

Figure 4b illustrates an enlarged portion of the functionalized polymer coated member showing a molecule or molecular segment for attaching a function group to the surface of the functionalized polymer coated member, according to some embodiments of the present invention.

Figure 5a shows at least part of a generalized a solid-phase body, e.g., functionalized polymer coated member, having some particles attached to the surface, according to some embodiments of the present invention.

Figure 5b illustrates an enlarged portion of the functionalized polymer coated member showing a wetted mineral particle attached to the hydrophobic surface of the functionalized polymer coated member, according to some embodiments of the present invention.

Figure 5c illustrates an enlarged portion of the functionalized polymer coated member showing a hydrophobic particle attached to the hydrophobic surface of the functionalized polymer coated member, according to some embodiments of the present invention.

Figures 6a and 6b illustrate some embodiments of the present invention wherein the synthetic bead or bubble have one portion functionalized to have collector molecules and another portion functionalized to be hydrophobic, according to some embodiments of the present invention.

Detailed Description of the Invention

Figures 1, 1a, 1b

By way of example, Figure 1 shows the present invention is the form of a machine, device, system or apparatus 10, e.g., for separating valuable material from unwanted material in a mixture 11, such as a pulp slurry, using a first processor 12 and a second processor 14. The first processor 12 and the second processor 14 are configured with a functionalized polymer coated member that is shown, e.g., as a functionalized polymer coated impeller 20 (Fig. 1a), 20' (Fig. 1b), according to some embodiments of the present invention. In operation, the impeller 20, 20' slowly

rotates in relation to the first processor 12 and the second processor 14, the impeller blades slowly pass through the attachment rich environment 16 in the first processor 12 where the valuable material is attached to the blades and through the release rich environment 18 in the second processor 14.is released from the blades. By way of example, the impeller 20 is shown rotating in a counterclockwise direction as indicated by arrow a, although the scope of the invention is not intended to be limited to the direction of the impeller rotation, or the manner in which the functionalized polymer coated impeller 20 (Fig. 1a), 20' (Fig. 1b) is arranged, mounted, or configured in relation to the first processor 12 and the second processor 14.

The first processor 12 may take the form of a first chamber, tank, cell or column that contains an attachment rich environment generally indicated as 16. The first chamber, tank or column 12 may be configured to receive via piping 13 the mixture or pulp slurry 11 in the form of fluid (e.g., water), the valuable material and the unwanted material in the attachment rich environment 16, e.g., which has a high pH, conducive to attachment of the valuable material. The second processor 14 may take the form of a second chamber, tank, cell or column that contains a release rich environment generally indicated as 18. The second chamber, tank, cell or column 14 may be configured to receive via piping 15, e.g., water 22 in the release rich environment 18, e.g., which may have a low pH or receive ultrasonic waves conducive to release of the valuable material. Attachment rich environments like that forming part of element environment 16 conducive to the attachment of a valuable material of interest and release rich environments like that forming part of environment 18 conducive to the release of the valuable material of interest are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future.

Moreover, a person skilled in the art would be able to formulate an attachment rich environment like environment 16 and a corresponding release rich environment like environment 18 based on the separation technology disclosed herein for any particular valuable mineral of interest, e.g., copper, forming part of any particular mixture or slurry pulp.

Although the invention is described as having a high pH in an attachment environment and a low pH in a release environment, embodiments are envisioned in which the invention will work equally as well where the pH of the attachment environment is selected to optimize the attachment of desired materials, such as a low, high or neutral pH, and the pH of the release environment is selected to be a different pH than the attachment environment and selected to optimize the release of the desired material.

In operation, the first processor 12 may be configured to receive the mixture or pulp slurry 11 of water, valuable material and unwanted material and the functionalized polymer coated member that is configured to attach to the valuable material in the attachment rich environment 16. In Figure 1, the functionalized polymer coated member is shown as the functionalized polymer coated impeller 20 (Fig. 1a), 20' (Fig. 1b). In Figure 1a, the functionalized polymer coated impeller 20 has a shaft 21 and at least one impeller blade 20a, 20b, 20c, 20d, 2e, 20f, 20g and is configured to rotate slowly inside the first processor 12 and the second processor 14. In Figure 1b, the functionalized polymer coated impeller 20' has a shaft 21' and impeller blades 20a', 20b', 20c', 20d', 2e', 20f', 20g' and 20h'. Each impeller blade in Figures 1 is understood to be configured and functionalized with a polymer coating to attach to the valuable material in the attachment rich environment 16. (The scope of the invention is not intended to be limited to the number of blades on the impeller 20,

20' and the embodiment in Figures 1a and 1b is shown with impellers 21, 21' having a different number of blades.)

In Figure 1, the first processor 12 is configured to receive at least one impeller blade of the functionalized polymer coated impeller 20 (Fig. 1a), 20' (Fig. 1b). In Figure 1b, the at least one impeller blade is shown as impeller blade 20g' being received in an attachment zone 30 that forms part of the attachment rich environment 16 defined by walls 30a, 30b. The first processor 12 may also be configured with a first transition zone generally indicated as 40 to provide drainage from piping 41 of, e.g., tailings 42 as shown in Figure 1a.

The first processor 12 may also be configured to provide at least one enriched impeller blade having the valuable material attached thereto, after passing through the attachment rich environment 16. In Figure 1b, the at least one enriched impeller blade is shown as the at least one enriched impeller blade 20c' being provisioned from the attachment rich environment 16 in the first processor 12 to the release rich environment 18 in the second processor 14.

The second processor 14 may be configured to receive via the piping 15 the fluid 22 (e.g. water) and the enriched functionalized polymer coated member to release the valuable material in the release rich environment 18. In Figure 1b, the second processor 14 is shown receiving the enriched impeller blade 20c' in a release zone 50, e.g., that forms part of the release rich environment 18 and is defined, e.g., by walls 30c and 30d.

The second processor 14 may also be configured to provide the valuable material that is released from the enriched functionalized polymer coated member into the release rich environment 18. For example, in Figure 1b the second processor 14 is shown configured with a second transition zone 60 defined by walls

30a and 30d to provide via piping 61 drainage of the valuable material in the form of a concentrate 62 (Fig. 1a).

Figure 2: The Functionalized Polymer Coated Conveyor Belt

By way of example, Figure 2 shows the present invention is the form of a machine, device, system or apparatus 100, e.g., for separating valuable material from unwanted material in a mixture 101, such as a pulp slurry, using a first processor 102 and a second processor 104. The first processor 102 and the second processor 104 are configured with a functionalized polymer coated member that is shown, e.g., as a functionalized polymer coated conveyor belt 120 that runs between the first processor 102 and the second processor 104, according to some embodiments of the present invention. The arrows A1, A2, A3 indicate the movement of the functionalized polymer coated conveyor belt 120. Techniques, including motors, gearing, etc., for running a conveyor belt like element 120 between two processors like elements 102 and 104 are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now know or later developed in the future. According to some embodiments of the present invention, the functionalized polymer coated conveyor belt 120 may be made of a mesh material.

The first processor 102 may take the form of a first chamber, tank, cell or column that contains an attachment rich environment generally indicated as 106. The first chamber, tank or column 102 may be configured to receive the mixture or pulp slurry 101 in the form of fluid (e.g., water), the valuable material and the unwanted material in the attachment rich environment 106, e.g., which has a high pH, conducive to attachment of the valuable material. The second processor 104

may take the form of a second chamber, tank, cell or column that contains a release rich environment generally indicated as 108. The second chamber, tank, cell or column 104 may be configured to receive, e.g., water 122 in the release rich environment 108, e.g., which may have a low pH or receive ultrasonic waves conducive to release of the valuable material. Consistent with that stated above, attachment rich environments like that forming part of element environment 106 conducive to the attachment of a valuable material of interest and release rich environments like that forming part of environment 108 conducive to the release of the valuable material of interest are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future. Moreover, a person skilled in the art would be able to formulate an attachment rich environment like environment 106 and a corresponding release rich environment like environment 108 based on the separation technology disclosed herein for any particular valuable mineral of interest, e.g., copper, forming part of any particular mixture or slurry pulp.

In operation, the first processor 102 may be configured to receive the mixture or pulp slurry 101 of water, valuable material and unwanted material and the functionalized polymer coated conveyor belt 120 that is configured to attach to the valuable material in the attachment rich environment 106. In Figure 2, the belt 120 is understood to be configured and functionalized with a polymer coating to attach to the valuable material in the attachment rich environment 106.

The first processor 102 may also be configured to provide drainage from piping 141 of, e.g., tailings 142 as shown in Figure 2.

The first processor 102 may also be configured to provide an enriched functionalized polymer coated conveyor belt having the valuable material attached thereto, after passing through the attachment rich environment 106. In Figure 2, the enriched functionalized polymer coated conveyor belt is shown, e.g., as that portion or part 120a of the belt 120 being provisioned from the attachment rich environment 106 in the first processor 102 to the release rich environment 108 in the second processor 104. It is understood that some other portions or parts of the belt 120 may be enriched, including the portion or part immediately leaving the attachment rich environment 106, as well as the portion or part immediately entering the release rich environment 108.

The second processor 14 may be configured to receive the fluid 122 (e.g. water) and the portion 120a of the enriched functionalized polymer coated conveyor belt 120 to release the valuable material in the release rich environment 108.

The second processor 104 may also be configured to provide the valuable material that is released from the enriched functionalized polymer coated member into the release rich environment 108. For example, in Figure 2 the second processor 104 is shown configured to provide via piping 161 drainage of the valuable material in the form of a concentrate 162.

In Figure 2, the first processor 102 is configured with the functionalized polymer coated conveyor belt 120 passing through with only two turns inside the attachment rich environment 106. However, embodiments are envisioned in which the first processor 102 may be configured to process the functionalized polymer coated conveyor belt 120 using a serpentine technique for winding or turning the belt 120 one way and another way, back and forth, inside the first processor to maximize

surface area of the belt inside the processor 102 and exposure of the belt 120 to the attachment rich environment 106.

Figure 3: The Functionalized Polymer Coated Filter

By way of example, Figure 3 shows the present invention is the form of a machine, device, system or apparatus 200, e.g., for separating valuable material from unwanted material in a mixture 201, such as a pulp slurry, using a first processor 202, 202' and a second processor 204, 204'. The first processor 202 and the second processor 204 are configured to process a functionalized polymer coated member that is shown, e.g., as a functionalized polymer coated collection filter 220 configured to be moved between the first processor 202 and the second processor 204' as shown in Figure 3 as part of a batch type process, according to some embodiments of the present invention. In Figure 3, by way of example the batch type process is shown as having two first processor 202, 202' and second processor 204, 204, although the scope of the invention is not intended to be limited to the number of first or second processors. Moreover, embodiments are envisioned using a different number of first and second processor, different types or kinds of processors, as well as different types or kinds of processors both now known or later developed in the future. According to some embodiments of the present invention, the functionalized polymer coated collection filter 220 may take the form of a membrane or a thin soft pliable sheet or layer. The arrow B1 indicates the movement of the functionalized polymer coated filter 220 from the first processor 202, and the arrow B2 indicates the movement of the functionalized polymer coated collection filter 220 into the second processor 202. Techniques, including motors, gearing, etc., for moving a filter like element 220 from one processor to another

processor like elements 202 and 204 are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now know or later developed in the future.

The first processor 202 may take the form of a first chamber, tank, cell or column that contains an attachment rich environment generally indicated as 206. The first chamber, tank or column 102 may be configured to receive the mixture or pulp slurry 201 in the form of fluid (e.g., water), the valuable material and the unwanted material in the attachment rich environment 206, e.g., which has a high pH, conducive to attachment of the valuable material. The second processor 204 may take the form of a second chamber, tank, cell or column that contains a release rich environment generally indicated as 208. The second chamber, tank, cell or column 204 may be configured to receive, e.g., water 222 in the release rich environment 208, e.g., which may have a low pH or receive ultrasonic waves conducive to release of the valuable material. Consistent with that stated above, attachment rich environments like that forming part of element environment 206 conducive to the attachment of a valuable material of interest and release rich environments like that forming part of environment 208 conducive to the release of the valuable material of interest are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future. Moreover, a person skilled in the art would be able to formulate an attachment rich environment like environment 206 and a corresponding release rich environment like environment 208 based on the separation technology disclosed herein for any particular valuable mineral of interest, e.g., copper, forming part of any particular mixture or slurry pulp.

In operation, the first processor 202 may be configured to receive the mixture or pulp slurry 101 of water, valuable material and unwanted material and the functionalized polymer coated collection filter 220 that is configured to attach to the valuable material in the attachment rich environment 206. In Figure 3, the functionalized polymer coated collection filter 220 is understood to be configured and functionalized with a polymer coating to attach to the valuable material in the attachment rich environment 106.

The first processor 202 may also be configured to provide drainage from piping 241 of, e.g., tailings 242 as shown in Figure 3.

The first processor 202 may also be configured to provide an enriched functionalized polymer coated collection filter having the valuable material attached thereto, after soaking in the attachment rich environment 106. In Figure 3, the enriched functionalized polymer coated collection filter 220 is shown, e.g., being provisioned from the attachment rich environment 206 in the first processor 202 to the release rich environment 208 in the second processor 204.

The second processor 204 may be configured to receive the fluid 222 (e.g. water) and the enriched functionalized polymer coated collection filter 220 to release the valuable material in the release rich environment 208.

The second processor 204 may also be configured to provide the valuable material that is released from the enriched functionalized polymer coated collection filter 220 into the release rich environment 208. For example, in Figure 3 the second processor 204 is shown configured to provide via piping 261 drainage of the valuable material in the form of a concentrate 262.

The first processor 202' may also be configured with piping 280 and pumping 280 to recirculate the tailings 242 back into the first processor 202'. The scope of the

invention is also intended to include the second processor 204' being configured with corresponding piping and pumping to recirculate the concentrate 262 back into the second processor 204'. Similar recirculation techniques may be implemented for the embodiments disclosed in relation to Figures 1-2 above.

The scope of the invention is not intended to be limited to the type or kind of batch process being implemented. For example, embodiments are envisioned in which the batch process may include the first and second processors 202, 204 being configured to process the enriched functionalized polymer coated collection filter 220 in relation to one type or kind of valuable material, and the first and second processors 202', 204' being configured to process the enriched functionalized polymer coated collection filter 220 in relation to either the same type or kind of valuable material, or a different type or kind of valuable material. Moreover, the scope of the invention is intended to include batch processes both now known and later developed in the future.

Figures 4a, 4b: The Synthetic Bead Chemistry

For aiding a person of ordinary skill in the art in understanding various embodiments of the present invention, Figure 4a shows at least part of a generalized solid-phase body, e.g., a functionalized polymer coated member, and Figure 4b shows an enlarged portion of the surface. As shown in Figures 4a and 4b, the functionalized polymer coated member 70 has a body to provide a surface 74. At least the outside part of the body may be made of a synthetic material, such as polymer, so as to provide a plurality of molecules or molecular segments 76 on the surface 74. The molecule 76 is used to attach a chemical functional group 78 to the surface 74. In general, the molecule 76 can be a hydrocarbon chain, for example,

and the functional group 78 can have an anionic bond for attracting or attaching a mineral particle of interest, such as copper to the surface 74. A xanthate, for example, has both the functional group 78 and the molecular segment 76 to be incorporated into the polymer that is used to make the synthetic bead 70, or the surface thereof. The functional group 78 is also known as a collector that can have a neutral or charged functional group for attachment to the desired mineral, e.g., via a non-ionizing or ionizing bond. The charged functional group may include an ionizing bond that is anionic or cationic. An anionic bond or groups may include an oxyhydryl, such as carboxylic, sulfates and sulfonates, and sulfhydral, such as xanthates and dithiophosphates. Other molecules or compounds that can be used to provide the function group 78 include thionocarboamates, thioureas, xanthogens, monothiophosphates, hydroquinones and polyamines.

Similarly, a chelating agent can be incorporated into the polymer as a collector site for attracting a mineral, such as copper. As shown in Figure 4b, a mineral particle 72 is attached to the functional group 78 on the molecule 76. In general, the mineral particle 72 is much smaller than the synthetic bead 70. Many mineral particles 72 can be attracted to or attached to the surface 74 of a functionalized polymer coated member 70.

In some embodiments of the present invention, a functionalized polymer coated member may take the form of a solid-phase body made of a synthetic material, such as polymer. (By way of example, the term "solid-phase body" is understood herein to be a body having a cohesive force of matter that is strong enough to keep the molecules or atoms in the given positions, restraining the thermal mobility.) The polymer can be rigid or elastomeric. An elastomeric polymer can be a bisoxazolone-based polymer, for example. The body has a surface

comprising a plurality of molecules with one or more functional groups for attracting mineral particles of interest to the surface. A polymer having a functional group to attract or collect mineral particles is referred to as a functionalized polymer. By way of example, the entire body of the functionalized polymer coated member may be made of the same functionalized material, or the body may be a shell, which can be formed around an inner material.

It should be understood that the surface of a functionalized polymer coated member, according to the present invention, is not limited to an overall smoothness of its surface as shown in Figure 4a. In some embodiments of the present invention, the surface can be irregular and rough. For example, the surface can have some physical structures like grooves or rods, or holes or dents. The surface can have some hair-like physical structures. In addition to the functional groups on the functionalized polymer coated member that attract mineral particles of interest to the surface, the physical structures can help trapping the mineral particles on the surface. The surface can be configured to be a honeycomb surface or a sponge-like surface for trapping the mineral particles and/or increasing the contacting surface. In effect, the scope of the invention is not intended to be limited to any particular type or kind of surface of the synthetic bead.

It should be noted that the functionalized polymer coated member of the present invention can be realized by a different way to achieve the same goal. Namely, it is possible to use a different means to attract the mineral particles of interest to the surface of the functionalized polymer coated member. For example, the surface of the polymer coated member can be functionalized with a hydrophobic chemical molecule or compound, as discussed below. Alternatively, the surface of the functionalized polymer coated member can be coated with hydrophobic chemical

molecules or compounds. In the pulp slurry, xanthate and hydroxamate collectors can also be added therein for collecting the mineral particles and making the mineral particles hydrophobic. When the functionalized polymer coated member are used to collect the mineral particles in the pulp slurry having a pH value around 8-9, it is possible to release the mineral particles on the enriched synthetic beads from the surface of the functionalized polymer coated member in an acidic solution, such as a sulfuric acid solution. According to some embodiment, it may also be possible to release the mineral particles carried with the enriched functionalized polymer coated member by sonic agitation, such as ultrasonic waves, or simply by washing it with water.

Figures 5a to 5c: Hydrophobicity

For aiding a person of ordinary skill in the art in understanding various embodiments of the present invention, Figure 5a shows at least part of a generalized functionalized polymer coated member having some particles attached to the surface. Figure 5b illustrates an enlarged portion of the functionalized polymer coated member showing a wetted mineral particle attached to the hydrophobic surface of the functionalized polymer coated member. Figure 5c illustrates an enlarged portion of the functionalized polymer coated member showing a hydrophobic particle attached to the hydrophobic surface of the functionalized polymer coated member.

The hydrophobic particle can be mineral related or non-mineral related.

As shown in Figure 5a, the functionalized polymer coated member 170 may have a body to provide a surface 174. At least the outside part of the body is made of a synthetic material, such as a hydrophobic polymer, or a coating of a hydrophobic

chemical. As such, hydrophobic particles 172, 172' are attracted to the surface 174 to form an enriched functionalized polymer coated member 175. As shown in Figures 5a and 5b, the surface 174 of the functionalized polymer coated member comprises a plurality of molecules 179 which renders the surface 174 hydrophobic. Polysiloxanates, such as hydroxyl-terminated polydimethysiloxanes, have a silicon-oxygen chain to provide the hydrophobic molecules 179. The hydrophobic particle 172', as shown in Figure 5b, can be a mineral particle 171' having one or more collectors 173 attached thereto. One end 178 of the collector 173 has an ionic bond or ionic group attached to the mineral particle of interest 171'. The other end of the collector 173 has a hydrophobic chain 176 which tends to move into the hydrophobic molecules 179. Thus, the hydrophobic particle 172' can be a wetted mineral particle. A collector, such as xanthate, has both the functional group 178 and the molecule 176. A xanthate, for example, has both the functional group 178 and the molecular segment 176 to be incorporated into the polymer that is used to make the functionalized polymer coated member 170. A functional group 178 is also known as a collector that can have a non-ionizing or ionizing bond. The ionizing bond or group can be anionic or cationic. An anionic bond or group may include an oxyhydryl, such as carboxylic, sulfates and sulfonates, and sulfhydral, such as xanthates and dithiophosphates. Other molecules or compounds that can be used to provide the function group 178 include thionocarboamates, thioureas, xanthogens, monothiophosphates, hydroquinones and polyamines.

The hydrophobic particle 172, as shown in Figure 5c, can be a particle that has a hydrophobic chain 176. Such particle can be non-mineral related, but it can be arranged to contact with the hydrophobic functionalized polymer coated member 170 of the present inventions. Thus the hydrophobic functionalized polymer coated

member 170, according to some embodiments of the present invention, can be used in non-mining applications, such as water-pollution control and water purification.

pH

In many releasing environments, the pH value is lower than the pH value for mineral attachment. It should be noted that, however, when the valuable material is copper, for example, it is possible to provide a lower pH environment for the attachment of mineral particles and to provide a higher pH environment for the releasing of the mineral particles from the synthetic beads or bubbles. In general, the pH value is chosen to facilitate the strongest attachment, and a different pH value is chosen to facilitate release. Thus, according to some embodiments of the present invention, one pH value is chosen for mineral attachment, and a different pH value is chosen for mineral releasing. The different pH could be higher or lower, depending on the specific mineral and collector.

Bead Size (range)

The synthetic beads, according to some embodiments of the present invention, can be made with different sizes in order to attract mineral particles of different sizes. For example, unlike air bubbles, the synthetic beads of a larger size can be used to attract mineral particles larger than, say, 200μm. Thus, the grinding of the blasted ore can be separated into different stages. In the first stage, the rock is crushed into particles in the order of 200 μm. After the separation process using the larger synthetic beads in the slurry containing these crude particles, the remaining slurry can be subjected to a finer grinding stage where the crushed rock is further crushed into particles in the order of 100μm. With the slurry containing the

finer mineral particles, synthetic beads with a smaller size may be more effective in interacting with the finer mineral particles. In a flotation cell application, the bead size can be smaller than 100μm. In a tailings pond application, the bead size can be 1mm to 10mm or larger. However, large beads would reduce the functionalized surfaces where the mineral particles can attach to the synthetic beads. Thus, according to some embodiments of the present invention, the synthetic beads are configured with a size less than 100 μm for attracting to mineral particles having a substantially similar size, including in applications related to flotation cells; the synthetic beads are configured with a size of about 100 μm for attracting or attaching to mineral particles having a substantially similar size, smaller size or larger size; the synthetic beads are configured with a size in a range of about 50-500 μm for attracting or attaching to mineral particles having a substantially similar size, smaller size or larger size; the synthetic beads are configured with a size about 200 μm for attracting to mineral particles having a substantially similar size; the synthetic beads are configured with a size in a range of about 1mm to 10mm, including in applications related to a tailings pond. In general, the synthetic beads are configured with a size in a range of about 50 μm to 10mm. But the beads can be smaller than 50 μm and larger than 10mm.

Relative size

According to some embodiments of the present invention, the synthetic beads are configured to be larger than the mineral particles. As such, a plurality of mineral particles may attach to one synthetic bead. According to other embodiments of the present invention, the synthetic beads are configured to be smaller than the mineral particles. As such, a plurality of synthetic beads may attach to one mineral particle.

The size of the synthetic beads can also be about the same as the size of the mineral particle.

Oilsands separation

It should be understood that the synthetic beads according to the present invention, whether functionalized to have a collector or functionalized to be hydrophobic, are also configured for use in oilsands separation – to separate bitumen from sand and water in the recovery of bitumen in an oilsands mining operation. Likewise, the functionalized filters and membranes, according to some embodiments of the present invention, are also configured for oilsands separation.

Portion of surface functionalized

According to some embodiments of the present invention, only a portion of the surface of the synthetic bead is functionalized to be hydrophobic. This has the benefits as follows:

1. Keeps too many beads from clumping together – or limits the clumping of beads,

2. Once a mineral is attached, the weight of the mineral is likely to force the bead to rotate, allowing the bead to be located under the bead as it rises through the flotation cell;

a. Better cleaning as it may let the gangue to pass through

b. Protects the attached mineral particle or particles from being knocked off, and

c. Provides clearer rise to the top collection zone in the flotation cell.

According to some embodiments of the present invention, only a portion of the surface of the synthetic bead is functionalized with collectors. This also has the benefits of

1. Once a mineral is attached, the weight of the mineral is likely to force the bead to rotate, allowing the bead to be located under the bead as it rises through the flotation cell;

a. Better cleaning as it may let the gangue to pass through

b. Protects the attached mineral particle or particles from being knocked off, and

c. Provides clearer rise to the top collection zone in the flotation cell.

Both collector and hydrophobic on same bead:

According to some embodiments of the present invention, one part of the synthetic bead is functionalized with collectors while another part of same synthetic bead is functionalized to be hydrophobic as shown in Figures 6a and 6b. As shown in Figure 6a, a synthetic bead 74 has a surface portion where polymer is functionalized to have collector molecules 73 with functional group 78 and molecular segment 76 attached to the surface of the bead 74. The synthetic bead 74 also has a different surface portion where polymer is functionalized to have hydrophobic molecules 179 (or 79). In the embodiment as shown in Figure 6b, the entire surface of the synthetic bead 74 can be functionalized to have collector molecules 73, but a portion of the surface is functionalized to have hydrophobic molecules 179 (or 79) render it hydrophobic.

Advantages of same bead

having both collector molecules and hydrophobic molecules

According to some embodiments of the present invention, one part of the synthetic bead is functionalized with collectors while another part of same synthetic bead is functionalized to be hydrophobic and this "hybrid" synthetic bead is configured for use in a traditional flotation cell as well. The "hybrid" synthetic bead (see Figures 6a and 6b) has a hydrophobic portion and a separate collector portion. When the "hybrid" beads are mixed with air in the flotation cell, some of them will attach to the air bubbles because of the hydrophobic portion. As the "hybrid" synthetic bead is attached to an air bubble, the collector portion of the attached bead can collect mineral particles with the functional groups. Thus, the synthetic beads, according to some embodiments of the present inventions, can be used to replace the air bubbles, or to work together with the air bubbles in a flotation process.

A Collector

According to some embodiments of the present invention, the surface of a synthetic bead can be functionalized to have a collector molecule. The collector has a functional group with an ion capable of forming a chemical bond with a mineral particle. A mineral particle associated with one or more collector molecules is referred to as a wetted mineral particle. According to some embodiments of the present invention, the synthetic bead can be functionalized to be hydrophobic in order to collect one or more wetted mineral particles.

Applications

The scope of the invention is described in relation to mineral separation, including the separation of copper from ore.

By way of example, applications are envisioned to include

Rougher, scavenger, cleaner and rougher/scavenger separation cells in the production stream, replacing the traditional flotation machines.

Tailings scavenger cells used to scavenge the unrecovered minerals from a tailings stream.

Tailings cleaning cell use to clean unwanted material from the tailings stream before it is sent to the disposal pond.

Tailings reclamation machine that is placed in the tailings pond to recover valuable mineral that has been sent to the tailings pond.

Other types or kinds of valuable material or minerals of interest, including gold, molybdenum, etc.

However, the scope of the invention is intended to include other types or kinds of applications either now known or later developed in the future, including applications related to oilsands separation that includes separating bitumen from sand and water in the recovery of bitumen in an oilsands mining operation.

The Scope of the Invention

It should be further appreciated that any of the features, characteristics, alternatives or modifications described regarding a particular embodiment herein may also be applied, used, or incorporated with any other embodiment described herein. In addition, it is contemplated that, while the embodiments described herein

are useful for homogeneous flows, the embodiments described herein can also be used for dispersive flows having dispersive properties (e.g., stratified flow). Although the invention has been described and illustrated with respect to exemplary embodiments thereof, the foregoing and various other additions and omissions may be made therein and thereto without departing from the spirit and scope of the present invention.

What is Claimed is:

1. Apparatus comprising:

a first processor configured to receive a mixture of fluid, valuable material and unwanted material and a functionalized polymer coated member configured to attach to the valuable material in an attachment rich environment, and provide an enriched functionalized polymer coated member having the valuable material attached thereto; and

a second processor configured to receive a fluid and the enriched functionalized polymer coated member in a release rich environment to release the valuable material, and provide the valuable material released from the enriched functionalized polymer coated member to the release rich environment.

2. Apparatus according to claim 1, wherein the first processor comprises a first chamber, tank or column, and the second processor comprises a second chamber, tank or column.

3. Apparatus according to claim 2, wherein the first chamber, tank or column is configured to receive a pulp slurry having water, the valuable material and the unwanted material in the attachment rich environment, which has a high pH, conducive to attachment of the valuable material.

4. Apparatus according to claim 2, wherein the second chamber, tank or column is configured to receive water in the release rich environment, which has a low pH or receives ultrasonic waves conducive to release of the valuable material.

5. Apparatus according to claim 1, wherein the functionalized polymer coated member comprises a functionalized polymer coated impeller having at least one impeller blade configured to rotate slowly inside the first processor and the second processor.

6. Apparatus according to claim 5, wherein

the first processor is configured to receive the at least one impeller blade in an attachment zone, and provide at least one enriched impeller blade having the valuable material attached thereto in the attachment zone; and

the second processor is configured to receive the at least one enriched impeller blade in a release zone and to provide the valuable material released from the at least one enriched impeller blade.

7. Apparatus according to claim 5, wherein the first processor is configured with a first transition zone to provide drainage of tailings, and the second processor is configured with a second transition zone to provide drainage of concentrate.

8. Apparatus according to claim 2, wherein the functionalized polymer coated member comprises a functionalized polymer coated conveyor belt configured to run between the first processor and the second processor.

9. Apparatus according to claim 8, wherein

the first processor is configured to receive the functionalized polymer coated conveyor belt and provide an enriched functionalized polymer coated conveyor belt having the valuable material attached thereto; and

the second processor is configured to receive the enriched functionalized polymer coated conveyor belt and provide the valuable material released from the enriched functionalized polymer coated conveyor belt.

10. Apparatus according to claim 8, wherein the functionalized polymer coated conveyor belt is made of a mesh material.

11. Apparatus according to claim 1, wherein the functionalized polymer coated member comprises a functionalized polymer coated collection filter configured to move between the first processor and the second processor as part of a batch type process.

12. Apparatus according to claim 11, wherein

the first processor is configured to receive the functionalized polymer coated collection filter and to provide an enriched functionalized polymer coated collection filter having the valuable material attached thereto; and

the second processor device is configured to receive the enriched functionalized polymer coated collection filter and provide the valuable material released from the enriched functionalized polymer coated collection filter.

13. Apparatus according to claim 1, wherein the first processor is configured to provide tailings containing the unwanted material, and the second processor is configured to provide a concentrate containing the valuable material.

14. Apparatus according to claim 1, wherein the functionalized polymer coated member comprises a membrane or a thin soft pliable sheet or layer.

15. A method comprising:

receiving in a first processor a mixture of fluid, valuable material and unwanted material and a functionalized polymer coated member configured to attach to the valuable material in an attachment rich environment, and providing from the first processor an enriched functionalized polymer coated member having the valuable material attached thereto; and

receiving in a second processor a fluid and the enriched functionalized polymer coated member in a release rich environment to release the valuable material, and providing the valuable material released from the enriched functionalized polymer coated member to the release rich environment.

16. A method according to claim 15, wherein the first processor comprises a first chamber, tank or column, and the second processor comprises a second chamber, tank or column.

17. A method according to claim 16, wherein the first chamber, tank or column is configured to receive a pulp slurry having water, the valuable material and the unwanted material in the attachment rich environment, which has a high pH, conducive to attachment of the valuable material.

18. A method according to claim 16, wherein the second chamber, tank or column is configured to receive water in the release rich environment, which has a low pH or receives ultrasonic waves conducive to release of the valuable material.

19. A method according to claim 15, wherein the functionalized polymer coated member comprises a functionalized polymer coated impeller having at least one impeller blade configured to rotate slowly inside the first processor and the second processor.

20. A method according to claim 19, wherein

the first processor is configured to receive the at least one impeller blade in an attachment zone, and provide at least one enriched impeller blade having the valuable material attached thereto in the attachment zone; and

the second processor is configured to receive the at least one enriched impeller blade in a release zone and to provide the valuable material released from the at least one enriched impeller blade.

21. A method according to claim 19, wherein the first processor is configured with a first transition zone to provide drainage of tailings, and the second processor is configured with a second transition zone to provide drainage of concentrate.

22. A method according to claim 16, wherein the functionalized polymer coated member comprises a functionalized polymer coated conveyor belt configured to run between the first processor and the second processor.

23. A method according to claim 22, wherein

the first processor is configured to receive the functionalized polymer coated conveyor belt and provide an enriched functionalized polymer coated conveyor belt having the valuable material attached thereto; and

the second processor is configured to receive the enriched functionalized polymer coated conveyor belt and provide the valuable material released from the enriched functionalized polymer coated conveyor belt.

24. A method according to claim 22, wherein the functionalized polymer coated conveyor belt is made of a mesh material.

25. A method according to claim 15, wherein the functionalized polymer coated member comprises a functionalized polymer coated collection filter configured to move between the first processor and the second processor as part of a batch type process.

26. A method according to claim 25, wherein

the first processor is configured to receive the functionalized polymer coated collection filter and to provide an enriched functionalized polymer coated collection filter having the valuable material attached thereto; and

the second processor device is configured to receive the enriched functionalized polymer coated collection filter and provide the valuable material released from the enriched functionalized polymer coated collection filter.

27. A method according to claim 15, wherein the first processor is configured to provide tailings containing the unwanted material, and the second processor is configured to provide a concentrate containing the valuable material.

28. A method according to claim 15, wherein the functionalized polymer coated member comprises a membrane or a thin soft pliable sheet or layer.

29. Apparatus comprising:

first means to receive a mixture of fluid, valuable material and unwanted material and a functionalized polymer coated member configured to attach to the valuable material in an attachment rich environment, and provide an enriched functionalized polymer coated member having the valuable material attached thereto; and

second means to receive a fluid and the enriched functionalized polymer coated member in a release rich environment to release the valuable material, and provide the valuable material released from the enriched functionalized polymer coated member.

30. Apparatus according to claim 29, wherein the first means is configured to receive a pulp slurry having water, the valuable material and the unwanted material in the attachment rich environment, which has a high pH, conducive to attachment of the valuable material; and the second means is configured to receive water in the release rich environment, which has a low pH or receives ultrasonic waves conducive to release of the valuable material.

31. Apparatus according to claim 1, wherein the functionalized polymer coated member comprises one of the following:

a functionalized polymer coated impeller having at least one impeller blade configured to rotate slowly inside the first means and the second means;;

a functionalized polymer coated conveyor belt configured to run between the first means and the second means; or

a functionalized polymer coated collection filter configured to move between the first means and the second means as part of a batch type process.

32. Apparatus according to claim 1, wherein the functionalized polymer coated member comprises a surface having molecules comprising a functional group selected for attracting or attaching to the valuable material in the mixture.

33. Apparatus according to claim 53, wherein the functionalized polymer coated member comprises a hydrophobic polymer, or a coating of a hydrophobic chemical.

34. Apparatus according to claim 1, wherein the functionalized polymer coated member is made from a synthetic material selected from a group consisting of polyamides (nylon), polyesters, polyurethanes, phenol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, polyacetal, polyethylene, polyisobutylene, polyacrylonitrile, poly(vinyl chloride), polystyrene, poly(methyl methacrylates), poly(vinyl acetate), poly(vinylidene chloride), polyisoprene, polybutadiene, polyacrylates, poly(carbonate), phenolic resin and polydimethylsiloxane.

35. Apparatus according to claim 1, only a part of the surface of the functionalized polymer coated member is configured to have the molecules attached thereto, wherein the molecules comprise collectors.

36. Apparatus according to claim 35, wherein another part of the surface of the functionalized polymer coated member is configured to be hydrophobic.

37. Apparatus according to claim 1, wherein a part of the surface of the functionalized polymer coated member is configured to be hydrophobic.

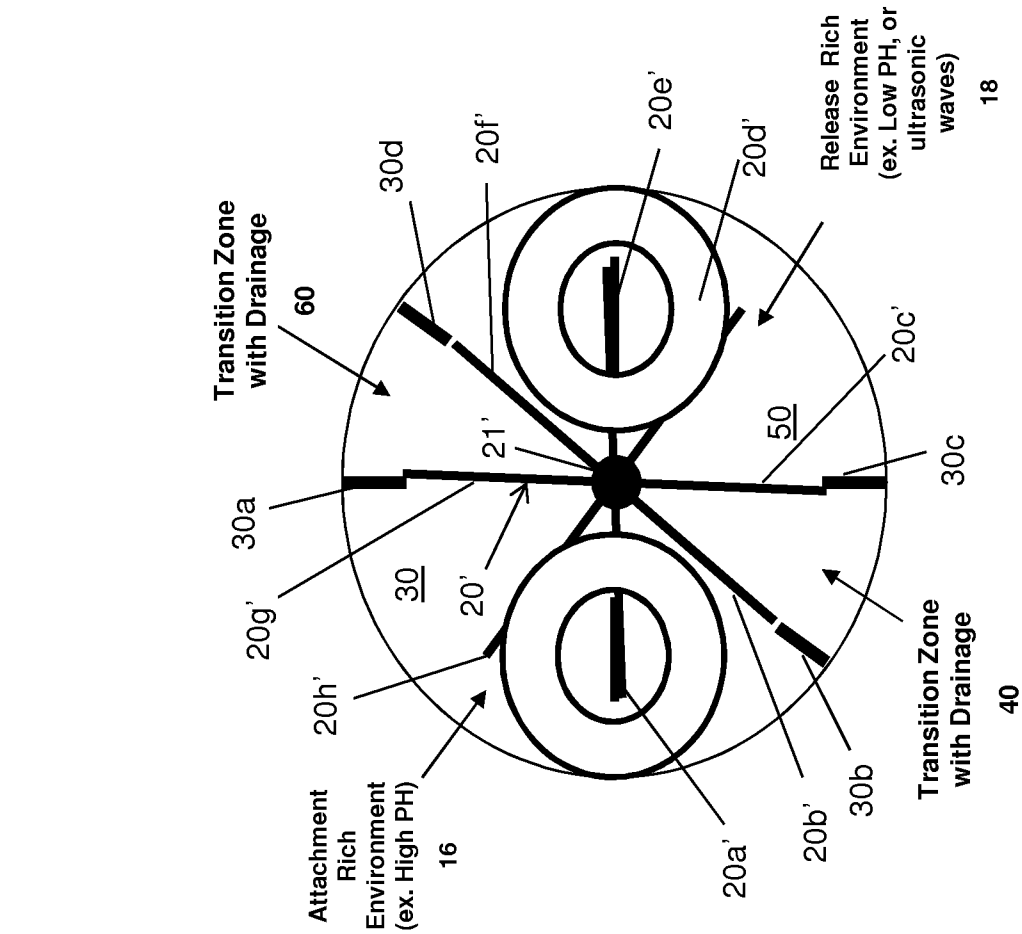

Figure 1b

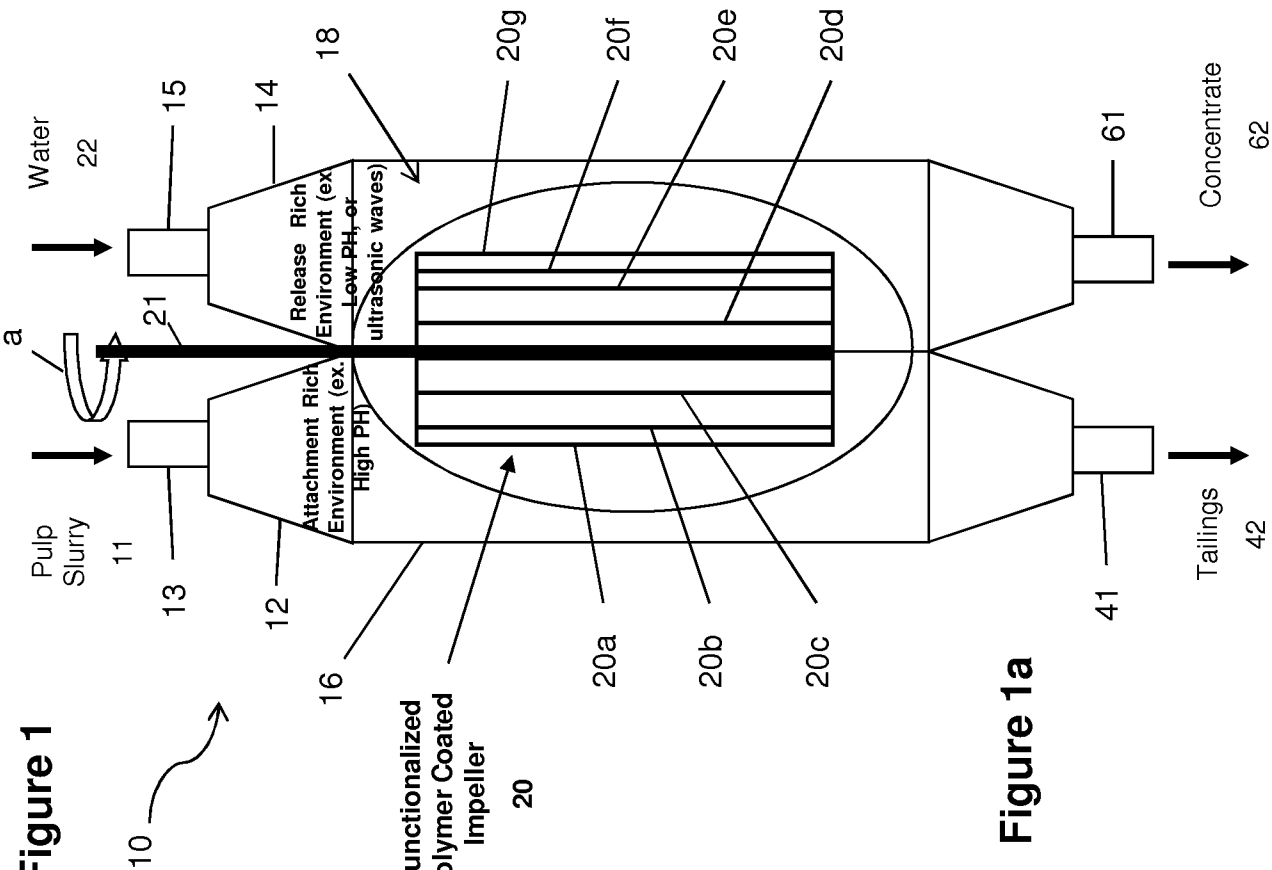

Figure 1a

Figure 1

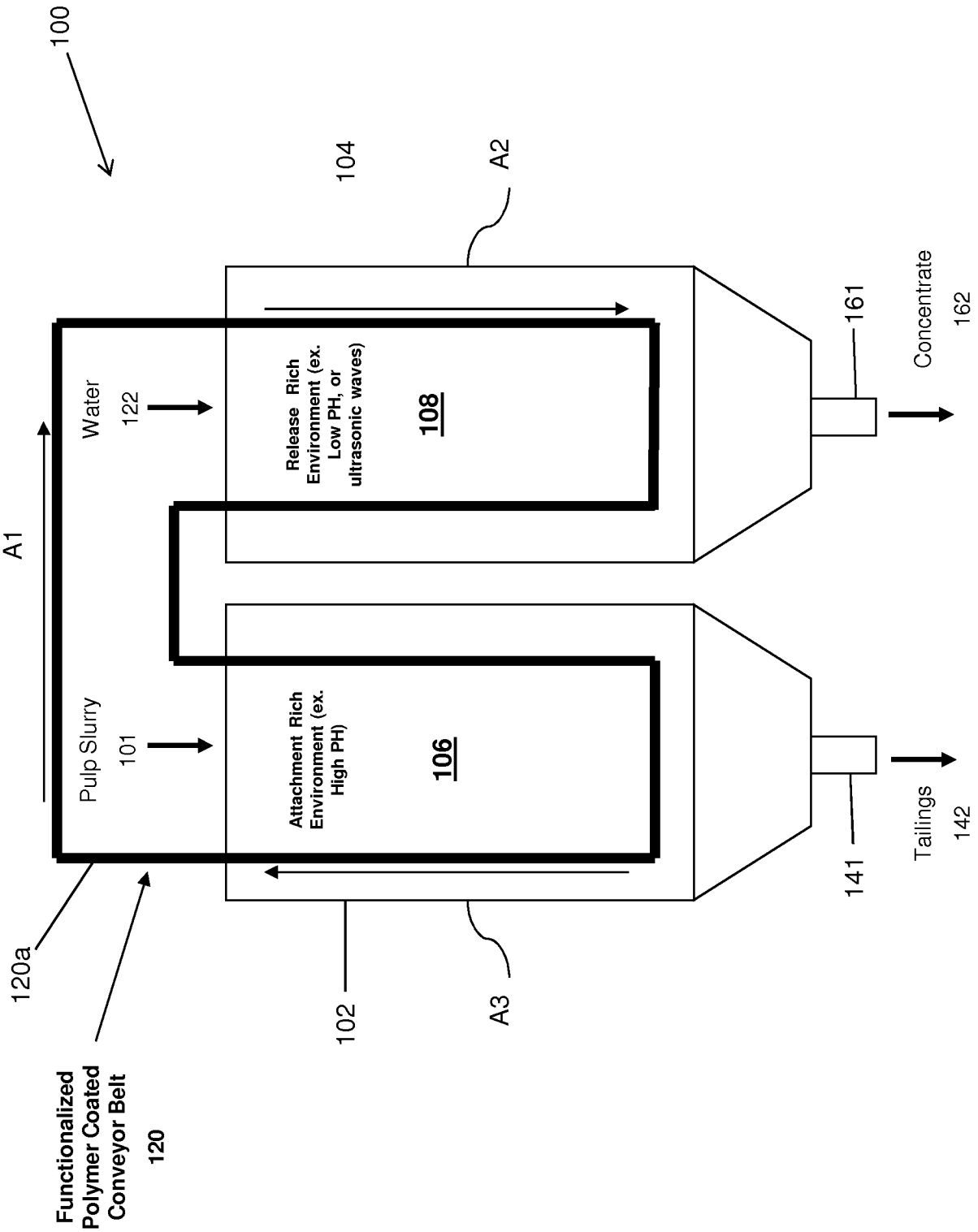
100
104
A2
Water
122
Release Rich Environment (ex. Low PH, or ultrasonic waves)
108
161
Concentrate
162
A1
Pulp Slurry
101
Attachment Rich Environment (ex. High PH)
106
120a
Functionalized Polymer Coated Conveyor Belt
120
102
A3
141
Tailings
142

Figure 2

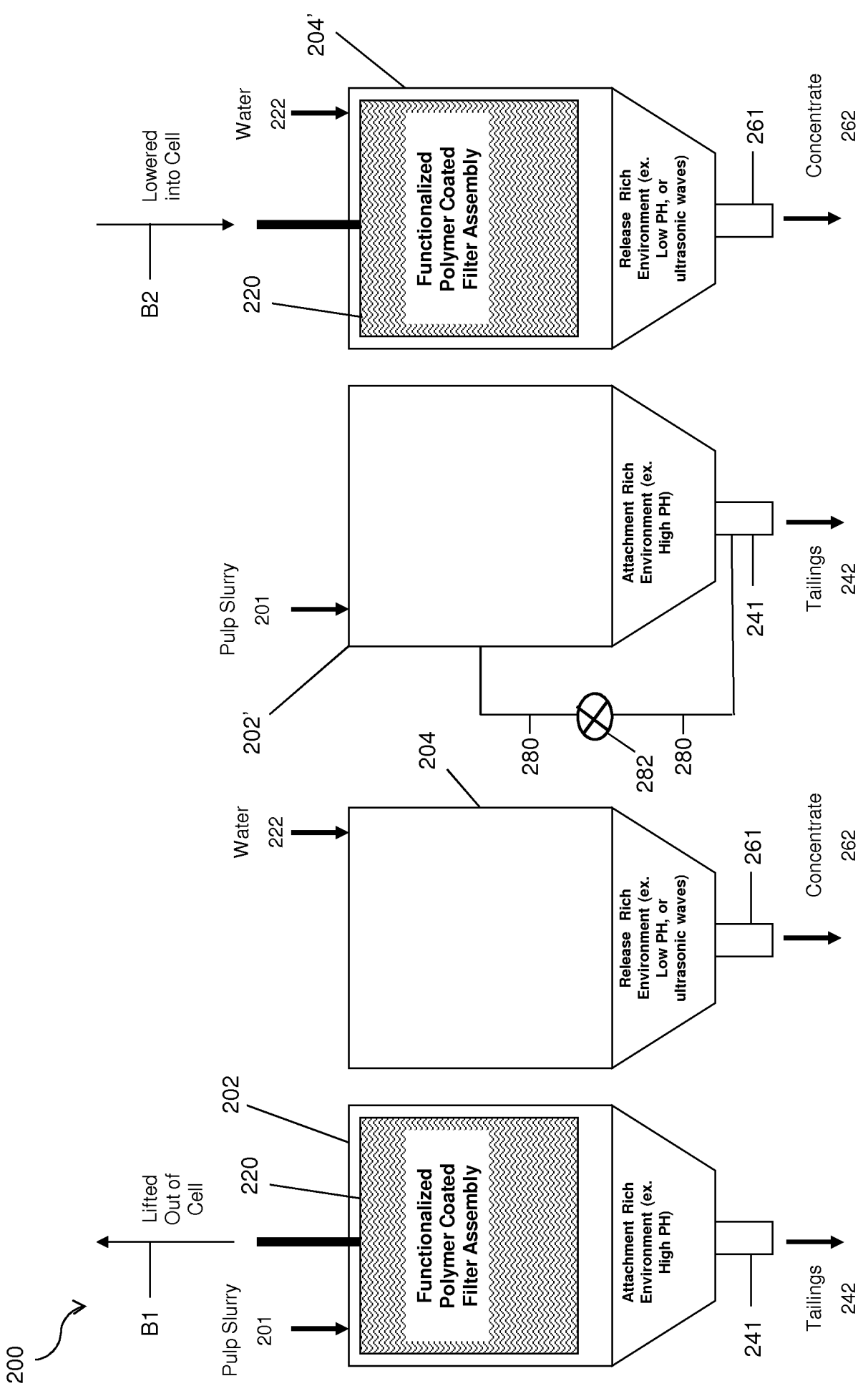
200
B1
Lifted Out of Cell
Pulp Slurry
201
220
202
Functionalized Polymer Coated Filter Assembly
Attachment Rich Environment (ex. High PH)
241
Tailings
242
Water
222
204
Release Rich Environment (ex. Low PH, or ultrasonic waves)
261
Concentrate
262
Pulp Slurry
201
202'
280
282
280
241
Tailings
242
Water
222
204'
Functionalized Polymer Coated Filter Assembly
220
B2
Lowered into Cell
Release Rich Environment (ex. Low PH, or ultrasonic waves)
261
Concentrate
262

Figure 3

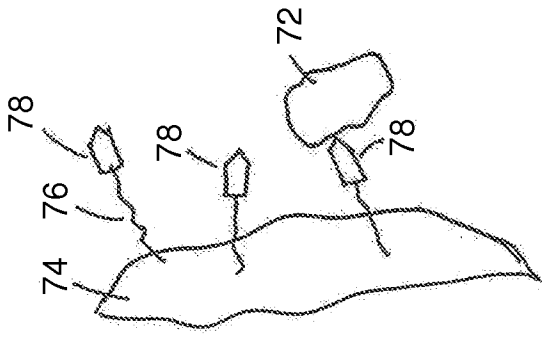

Figure 4b

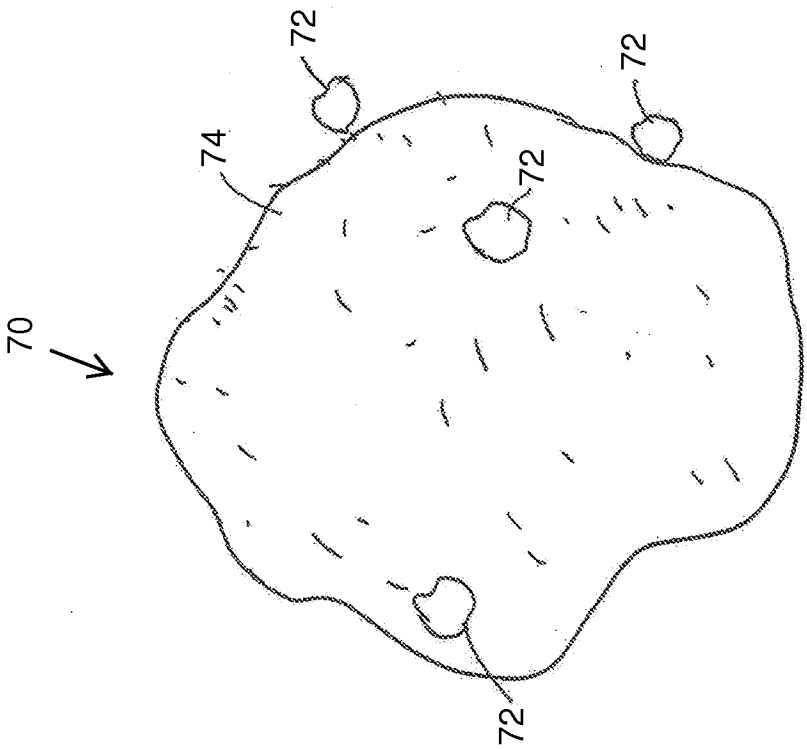

Figure 4a

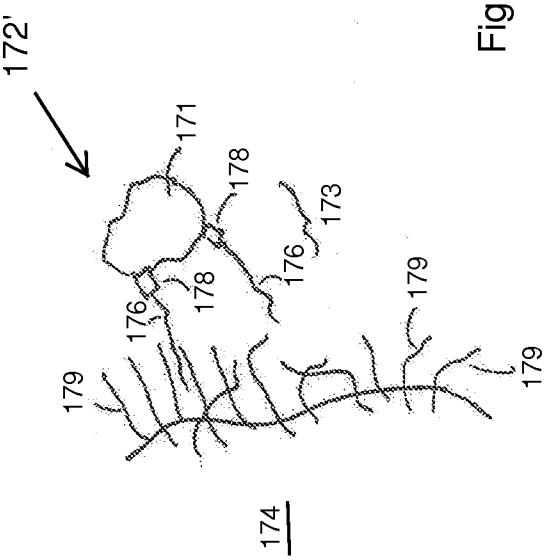

Figure 5b

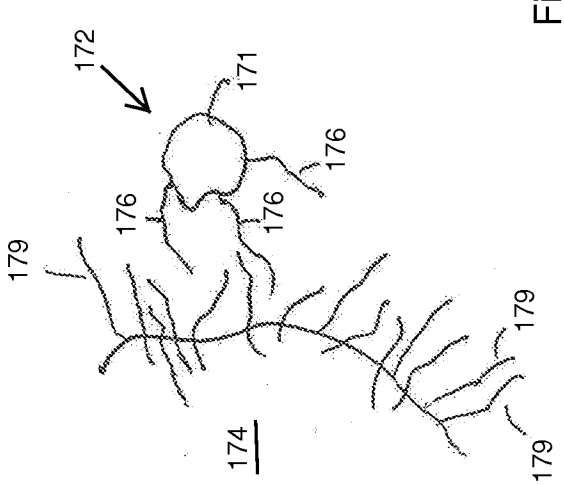

Figure 5c

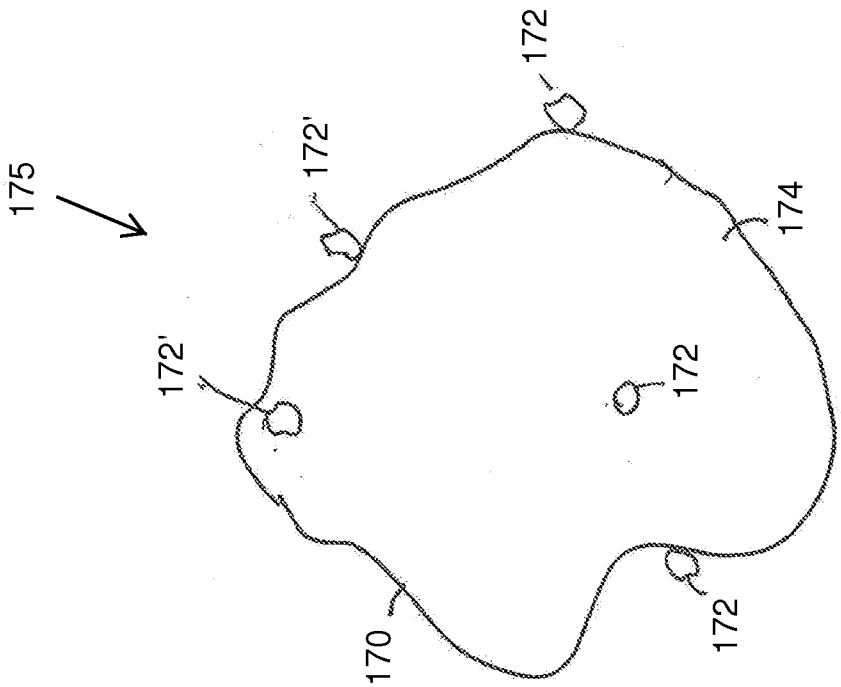

Figure 5a

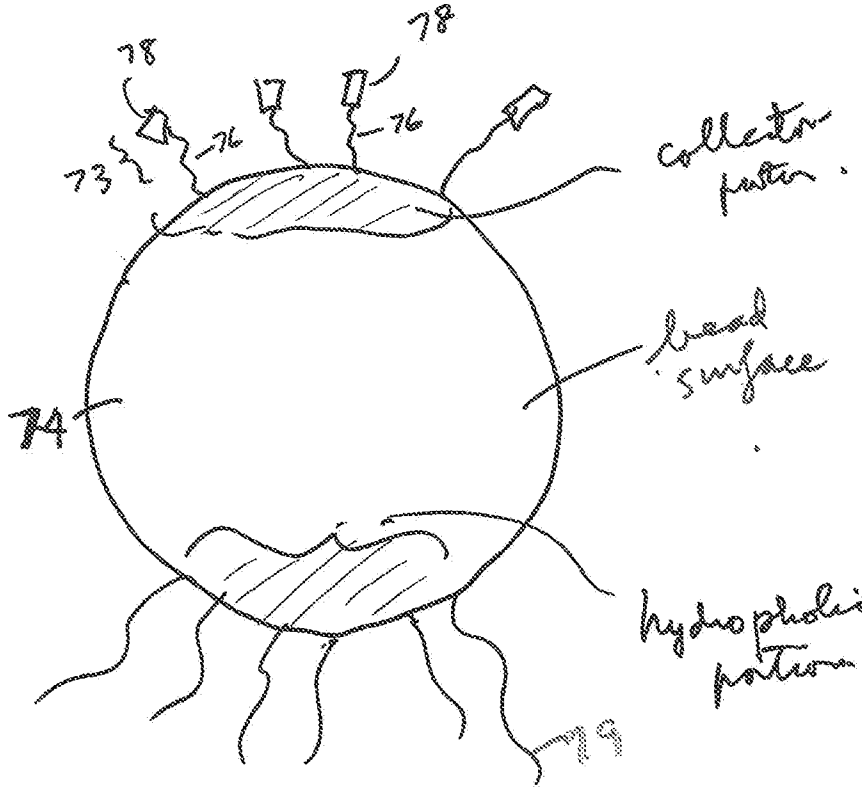
78
78
78
76
76
73
collector portion
bead surface
74
hydrophilic portion
79

Fig 6a

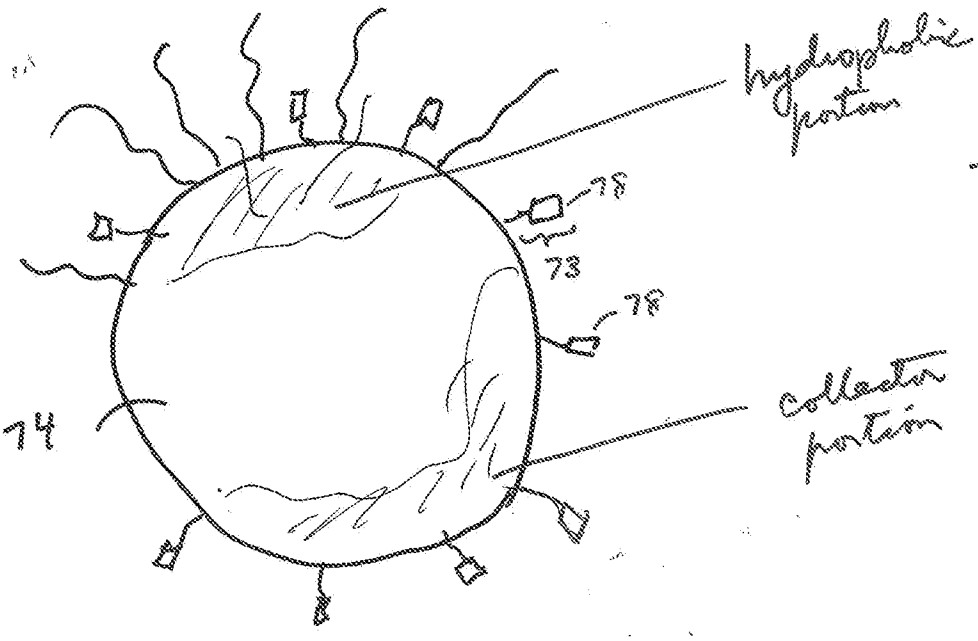
hydrophilic portion
78
73
78
74
collector portion

Fig 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/39534

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 37/02 (2012.01)
USPC - 210/767; 210/777; 75/392
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)
IPC(8) -- B01D 37/02 (2012.01)
USPC -- 210/767; 210/777; 75/392

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) -- B01D 37/02; B01D (2012.01)
USPC -- 210/679, 767; 210/777, $; 75/392, $

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (PGPB,USPT,USOC,EPAB,JPAB); USPTO; Espacenet; Google Patents; Google Scholar; Google -- BATCH BENIFICIAT$ COPPER FILTER FUNCTIONALIZ$ FUNCTIONAL GROUPS HYDROPHOBIC$ MEMBRANE MINERAL MINING PADDLE SEPARAT$ SLURRY

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2010/0200510 A1 (Domke et al.) 12 August 2010 (12.08.2010) Fig 1; Fig 2; para [0019]; [0020]; [0047]; [0050]; [0054]; [0063]; [0066]; [0072]; [0082] to [0086]; [0088]	1,2,8-10,13-16,22-24,27-29,31-37 --- 3-7,11,12,17-21,25,26,30
Y	US 2010/0294725 A1 (Bush et al.) 25 November 2010 (25.11.2010) para [0002]; [0045]; [0055]; [0071]; [0073]; [0203]	3-7,11,12,17-21,25,26,30
Y	US 2004/0000523 A1 (Rosenberg et al.) 01 January 2004 (01.01.2004) para [0007]; [0008]; [0010]; [0027]	11,12,25,26
Y	US 2,699,872 A (Kelsey) 18 January 1955 (18.01.1955) Fig 1; Fig 2; col 1, ln 15-20; col 4, ln 47-52	5,6,7,19,20,21
Y	US 2,585,473 A (Kennedy) 12 February 1952 (12.02.1952) Fig 1; col 1, ln 1-2; col 4, ln 39-44; col 5, ln 55-66; col 5, ln 75 to col 6, ln 1; col 7, ln 69-73	5,6,7,19,20,21

☒ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 SEPTEMBER 2012 (14.09.2012)	24 SEP 2012
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/39534

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/0206040 A1 (Berg et al.) 20 August 2009 (20.08.2009) para [0021]; [0022]; [0023]; [0029]; [0036]; [0056]	1-37
A	US 2006/0151397 A1 (Wright et al.) 13 July 2006 (13.07.2006) para [0028]; [0075]	1-37
A	US 2001/0008617 A1 (Robles) 19 July 2001 (19.07.2001) para [0003]; [0032]; [0073]	1-37
A	US 4,313,832 A (Shimizu et al.) 02 February 1982 (02.02.1982) abstract	1-37
A	US 2,588,976 A (Fuhrmeister) 11 March 1952 (11.03.1952) Fig 3	1-37