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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 June 2012 (07.06.2012)

(10) International Publication Number
WO 2012/074525 A1

(51) International Patent Classification:
B09B 3/00 (2006.01) *B09C 1/00* (2006.01) *B09C 1/02* (2006.01) *B09C 1/08* (2006.01) *E02D 3/11* (2006.01) *E02D 31/00* (2006.01)

(21) International Application Number: PCT/US2010/058580

(22) International Filing Date: 1 December 2010 (01.12.2010)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **EMPIRE TECHNOLOGY DEVELOPMENT LLC** [US/US]; 2711 Centerville Road, Suite 400, Wilmington, DE 19808 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **KRUGLICK, Ezekiel** [US/US]; 13842 Deergrass Ct., Poway, CA 92064-2276 (US).

(74) Agent: **HINCHLIFFE, Robert, D.**; Omikron IP Law Group, 16325 Boones Ferry Road Suite 204, Lake Oswego, OR 97035 (US).

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

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

[Continued on next page]

(54) Title: SUBSURFACE INDUCED PORE CLOGGING TO PREVENT SPILL FLOW

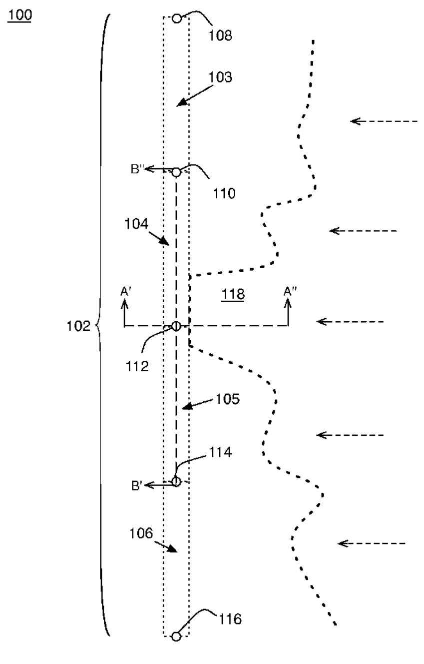


FIG. 1

(57) Abstract: A method for forming a subsurface permeation barrier, the method comprising: providing surfactant material adjacent to at least one of a cathode electrode or an anode electrode, wherein the cathode electrode and the anode electrode are configured to facilitate permeation of the surfactant material within a subsurface soil volume; causing the surfactant material to permeate at least a portion of the subsurface soil volume; providing acidifying material adjacent to at least one of the cathode electrode or the anode electrode; and causing the acidifying material to at least partially permeate the portion of the subsurface soil volume.

WO 2012/074525 A1

Published:

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

SUBSURFACE INDUCED PORE CLOGGING TO PREVENT SPILL FLOW

BACKGROUND

[0001] Unless otherwise indicated herein, the approaches described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

[0002] For environmental spills or contamination the first step is typically containment, even though it may take years for a pollutant to spread. Conventional spill containment typically involves digging a trench and filling the trench with clay material. Sometimes surface structures must be demolished or otherwise damaged to form the containment trenches. It might be useful to devise a spill containment response that leverages electro-remediation techniques in order to avoid damage to surface structures while still impeding the spread of harmful pollution.

SUMMARY

[0003] In accordance with some implementations, methods for method for forming subsurface permeation barriers may generally include providing surfactant material to a subsurface soil volume and acidifying the subsurface soil volume. For instance, surfactant material may be provided to a cathode module or an anode module, where the cathode module and the anode module have been arranged to provide permeation of the surfactant material within a subsurface soil volume. The surfactant material may then be caused to permeate at least a portion of the subsurface soil volume. Acidifying material may also be provided to the cathode module and/or the anode module. The acidifying material may then be caused to permeate the portion of the subsurface soil volume.

[0004] In accordance with some implementations, pollution containment systems are generally described that may include multiple electrodes and a subsurface permeation barrier including at least one barrier segment extending between two of the electrodes. The barrier segment may include surfactant adhered material.

[0005] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings.

[0007] In the drawings:

FIG. 1 is an illustrative diagram of an example system;

FIG. 2 is an illustration of a portion of the example system of **FIG. 1**;

FIG. 3 is an illustration of a portion of the example system of **FIG. 1**;

FIG. 4 is a flow diagram illustrating an example process;

FIG. 5 is a flow diagram illustrating another example process;

FIG. 6 is an illustrative diagram of another example system;

FIG. 7 is an illustrative diagram of an example system for implementing at least portions of the processes of **FIGS. 4** and **5**;

FIG. 8 is an illustration of an example computer program product; and

FIG. 9 is an illustration of an example computing device, all arranged in accordance with at least some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0008] The following description sets forth various examples along with specific details to provide a thorough understanding of claimed subject matter. It will be understood by those skilled in the art, however, that claimed subject matter may be practiced without some or more of the specific details disclosed herein. Further, in some circumstances, well-known methods, procedures, systems, components and/or circuits have not been described in detail in order to avoid unnecessarily obscuring claimed subject matter. In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the embodiments of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and make part of this disclosure.

[0009] This disclosure relates to methods, apparatus, and systems generally related to the containment of underground pollution sources and more particularly to the *in situ* formation of underground permeation barriers.

[0010] In accordance with various implementations of the present disclosure, electro-remediation equipment such as arrangements of electro-remediation electrode structures may be used to generate an in ground permeation barrier with the ability to substantially prevent permeation of subsurface contaminants through the barrier. In some examples an underground area or region may be permeated with a basic (high pH) and/or buffered surfactant solution and the barrier structure may then be formed *in situ* by subsequently permeating that region with an aqueous solution, an un-buffered solution and/or an acidic (low pH) solution to cause the surfactant to adhere to soil particles in the region. In some examples an underground region may be permeated with a buffered and/or acidic solution surfactant solution and the barrier structure may then be formed *in situ* by subsequently permeating that region with a buffered and/or basic surfactant solution to cause the surfactant to adhere to soil particles in the region.

[0011] Electro-remediation techniques may be employed to effect the movement and/or permeation of chemical compounds, including surfactants, buffer, acid and/or base compounds, within a subsurface soil volume. The transport or permeation of such materials through the soil volume may take place by electro-osmosis, electro-migration and/or electrophoresis. Soil material may include gravel, sand, silt and/or clay material.

[0012] **FIG. 1** illustrates a top down view of an example pollution containment system **100** in accordance with at least some embodiments of the present disclosure. System **100** includes a subsurface pollution containment dike or permeation barrier **102** having barrier segments **103**, **104**, **105** and **106**. Permeation barrier **102** is associated with electrode modules **108**, **110**, **112**, **114** and **116** that may be, in some implementations, components of an electro-remediation system. Electrode modules **108**, **110**, **112**, **114** and **116** may be configured to facilitate permeation of surfactant material within a subsurface soil volume corresponding, at least in part, to barrier **102**. Individual barrier segments **103**, **104**, **105** and **106** may be associated with electrode modules pairs **108/110**, **110/112**, **112/114** and **114/116** respectively.

[0013] As will be described in greater detail below, barrier **102** may be formed *in situ* to control pollution by, for example, inhibiting a pollution plume **118** (shown in **FIG. 1** as flowing from right to left) from passing through barrier **102**. Barrier **102** may include surfactant adhered soil material formed from surfactant molecules that have undergone sorption to soil particles within the barrier volume. The surfactant adhered soil material of barrier **102** may inhibit the flow of plume **118** by at least partially blocking soil pores within barrier segments **103**, **104**, **105** and/or **106**.

[0014] **FIG. 2** illustrates an elevational side view of portions of example system **100** taken along transect A′—A″ as illustrated in **FIG. 1** in accordance with at least some embodiments of the present disclosure. As shown in **FIG. 2**, electrode module **112** includes an electrode **202** positioned in an electrode reservoir or well **204**. As previously noted, electrode module **112** may be part of an electro-remediation system. Electrode module **112** may be positioned such that it extends from soil surface **206** downward into subsurface soil **208** such that barrier segment **104** may be formed in a location suitable to at least partially contain the flow of plume **118**.

[0015] **FIG. 3** illustrates another elevational side view of portions of example system **100** taken along transect B′—B″ as illustrated in **FIG. 1** in accordance with at least some embodiments of the present disclosure. As shown in **FIG. 3**, electrode modules **110**, **112** and **114** include respective electrodes **302**, **202** and **306** positioned in corresponding electrode wells **304**, **204** and **308**. In various implementations, any one of electrodes **202**, **302** and/or **306** may be a cathode electrode or an anode electrode. In certain embodiments, adjacent electrodes may be the same or different in type, that is, an anode electrode can be adjacent to a cathode electrode, or adjacent to another anode electrode. For example, electrode **202** may be a cathode electrode and electrodes **302** and **306** may be anode electrodes. In another example, electrode **202** may be an anode electrode and electrodes **302** and **306** may be cathode electrodes.

[0016] In various implementations, an electrode, such as electrode **202** of electrode module **112**, may be formed from conductive material. In some non-limiting examples, an electrode may be formed from metallic materials such as copper, stainless steel, activated titanium, iron etc and/or from non-metallic conductive material such as graphite. In various non-limiting examples, an electrode may be formed from a conductive metal such as copper that has been coated with another material such as a conductive ceramic. In some non-limiting examples, an electrode well, such as electrode well **204**, may be any type of structure, such as a porous casing structure, that may accept solutions including dissolved chemical compounds and may permit those solutions to pass between the interior of the electrode well and the surrounding soil.

[0017] Placement of electrode modules **108**, **110**, **112**, **114** and **116** may depend on soil type, soil density and/or pore size, thus, prior to forming barrier **102**, subsurface soil **208** may be tested using known techniques to characterize permeation rates for various materials. Such techniques may be employed to determine the separation between electrodes. Generally, the separation between electrodes may be any distance. In some non-limiting examples, the separation between electrodes may be about 10-30 meters resulting in barrier segments **103**, **104**, **105** and **106** having corresponding lengths of about 10-30 meters and having widths of about 30 cm. The separation between adjacent electrodes may be uniform in distance, or variable in distance.

[0018] **FIG. 4** illustrates a flow diagram of an example process **400** according to various implementations of the present disclosure. Process **400** may include one or more operations, functions or actions as illustrated by one or more of blocks **402** and/or **404**. Process **400** may begin at block **402**.

[0019] At block **402**, surfactant material may be provided to a subsurface soil volume. In some examples, referring also to **FIGS. 1-3**, block **402** may involve providing a solution of surfactant material to one or more of electrode modules **108**, **110**, **112**, **114** and **116** and then employing known electro-remediation electrokinetic techniques to cause the surfactant material to permeate a subsurface soil volume located between two or more electrode modules. For instance, a soil volume corresponding to barrier segment **104** may be permeated by surfactant material by placing a solution of surfactant material in electrode well **204**, adjacent to electrode **202**, and configuring electrodes **202** and **302** as a cathode/anode pair of an electro-remediation system. Surfactant material may then be caused to permeate through at least portions of the subsurface soil volume by applying an electric field between the cathode/anode electrode pair.

[0020] A surfactant solution employed at block **402** may include one or more surfactant compounds added to an aqueous solution. For instance, in various non-limiting examples surfactant may be added to water at a concentration of 1-2 grams per liter although specific types of surfactant compounds and/or concentrations of surfactant compounds employed may depend on specific soil types and/or conditions. In some examples, the surfactant material may be provided to the subsurface soil volume in a basic and/or buffered solution. For instance, in various non-limiting examples surfactant material may be provided in the form of a pH buffered solution, for example, a solution containing surfactant compounds that has been buffered to a neutral or basic pH using electrolytes such as NaCl, Na_2CO_3, etc. For instance, a solution employed at block **402** may include surfactant compounds dissolved in a 0.003 M Na_2CO_3 solution. Alternatively, the surfactant material employed at block **402** may be provided without a solvent or not in solution. This may be convenient when the subsurface soil volume already contains water sufficient to dissolve the surfactant material or when the subsurface soil volume is already saturated with water. The surfactant material may be provided to the subsurface soil volume all at once, in separate portions, or continuously over time.

[0021] In accordance with the present disclosure, various surfactant compounds and/or combinations of surfactant compounds may be employed at block **402**. In various implementations, anionic, non-ionic, cationic and/or amphoteric surfactants may be employed. For example, surfactants such as, but not limited to, hydroxypropyl beta cyclodextrin (HPCD), polysorbate 80, trimethylammonium bromide, cetyltrimethylammonium bromide, tetradecyltrimethylammonium bromide, octadecyltrimethylammonium bromide, polyacrylamide, methyl cellulose, dioctyl sulfonate, diphenyl oxide disulfonate, polyoxyalkylated fatty acid ester and/or a sodium dodecyl sulfate may be employed.

[0022] Further, in various implementations, surfactant material employed at block **402** may include biodegradable surfactants and/or biosurfactants. For example, biosurfactants such as, but not limited to, trehalolipids, rhamnolipids, sophorolipids, glycolipids, diglycosyl diglycerides, surfactin, liposan and/or emulsan may be employed. In addition, surfactant material employed at block **402** may include coating and/or binding polymeric material such as, but not limited to, polysiloxanes.

[0023] In implementing block **402** various direct current (DC) voltages may be placed across two or more electrodes. For instance, in various non-limiting examples, voltages of between about 100 volts and about 10,000 volts may be applied to the electrodes, although electrical conditions employed may depend on specific soil types and/or conditions. In some examples, block **402** may be undertaken using pulsed DC voltages. For instance, in a non-limiting example, DC voltage pulses of one second in duration may be applied every ten seconds over a span of three to seven days during which surfactant molecules may be electro-osmotically transferred into the subsurface soil volume.

[0024] Process **400** may continue with the acidification of the subsurface soil volume at block **404**. In various implementations, block **404** may involve providing an acidic or low pH solution adjacent to the same electrode employed at block **402**. In other implementations, the acidic or low pH solution may be provided adjacent to another electrode. For instance, if surfactant has been caused to permeate subsurface soil volume **105** at block **402** by, in part, providing surfactant material to electrode well **204**, block **404** may involve providing an acidic or low pH solution to either electrode well **202** or electrode well **308**. The acidic or low pH solution may then be caused to permeate and thereby acidify at least portions of the subsurface soil volume by applying an electric field between the cathode/anode electrode pair. Similar electrical conditions to those previously described may be employed. The acidification may be performed all at once, in separate portions, or continuously over time.

[0025] In some implementations, the un-buffered and/or acidic solutions employed at block **404** may include un-buffered and/or acidic surfactant solutions having the same and/or different surfactant compounds employed at block **402**. For instance, block **402** may involve using a buffered HPCD solution to permeate the subsurface soil volume with HPCD and block **404** may involve using an un-buffered HPCD solution to cause acidification of that subsurface volume resulting in the formation of HPCD adhered soil within that subsurface volume. In various other implementations, the un-buffered and/or acidic solutions may also be aqueous acidic solutions including hydrochloric, sulfuric, and/or acetic acid solutions to name just a few non-limiting examples.

[0026] While process **400** has been described above as involving the implementation of block **402** followed by the implementation of block **404**, claimed subject matter is not limited in this regard and block **404** may be implemented before, during or after block **402**. For instance, in some implementations, block **404** may be undertaken by, for example, causing an acidic solution to permeate a subsurface soil volume resulting in acidification of the soil volume. Subsequently, block **402** may be undertaken by causing a high pH or buffered surfactant solution to permeate the same soil volume resulting in the formation of surfactant adhered soil within that subsurface volume. In addition, in some implementations, block **402** and/or block **404** may be implemented multiple times to form a permeation barrier in accordance with the present disclosure. For example, blocks **402** and **404** may be followed by another iteration of block **402** and/or another iteration of block **404**.

[0027] **FIG. 5** illustrates a flow diagram of an example process **500** according to various implementations of the present disclosure. Process **500** may include one or more operations, functions or actions as illustrated by one or more of blocks **502**, **504**, **506** and/or **508**. Process **500** may begin at block **502**.

[0028] At block **502**, surfactant material may be provided adjacent to at least one of a cathode electrode or an anode electrode. In some examples, referring also to **FIGS. 1-3**, block **502** may involve providing a solution of surfactant material, such as a buffered HPCD solution, to one or more of electrode modules **108**, **110**, **112**, **114** and **116**. At block **504**, the surfactant material may be caused to permeate at least a portion of a subsurface soil volume. For instance, electro-remediation techniques may be employed to cause HPCD surfactant to permeate a subsurface soil volume located between two or more of electrode modules **108**, **110**, **112**, **114** and **116**.

[0029] At block **506**, acidifying material may be provided adjacent to at least one of the cathode electrode or anode electrode and, at block **508**, the acidifying material may be caused to permeate the portion of the subsurface soil volume permeated by surfactant material at block **504**. For instance, if a buffered HPCD solution has been provided to electrode module **112** at block **502**, and the HPCD material has been caused to permeate at least a portion of soil volume corresponding to barrier segments **104** and/or **105** at block **504**, then blocks **506** and **508** may involve providing an un-buffered or acidic solution to one or more of electrode modules **110**, **112** and/or **114** and then causing the un-buffered or acidic solution to permeate the soil volume corresponding to barrier segments **104** and **105**.

[0030] **FIG. 6** illustrates portions of another example pollution containment system **600** in accordance with at least some embodiments of the present disclosure.

System **600** includes four example permeation barriers **602**, **604**, **606** and **607** that may be implemented to contain a pollution plume **605**. Barrier **602** may have been formed, employing techniques described herein, using selected electrode modules **608** of an existing electro-remediation field **610** as well as additional electrode modules **612** provided for the purposes of forming barrier **602**. In this case, example barriers **602** and **607** are not linear in arrangement.

[0031] Example barriers **604**, **606** and **607** of system **600** may have been formed, employing techniques described herein, using selected electrode modules of existing electro-remediation field **610**. Barriers **604** and **606**, as shown in this example arranged adjacent to each other, may act to provide additional containment of plume **605**. In this case, barriers **604** and **606** are linear in arrangement. Further, example barrier **607** intersects barriers **604** and **606** and employs some electrode modules of field **610** in common with barriers **604** and **606**. While **FIG. 6** illustrates several example barrier configurations such example configurations are non-limiting and permeation barriers in accordance with the present disclosure may take any configuration having any shape including open configurations such as lines, linear or otherwise, as well as closed configurations such as rectangular configurations, circular configurations, etc. For example, additional barrier segments **609** and **611** may be combined with barriers **602** and **604** to provide a closed circular-shaped barrier configuration surrounding plume **605**.

[0032] **FIG. 7** illustrates an example system **700** for providing and/or implementing pollution control systems in accordance with at least some implementations of the present disclosure. System **700** may include a processing unit **702** operably coupled to a processor **706** that may include processing unit control logic **704**. Processing unit **702** may include any arrangement of devices or subsystems configured to undertake the manufacture of systems such as those illustrated in **FIGS. 1** and **6** using, for example, processes **400** and/or **500**.

[0033] Processing unit control logic **704** may be configured to provide functional control of any arrangement of devices or subsystems and may include hardware, software or firmware logic and/or any combination thereof although claimed subject matter is not limited to specific types or manifestations of processing unit control logic. Processor **706** may be a microprocessor or Central Processing Unit (CPU). In other implementations, processor **706** may be an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a digital signal processor (DSP), or other integrated formats. Processor **706** and processing unit **702** may be configured to communicate by any suitable means, such as, for example, by wired connections or wireless connections.

[0034] **FIG. 8** illustrates an example computer program product **800** arranged in accordance with at least some examples of the present disclosure. Program product **800** may include a signal bearing medium **802**. Signal bearing medium **802** may include one or more instructions **804** that, when executed by, for example, a processor, may provide the functionality described above with respect to **FIGS. 4** and **5**. Thus, for example, referring to the system of **FIG. 7**, one or more of control logic **704** and/or processor **706** may undertake one or more of the blocks shown in **FIGS. 4** and **5** in response to instructions **804** conveyed by medium **802**.

[0035] In some implementations, signal bearing medium **802** may encompass a computer-readable medium **806**, such as, but not limited to, a hard disk drive, a Compact Disc (CD), a Digital Versatile Disk (DVD), a digital tape, memory, etc. In some implementations, signal bearing medium **802** may encompass a recordable medium **808**, such as, but not limited to, memory, read/write (R/W) CDs, R/W DVDs, etc. In some implementations, signal bearing medium **802** may encompass a communications medium **810**, such as, but not limited to, a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.). Thus, for example, referring to the system of **FIG. 7**, program product **800** may be wirelessly conveyed to processing unit **702** by signal bearing medium **802**, where signal bearing medium **802** is conveyed to processing unit **702** by a wireless communications medium **810** (e.g., an wireless communications medium conforming with the 802.11 standard).

[0036] **FIG. 9** is a block diagram illustrating an example computing device **900** in accordance with various implementations of the present disclosure. In a very basic configuration **901**, computing device **900** typically includes one or more processors **910** and system memory **920**. A memory bus **930** can be used for communicating between the processor **910** and the system memory **920**.

[0037] Depending on the desired configuration, the system memory **920** can be of any type including but not limited to volatile memory (such as RAM), non-volatile memory (such as ROM, flash memory, etc.) or any combination thereof. System memory **920** typically includes an operating system **921**, one or more applications **922**, and program data **924**. Application **922** may include instructions **923** that are arranged to perform the functions as described herein including the actions described with respect to the flow charts shown in **FIGS. 4** and **5**. Program Data **924** may include electro-remediation (ER) data **925**, such as voltages, voltage pulsing schemes etc. that may be useful for implementing instructions **923**. In some examples, application **922** can be arranged to operate with program data **924** on an operating system **921** such that implementations of the present disclosure, as described herein, may be provided. This described basic configuration is illustrated in **FIG. 9** by those components within dashed line **901**.

[0038] Computing device **900** can have additional features or functionality, and additional interfaces to facilitate communications between the basic configuration **901** and any required devices and interfaces. For example, a bus/interface controller **940** can be used to facilitate communications between the basic configuration **901** and one or more data storage devices **950** via a storage interface bus **941**. The data storage devices **950** can be removable storage devices **951**, non-removable storage devices **952**, or a combination thereof. Examples of removable storage and non-removable storage devices include magnetic disk devices such as flexible disk drives and hard-disk drives (HDD), optical disk drives such as compact disk (CD) drives or digital versatile disk (DVD) drives, solid state drives (SSD), and tape drives to name a few. Example computer storage media can include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data.

[0039] System memory **920**, removable storage **951** and non-removable storage **952** are all examples of computer storage media. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computing device **900**. Any such computer storage media can be part of device **900**.

[0040] Computing device **900** can also include an interface bus **942** for facilitating communication from various interface devices (e.g., output interfaces, peripheral interfaces, and communication interfaces) to the basic configuration **901** via the bus/interface controller **940**. Example output interfaces **960** include a graphics processing unit **961** and an audio processing unit **962**, which can be configured to communicate to various external devices such as a display or speakers via one or more A/V ports **963**. Example peripheral interfaces **960** include a serial interface controller **971** or a parallel interface controller **972**, which can be configured to communicate with external devices such as input devices (e.g., keyboard, mouse, pen, voice input device, touch input device, etc.) or other peripheral devices (e.g., printer, scanner, etc.) via one or more I/O ports **973**. An example communication interface **980** includes a network controller **981**, which can be arranged to facilitate communications with one or more other computing devices **990** over a network communication via one or more communication ports **982**. A network communication connection is one example of a communication media. Communication media may typically be embodied by computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave or other transport mechanism, and includes any information delivery media. A “modulated data signal” can be a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media can include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency (RF), infrared (IR) and other wireless media. The term computer readable media as used herein can include both storage media and communication media.

[0041] Computing device **900** can be implemented as a portion of a small-form factor portable (or mobile) electronic device such as a cell phone, smart phone, a personal data assistant (PDA), a personal media player device, a wireless web-watch device, a personal headset device, an application specific device, or a hybrid device that include any of the above functions. Computing device **900** can also be implemented as a personal computer including both laptop computer and non-laptop computer configurations or implemented in a workstation or a server configuration.

[0042] References made in this disclosure to the term “responsive to” or “in response to” are not limited to responsiveness to only a particular feature and/or structure. A feature may also be responsive to another feature and/or structure and also be located within that feature and/or structure. Moreover, when terms or phrases such as “coupled” or “responsive” or “in response to” or “in communication with”, etc. are used herein or in the claims that follow, these terms should be interpreted broadly. For example, the phrase “coupled to” may refer to being communicatively, electrically and/or operatively coupled as appropriate for the context in which the phrase is used.

[0043] Some portions of the foregoing detailed description are presented in terms of algorithms or symbolic representations of operations on data bits or binary digital signals stored within a computing system memory, such as a computer memory. These algorithmic descriptions or representations are examples of techniques used by those of ordinary skill in the data processing arts to convey the substance of their work to others skilled in the art. An algorithm is here, and generally, is considered to be a self-consistent sequence of operations or similar processing leading to a desired result. In this context, operations or processing involve physical manipulation of physical quantities. Typically, although not necessarily, such quantities may take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared or otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to such signals as bits, data, values, elements, symbols, characters, terms, numbers, numerals or the like. It should be understood, however, that all of these and similar terms are to be associated with appropriate physical quantities and are merely convenient labels. Unless specifically stated otherwise, as apparent from the following discussion, it is appreciated that throughout this specification discussions utilizing terms such as "processing," "computing," "calculating," "determining" or the like refer to actions or processes of a computing device, that manipulates or transforms data represented as physical electronic or magnetic quantities within memories, registers, or other information storage devices, transmission devices, or display devices of the computing device.

[0044] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a flexible disk, a hard disk drive (HDD), a Compact Disc (CD), a Digital Versatile Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[0045] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein can be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system generally includes one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[0046] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable", to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0047] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0048] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to implementations containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation *is* explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean *at least* the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means *at least* two recitations, or *two or more* recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0049] It should also be understood that, the term “optimize” may include maximization and/or minimization. The term “minimization” and/or the like as used herein may include a global minimum, a local minimum, an approximate global minimum, and/or an approximate local minimum. Likewise, it should also be understood that, the term “maximization” and/or the like as used herein may include an global maximum, a local maximum, an approximate global maximum, and/or an approximate local maximum.

[0050] Reference in the specification to "an implementation," "one implementation," “some implementations,” or "other implementations" may mean that a particular feature, structure, or characteristic described in connection with one or more implementations may be included in at least some implementations, but not necessarily in all implementations. The various appearances of “an implementation,” “one implementation,” or “some implementations” in the preceding description are not necessarily all referring to the same implementations.

[0051] While certain example techniques have been described and shown herein using various methods and systems, it should be understood by those skilled in the art that various other modifications may be made, and equivalents may be substituted, without departing from claimed subject matter. Additionally, many modifications may be made to adapt a particular situation to the teachings of claimed subject matter without departing from the central concept described herein. Therefore, it is intended that claimed subject matter not be limited to the particular examples disclosed, but that such claimed subject matter also may include all implementations falling within the scope of the appended claims, and equivalents thereof.

WHAT IS CLAIMED:

1. A method for forming a subsurface permeation barrier, the method comprising:

providing surfactant material to a subsurface soil volume; and

acidifying the subsurface soil volume.

2. The method of claim 1, wherein the acidifying the subsurface soil volume step is performed before the providing surfactant material to the subsurface soil volume step.

3. The method of claim 1, wherein providing surfactant material to the subsurface soil volume comprises:

providing surfactant material adjacent to at least one of a cathode electrode or an anode electrode, wherein the cathode electrode and the anode electrode are configured to facilitate permeation of the surfactant material within the subsurface soil volume; and

causing the surfactant material to permeate at least a portion of the subsurface soil volume.

4. The method of claim 3, wherein acidifying the subsurface soil volume comprises:

providing acidifying material adjacent to at least one of the cathode electrode or the anode electrode; and

causing the acidifying material to at least partially permeate the portion of the subsurface soil volume.

5. The method of claim 1, wherein the surfactant material comprises at least one of a buffered surfactant solution, or a basic surfactant solution.

6. The method of claim 1, wherein the surfactant material comprises polysiloxane.

7. The method of claim 1, wherein the surfactant material comprises at least one of hydroxypropyl beta cyclodextrin, polysorbate 80, trimethylammonium bromide, cetyltrimethylammonium bromide, tetradecyltrimethylammonium bromide, octadecyltrimethylammonium bromide, polyacrylamide, methyl cellulose, dioctyl sulfonate, diphenyl oxide disulfonate, polyoxyalkylated fatty acid ester, sodium dodecyl sulfate, trehalolipids, rhamnolipids, sophorolipids, glycolipids, diglycosyl diglycerides, surfactin, liposan, or emulsan.

8. The method of claim 1, wherein acidifying the subsurface soil volume comprises providing acidifying material to the subsurface soil volume, wherein the acidifying material comprises at least one of an un-buffered surfactant solution, an acidic surfactant solution, an acidified water solution, or water.

9. A pollution containment system comprising:

a plurality of electrodes including at least a first electrode and a second electrode; and a subsurface permeation barrier including at least one barrier segment, wherein the barrier segment extends between the first electrode and the second electrode, and wherein the barrier segment includes surfactant adhered material.

10. The system of claim 9, wherein the surfactant adhered material comprises soil that is less permeable in the presence of adhered surfactant material than in the absence of adhered surfactant material.

11. The system of claim 9, wherein the surfactant adhered material comprises at least one of hydroxypropyl beta cyclodextrin, polysorbate 80, trimethylammonium bromide, cetyltrimethylammonium bromide, tetradecyltrimethylammonium bromide, octadecyltrimethylammonium bromide, polyacrylamide, methyl cellulose, dioctyl sulfonate, diphenyl oxide disulfonate, polyoxyalkylated fatty acid ester, sodium dodecyl sulfate, trehalolipids, rhamnolipids, sophorolipids, glycolipids, diglycosyl diglycerides, surfactin, liposan, or emulsan.

12. The system of claim 9, wherein the surfactant adhered material comprises polysiloxane.

13. The system of claim 9, wherein:

the plurality of electrodes includes a third electrode;

the subsurface permeation barrier includes a second barrier segment;

the second barrier segment extends between the second electrode and the third electrode; and

the second barrier segment includes surfactant adhered material.

14. The system of claim 9, wherein at least one of the first electrode and the second electrode comprises an electrode configured to provide electroremediation.

15. The system of claim 9, wherein the subsurface permeation barrier is configured to substantially contain permeation of subsurface pollution.

16. A method for forming a subsurface permeation barrier, the method comprising:

providing surfactant material adjacent to at least one of a cathode electrode or an anode electrode, wherein the cathode electrode and the anode electrode are configured to facilitate permeation of the surfactant material within a subsurface soil volume;

causing the surfactant material to permeate at least a portion of the subsurface soil volume;

providing acidifying material adjacent to at least one of the cathode electrode or the anode electrode; and

causing the acidifying material to at least partially permeate the portion of the subsurface soil volume.

17. The method of claim 16, wherein the surfactant material comprises at least one of a buffered surfactant solution, or a basic surfactant solution.

18. The method of claim 16, wherein the surfactant material comprises polysiloxane.

19. The method of claim 16, wherein the surfactant material comprises at least one of hydroxypropyl beta cyclodextrin, polysorbate 80, trimethylammonium bromide, cetyltrimethylammonium bromide, tetradecyltrimethylammonium bromide, octadecyltrimethylammonium bromide, polyacrylamide, methyl cellulose, dioctyl sulfonate, diphenyl oxide disulfonate, polyoxyalkylated fatty acid ester, sodium dodecyl sulfate, trehalolipids, rhamnolipids, sophorolipids, glycolipids, diglycosyl diglycerides, surfactin, liposan, or emulsan.

20. The method of claim 16, wherein the acidifying material comprises at least one of an un-buffered surfactant solution, an acidic surfactant solution, an acidified water solution, or water.

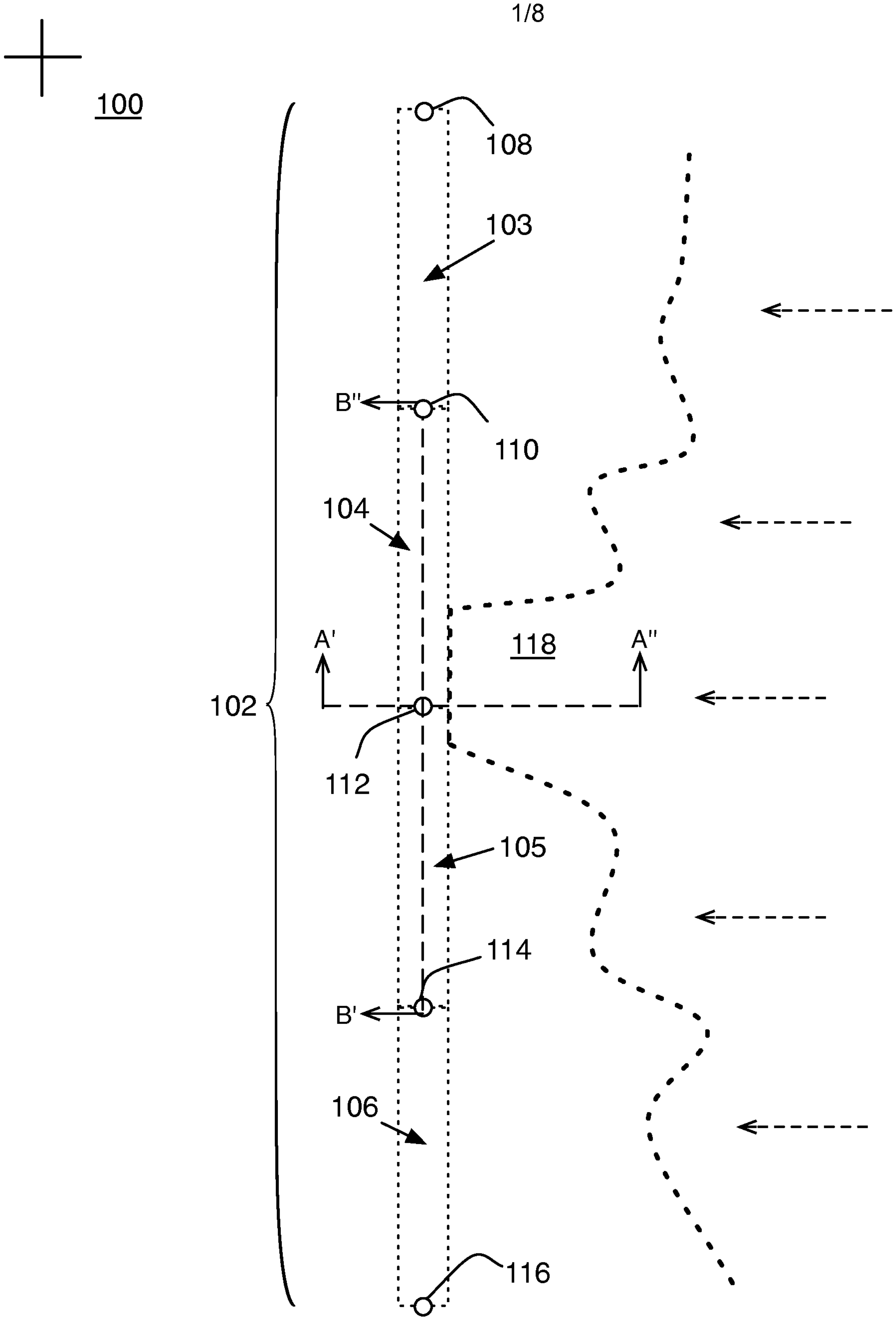


FIG. 1

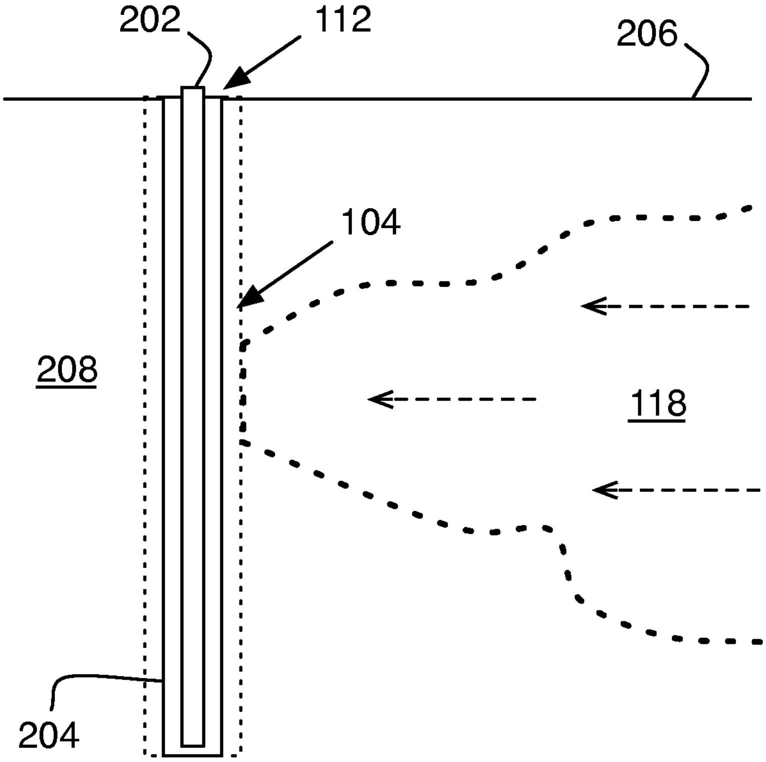

202
112
206
104
208
118
204

FIG. 2

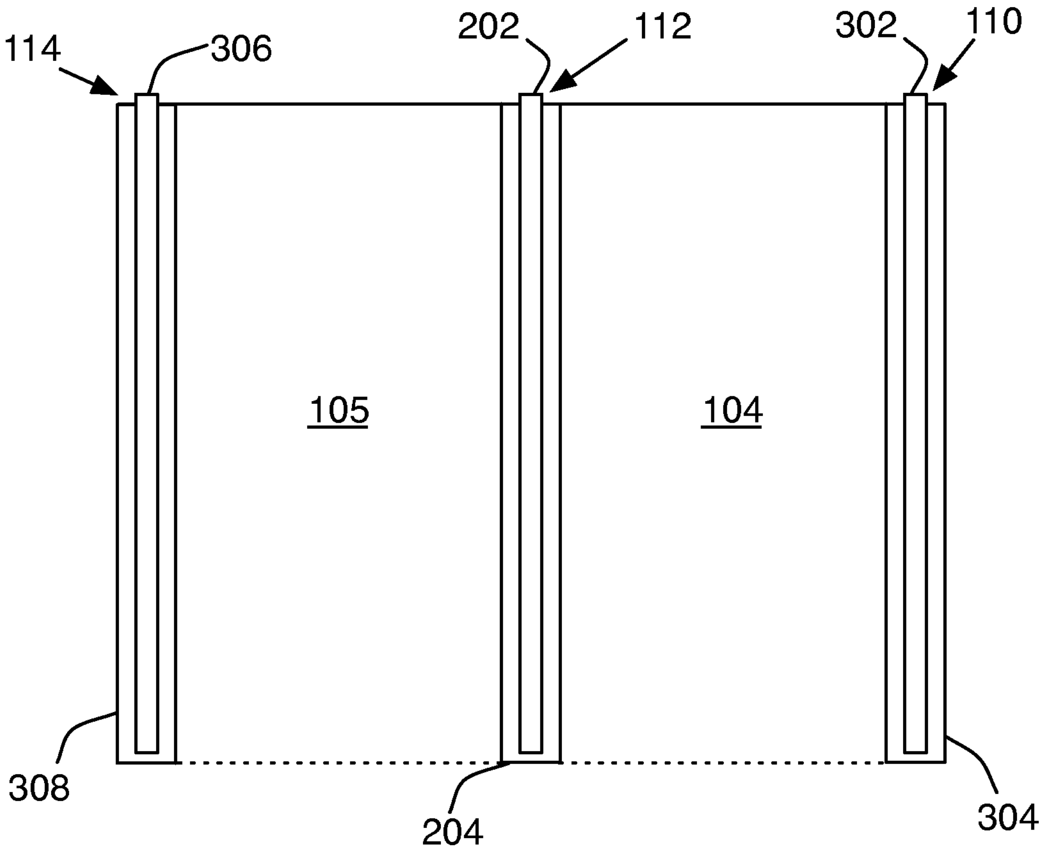

114
306
202
112
302
110
105
104
308
204
304

FIG. 3

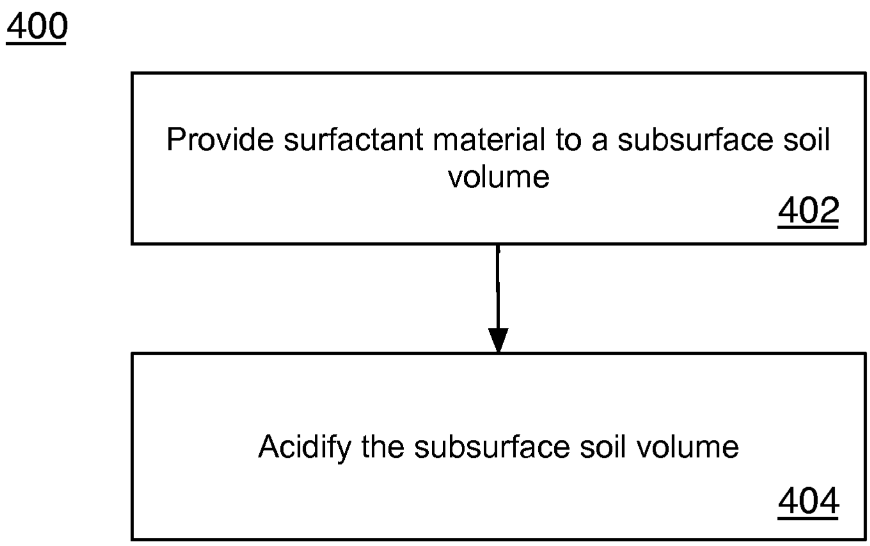

400
Provide surfactant material to a subsurface soil volume
402
Acidify the subsurface soil volume
404

FIG. 4

500

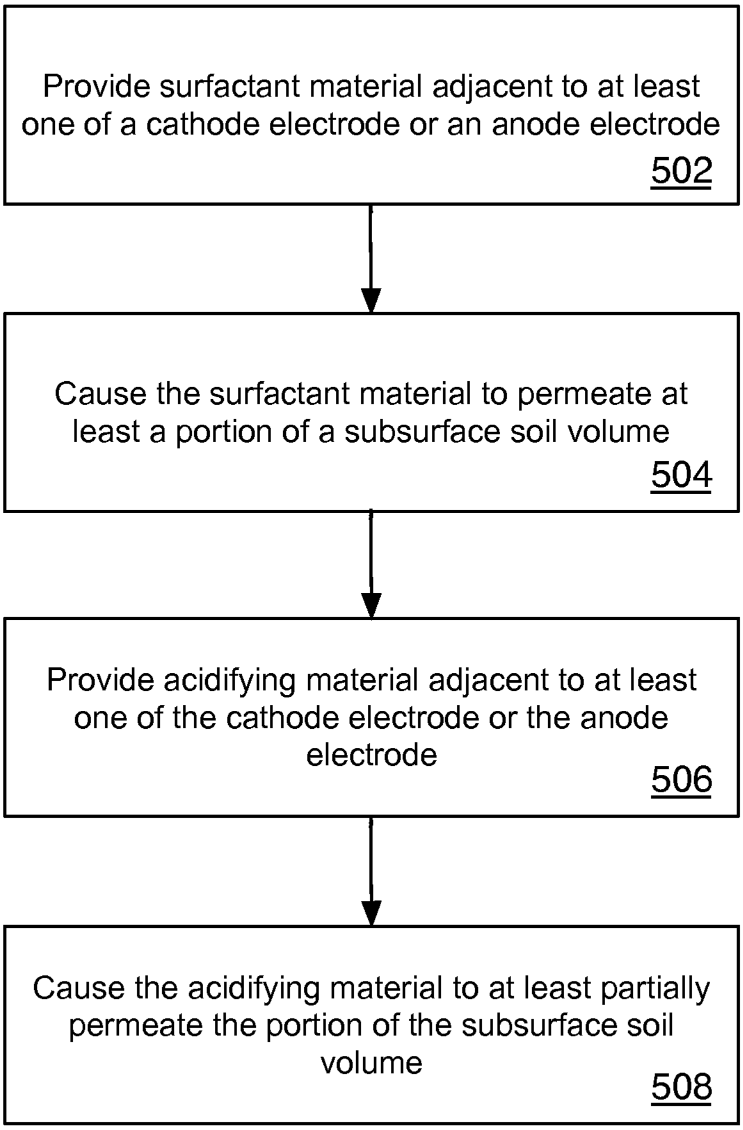

Provide surfactant material adjacent to at least one of a cathode electrode or an anode electrode
502
Cause the surfactant material to permeate at least a portion of a subsurface soil volume
504
Provide acidifying material adjacent to at least one of the cathode electrode or the anode electrode
506
Cause the acidifying material to at least partially permeate the portion of the subsurface soil volume
508

FIG. 5

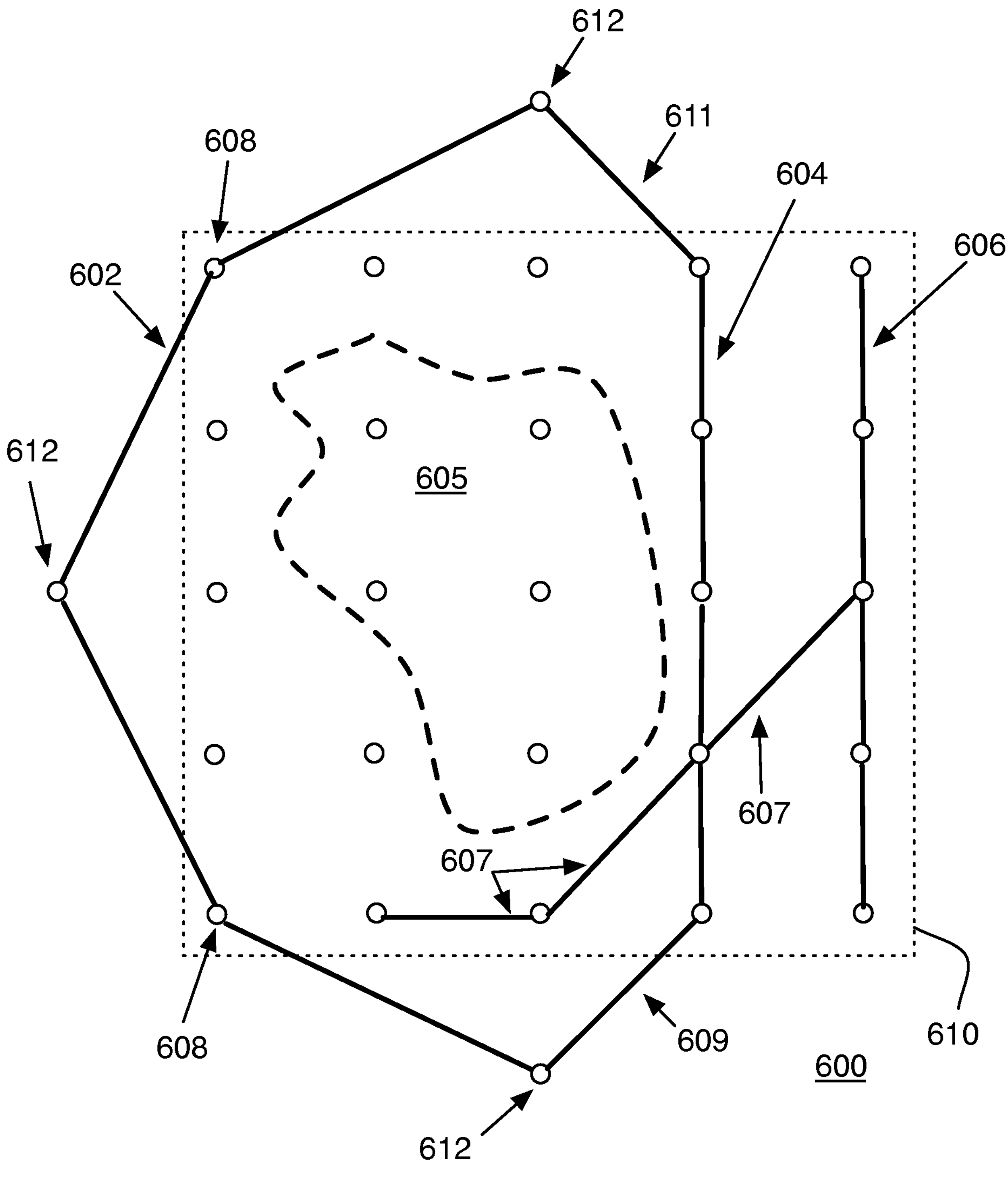


FIG. 6

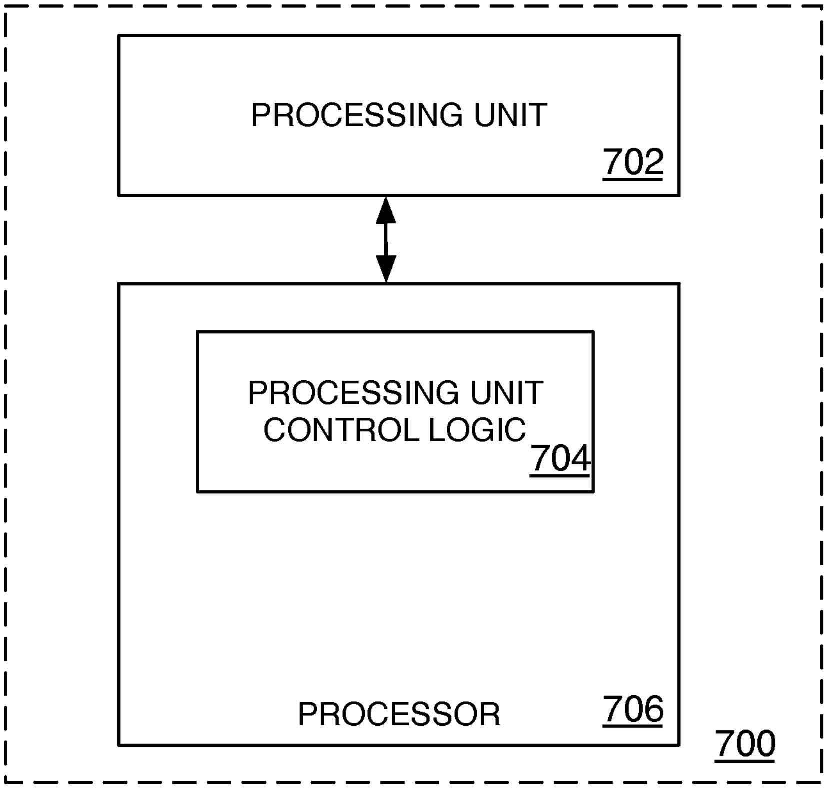

PROCESSING UNIT
702
PROCESSING UNIT
CONTROL LOGIC
704
PROCESSOR
706
700

FIG. 7

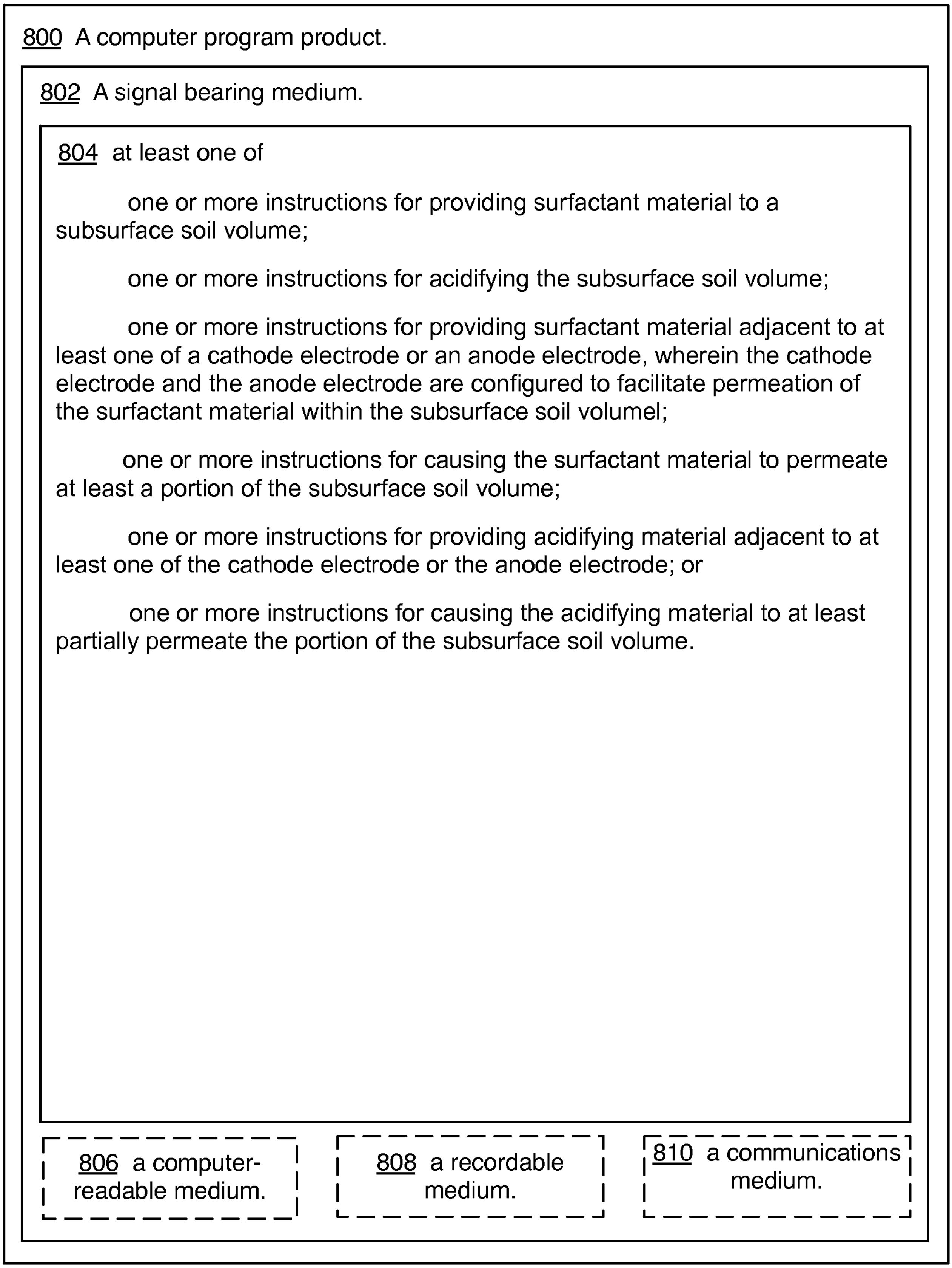
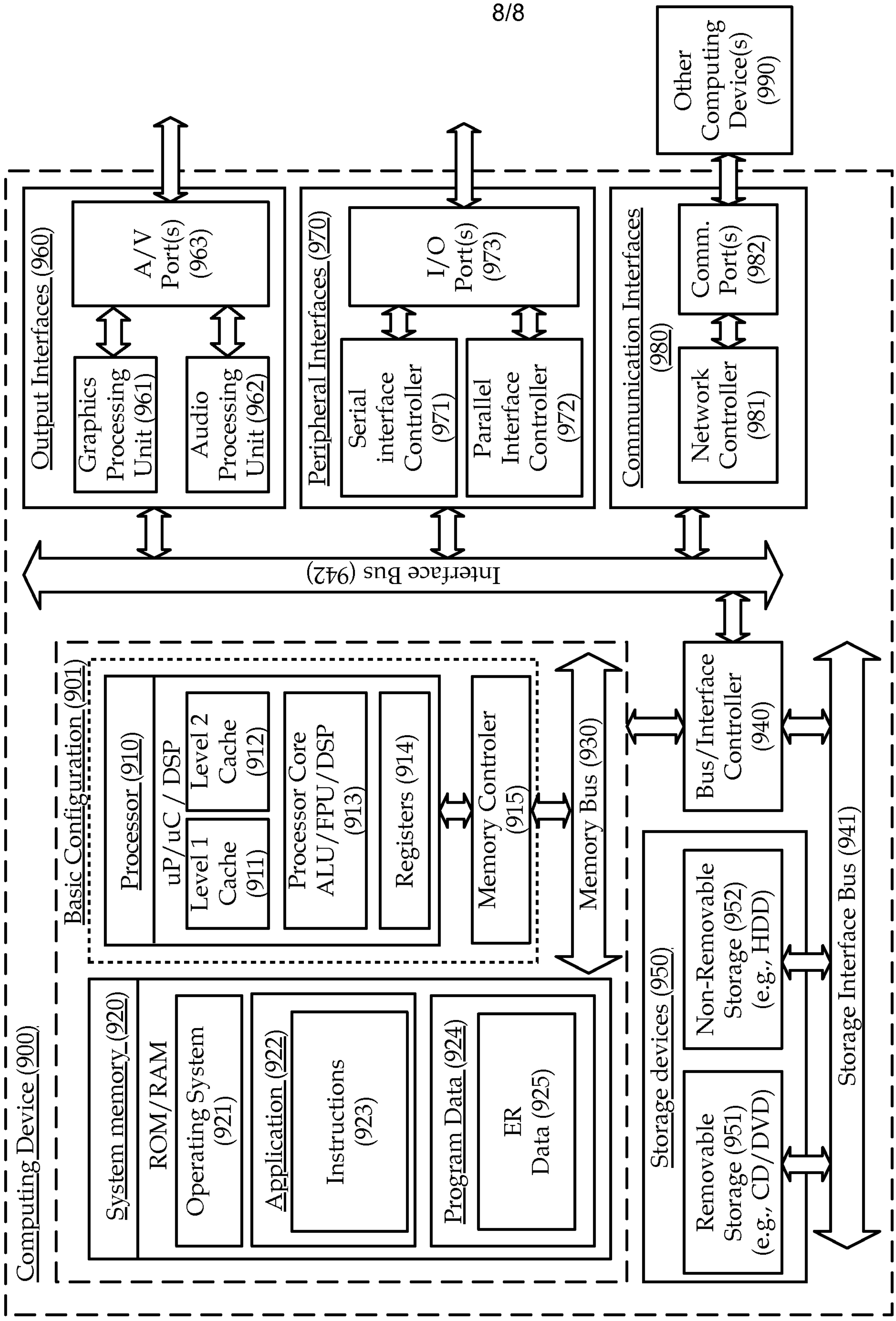

800 A computer program product.
802 A signal bearing medium.
804 at least one of
one or more instructions for providing surfactant material to a subsurface soil volume;
one or more instructions for acidifying the subsurface soil volume;
one or more instructions for providing surfactant material adjacent to at least one of a cathode electrode or an anode electrode, wherein the cathode electrode and the anode electrode are configured to facilitate permeation of the surfactant material within the subsurface soil volumel;
one or more instructions for causing the surfactant material to permeate at least a portion of the subsurface soil volume;
one or more instructions for providing acidifying material adjacent to at least one of the cathode electrode or the anode electrode; or
one or more instructions for causing the acidifying material to at least partially permeate the portion of the subsurface soil volume.
806 a computer-readable medium.
808 a recordable medium.
810 a communications medium.

FIG. 8



Computing Device (900)
Basic Configuration (901)
Processor (910)
uP/uC / DSP
Level 1 Cache (911)
Level 2 Cache (912)
Processor Core ALU/FPU/DSP (913)
Registers (914)
Memory Controler (915)
Memory Bus (930)
System memory (920)
ROM/RAM
Operating System (921)
Application (922)
Instructions (923)
Program Data (924)
ER Data (925)
Interface Bus (942)
Bus/Interface Controller (940)
Storage Interface Bus (941)
Storage devices (950)
Removable Storage (951) (e.g., CD/DVD)
Non-Removable Storage (952) (e.g., HDD)
Output Interfaces (960)
Graphics Processing Unit (961)
Audio Processing Unit (962)
A/V Port(s) (963)
Peripheral Interfaces (970)
Serial interface Controller (971)
Parallel Interface Controller (972)
I/O Port(s) (973)
Communication Interfaces (980)
Network Controller (981)
Comm. Port(s) (982)
Other Computing Device(s) (990)

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/058580

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

B09B 3/00 (2006.01) *B09C 1/02* (2006.01) *E02D 3/11* (2006.01)
B09C 1/00 (2006.01) *B09C 1/08* (2006.01) *E02D 31/00* (2006.01)

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)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI, EPODOC: B09B3/00/IC/EC OR B09C1/00/IC/EC OR B09C1/08/IC/EC OR B09C1/02/IC/EC OR E02D3/11/IC/EC OR E02D31/00/IC/EC; UNDER_GROUND OR BELOW_GROUND OR SUB_SURFAC+ OR GROUND OR SUB_TERRANEA+ OR BURIED; (SURFACTANT? OR ANIONIC OR CATIONIC OR LIPOSAN OR EMULSAN OR AMPHOTERIC OR BUFFER+ OR HPCD OR +BROMIDE OR POLYSILOXANE? OR +DEXTRIN+ OR +SORBAT+ OR +METHYL_AMMONIUM+ OR +SULPHONAT+ OR +SULFONAT+ OR +DODECYL+ OR +REHALOLIPID+ OR RHAMNOLIPID+ OR SOPHOROLIPID+ OR GLYCOLIPID+ OR GLYCO+ OR +GLYCERID+ OR +CELLULOS+ OR +ACRYLAMID+ OR +SILOXANE+)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6193867 B1 (HITCHENS 27 February 2001. See abstract; figures 1, 4, 5, and 7; column 1, lines 18- 63; column 2, line 50- column 5, line 18; example 1; column 7, lines 8- 38; column 8, lines 24- 27; column 9, lines 9- 36; column 10, lines 9- 25; and claims.	**1- 20**
X	US 5725752 A (SUNDERLAND et al.) 10 March 1998. See abstract; figures 1, 2 and 4; column 1, lines 4- 38; column 2, lines 19- 39; column 2, line 52- column 3, line 3; column 3, lines 9- 21 and 26- 54; column 3, line 59- column 4, line 16; column 4, lines 29- 32 and 63- 65; column 5, line 21- column 6, line 6; column 6, line 35- column 7, line 22; and claims.	**1- 5, 8- 10, 13- 17, 20**

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

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

Date of the actual completion of the international search	Date of mailing of the international search report
10 March 2011	15 MAR 2011

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaustralia.gov.au
Facsimile No. +61 2 6283 7999

Authorized officer
PETER ELLIS
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No : +61 (02) 6225 6106

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 5240570 A (CHANG et al.) 31 August 1993. See abstract; column 2, line 67- column 4, line 26; and claims.	
A	PATENT ABSTRACTS OF JAPAN, JP 09-047748 A (OHBAYASHI CORP. [JP]) 18 February 1997. See English language abstract. See whole abstract.	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2010/058580

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
US	6193867	US	6086739	US	6221224
US	5725752	EP	0724492	WO	9511095
US	5240570	NONE			
JP	9047748	NONE			

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX