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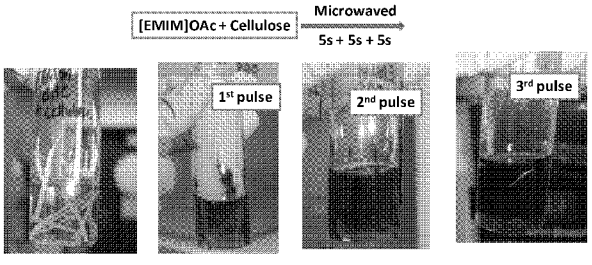


FIGURE 1

(57) Abstract: A subterranean formation penetrated by a wellbore is treated by introducing into the wellbore an encapsulated material comprising an encapsulating component formed from a regenerated ionic-liquid-dissolved compound and an active component that is encapsulated by the encapsulating component. The encapsulating material is then allowed to release the active component into the formation. In another treatment method, an encapsulated material comprising an encapsulating component and an active component that is encapsulated by the encapsulating component are introduced into the wellbore. The encapsulating component is degradable when subjected to electromagnetic radiation having a frequency of from about 300 MHz to about 300. The encapsulated material is then subjected to electromagnetic energy in the frequency range of from about 300 MHz to about 300 GHz to degrade the encapsulating component and facilitate the release the active component into the formation.

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# ENCAPSULATED MATERIALS AND THEIR USE IN OIL AND GAS WELLS

## FIELD OF THE INVENTION

**[0001]** This invention relates to compositions and methods for treating subterranean formations in oil and gas wells with encapsulated materials.

## BACKGROUND

**[0002]** The statements made in this section merely provide information related to the present disclosure and may not constitute prior art, and may describe some embodiments illustrating the invention.

**[0003]** Encapsulated materials have been used in the oil and gas well industry for the controlled or delayed release of materials downhole. Such materials employ the use of an encapsulating material that contains the active or useful material from being prematurely released. A variety of different materials and encapsulating techniques have been used. While encapsulated materials and their use are known, new and improved materials and methods related to encapsulated materials are desired.

## SUMMARY

**[0004]** A method of treating a subterranean formation penetrated by a wellbore is performed by introducing an encapsulated material into the wellbore. The encapsulated material is comprised of an encapsulating component formed from a regenerated ionic-liquid-dissolved compound and an active component that is encapsulated by the encapsulating component. The encapsulating material is allowed to release the active component into the formation.

**[0005]** In particular embodiments, the regenerated ionic-liquid-dissolved compound is a cellulose material. The encapsulated material may release the active component when subjecting the encapsulated material to electromagnetic energy. The encapsulated

material may further include a susceptor. The susceptor may be selected from at least one of a metal, graphite, and carbon-black.

**[0006]** In certain applications the active component may be selected from at least one of a breaker, an emulsifier, a cross-linking agent, an acid, a base, an oxidizer, an acid precursor, and a base precursor. The encapsulating material may release the active component into the formation when the encapsulated material is subjected to at least one of temperatures, mechanical forces, and degrading materials that facilitate degrading of the encapsulating component.

**[0007]** In another embodiment of the invention, method of treating a subterranean formation penetrated by a wellbore is performed by introducing an encapsulated material into the wellbore comprising an encapsulating component formed from a regenerated ionic-liquid-dissolved cellulose and an active component that is encapsulated by the encapsulating component. The encapsulating material is allowed to release the active component into the formation.

**[0008]** In certain embodiments of this invention, the encapsulated material releases the active component by subjecting the encapsulated material to electromagnetic energy. The encapsulated material may further comprises a susceptor, which may be selected from at least one of metal, graphite, and carbon-black. The active component may be selected from at least one of a breaker, an emulsifier, a cross-linking agent, an acid, a base, an oxidizer, an acid precursor, and a base precursor.

**[0009]** In allowing the encapsulating material to release the active component into the formation, this may include subjecting the encapsulated material to at least one of temperatures, mechanical forces, degrading materials sufficient to degrade the encapsulating component.

**[0010]** In still another embodiment of the invention, a method of treating a subterranean formation penetrated by a wellbore is performed by introducing an encapsulated material comprising an encapsulating component and an active component that is encapsulated by the encapsulating component into the wellbore. The encapsulating component is degradable when subjected to electromagnetic radiation having a frequency of from about 300 MHz to about 300 GHz. The encapsulated material is subjected to electromagnetic energy in the frequency range of from about 300 MHz to about 300 GHz to degrade the

encapsulating component and facilitate the release the active component into the formation.

**[0011]** In particular embodiments, the encapsulating component is formed from a regenerated ionic-liquid-dissolved compound. The regenerated ionic-liquid-dissolved compound may be a regenerated ionic-liquid-dissolved cellulose material. The encapsulated material may further comprise a susceptor, which may be selected from at least one of a metal, graphite, and carbon-black. The active component may be selected from at least one of a breaker, an emulsifier, a cross-linking agent, an acid, a base, an oxidizer, an acid precursor, a base precursor.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]** For a more complete understanding of embodiments of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying figures, in which:

**[0013]** FIGURE 1 shows a series of photos of cellulose filter paper strips in an ionic liquid after microwaving the mixture in three microwave pulses showing the degree of dissolution after each pulse;

**[0014]** FIGURE 2 shows photos of regenerated ionic-liquid-dissolved cellulose particles before and after microwaving in water: and

**[0015]** FIGURE 3 shows photos of examples of encapsulated PLA beads encapsulated with a regenerated ionic-liquid-dissolved cellulose encapsulating material before and after being microwaved in water.

## DETAILED DESCRIPTION

**[0016]** At the outset, it should be noted that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system related and business related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time consuming but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure. In addition, the composition used/disclosed herein can also

comprise some components other than those cited. In the summary of the invention and this detailed description, each numerical value should be read once as modified by the term "about" (unless already expressly so modified), and then read again as not so modified unless otherwise indicated in context. Also, in the summary of the invention and this detailed description, it should be understood that a concentration range listed or described as being useful, suitable, or the like, is intended that any and every concentration within the range, including the end points, is to be considered as having been stated. For example, "a range of from 1 to 10" is to be read as indicating each and every possible number along the continuum between about 1 and about 10. Thus, even if specific data points within the range, or even no data points within the range, are explicitly identified or refer to only a few specific, it is to be understood that inventors appreciate and understand that any and all data points within the range are to be considered to have been specified, and that inventors possessed knowledge of the entire range and all points within the range.

**[0017]** The encapsulated materials of embodiments of the invention are designed to enclose and/or protect their contents until they are at an intended site of delivery or until conditions of delivery are encountered. In this way, they can be used as a means to contain potentially hazardous or difficult-to-handle components and/or to deliver such components to a well bore or a surrounding subterranean formation to perform a desired function. The encapsulated materials also facilitate separating components of a downhole fluid where it is desired to have such components temporarily separated until they reach a desired location or until a desired amount of time has elapsed or conditions exists. Thereafter, the active component of the encapsulated material may be released so that the active component reacts or performs its particular function. As used herein, the term "active" with respect to the active component is merely used to indicate that it is the component that is desired to be released from the encapsulating component or material and it does not necessarily refer or relate to its reactivity, as some active component materials may be chemically inert or non-reactive in nature, but their separation or delayed release may still be desired for a particular use or purpose.

**[0018]** Ionic liquids (ILs) are used to form the encapsulated materials of the invention. Ionic liquids are salts with a melting temperature below 150 °C, more typically below

100 °C. The ionic liquids are made of ions and have many desirable properties. They are chemically and thermally stable, non-flammable, and have an immeasurably low vapor pressure. They may be available as solid and liquid forms at room temperature. Because the ionic liquids are formed from solely ionized species, they are highly responsive to electromagnetic radiation, such as microwave radiation. Exposure to such radiation at even very low levels or for short durations can rapidly heat the ionic liquids. They also exhibit unusual solvent properties for both polar and non-polar compounds. The ionic liquids can be used for water-sensitive processes and because of their low or non-existent vapor pressure, the ionic liquids may be an environmentally-friendly alternative for other organic solvents.

**[0019]** The ionic liquids are typically based on ammonium, imidazolium or pyridinium salts, although other salts exist. The ionic liquids can be soluble (hydrophilic) or insoluble (hydrophobic) in water. Non-limiting examples of hydrophilic ILs are those described in U.S. Patent No. 6,808,557, which is herein incorporated by reference in its entirety for all purposes. Non-limiting examples of hydrophobic ILs are those described in U.S. Patent No. 5,827,602, which is herein incorporated by reference in its entirety for all purposes. Specific non-limiting examples of hydrophilic ILs include 1-butyl-3-methylimidazolium chloride ([BMIM]Cl), 1-butyl-3-methlimidazolium acetate ([BMIM]OAc), 1-ethyl-3-methylimidazolium chloride ([EMIM]Cl) and 1-ethyl-3-methylimidazolium acetate ([EMIM]OAc). Specific non-limiting examples of hydrophobic ILs include 1-butyl-3-methylimidazolium bis(trifluoromethane sulonyl)imide ([BMIM][$CF_3SO_2$]$_2$N) and 1-butyl-3-methylimidazolium hexafluorophosphate (BMIM][$PF_6$]).

**[0020]** Due to the ionic liquid's properties as a solvent, various materials can be dissolved in the ionic solvents. Such dissolved compounds can then be used to form an encapsulating material. To dissolve the materials, the materials may be immersed or contacted with the ionic liquids. The ionic liquids may be heated, such as through microwaving or other heating means to facilitate dissolving of the contacted materials. Once dissolved, the formed solution may be used as an encapsulating material to encapsulate the active component. The active component may be a solid or liquid compound. Various encapsulating techniques may be used. Active component solids

may be coated with the IL solution to provide the encapsulation. Active component liquids may be dissolved in the solution itself or droplets of the liquid active component may be contacted with the solution. U.S. Patent No. 6,808,557 describes suitable encapsulation techniques.

**[0021]** By reducing the temperature of the dissolved encapsulating material, the encapsulating material with the ionic liquid hardens to form the encapsulating material, which now constitutes a regenerated ionic-liquid dissolved compound. The ionic liquid is also incorporated into the encapsulated material and may serve as a solvent to facilitate subsequent dissolving of the non-ionic-liquid encapsulating component for release of the active component. The active component itself may be at a reduced temperature prior to contacting with the dissolved encapsulating material to facilitate the hardening of the dissolved encapsulating material. Contacting the solution with a regenerating fluid or non-solvent diluent may also be used to regenerate the encapsulating material. The regenerating fluid or non-solvent diluent may be a non-solvent for the active component and encapsulating material. The regenerating fluid or non-solvent diluent may be miscible with the ionic liquid, however. Thus, contacting the IL phase of the dissolved encapsulating material induces the regeneration of the encapsulating material along with the active component that is encapsulated. Such techniques are described in U.S. Patent No. 6,808,557.

**[0022]** One particular type of materials that are particularly well suited for the encapsulating material are cellulose materials. Cellulose exhibits high solubility in ionic liquids. The cellulose materials may be any cellulose material that can be dissolved in the ionic liquids and that provides a suitable encapsulating material once regenerated. Non-limiting examples of suitable cellulose materials may include those from wood, cotton, grass, straw, hemp, etc., or other naturally occurring cellulosic materials. They may also include those made from viscose materials, such as cellophane, Rayon, etc. Combinations of different cellulose materials may also be used. The cellulose materials may be in a variety of initial forms including powder, fiber, sheets, paper, cloth, sponge, wood, straw, grass, etc. The cellulose materials can be dissolved in the ionic liquids, by heating or microwaving the ionic liquid to dissolve the cellulose material. For example, it has been found that when cellulose is added to [EMIM]OAc and heated with a series of

3 to 5 second microwave pulses, a clear cellulose solution can be obtained. The same solution can be obtained by merely heating without microwaves if the mixture is kept at 200 °F (93.3 °C) for several hours.

**[0023]** The cellulose may be used in varying amounts in the ionic liquids. As used herein, for ease of discussion, although specific reference is made to cellulose materials in the discussion that follows, it should be read to include other suitable encapsulating materials that may be dissolved in the ionic liquids and used in a similar manner to cellulose, unless otherwise stated or is otherwise apparent from the context. In certain embodiments, the cellulose may make up from about 5% to about 35% by weight of the cellulose/IL solution. More particularly, the cellulose may make up from about 5% to about 25% by weight of solution, and still more particularly from about 10% to about 25% by weight of the solution.

**[0024]** The active component may include a variety of different materials. These may include breakers, emulsifiers, gelling agents, cross-linking agents, acids, bases, oxidizers, etc., including any precursors of such materials that form the materials in situ, such as polylactic acid (PLA) or polyglycolic acid (PGA).

**[0025]** The amount of cellulose to the active component may also vary. In certain embodiments, the active component may be used in an amount of from about 1000:1 to about 1:2 by weight cellulose component to active component. In more particular embodiments, the active component makes up from bout 100:1 to about 1:1 by weight of cellulose component to active component. Similar weight ratios may also be reflected in the regenerated product.

**[0026]** The regenerated ionic-liquid-dissolved cellulose will contain or have incorporated into it the ionic liquid. The ionic may be trapped inside or coated with the cellulose material or otherwise be incorporated therein. Because the ionic liquid may form a part of the encapsulated material and due to its high responsiveness to electromagnetic radiation, it may tend to act as a susceptor that facilitates heating of the encapsulated particle when subjected to electromagnetic radiation or energy, such as microwaves. The heating of encapsulated material causes the encapsulating material to degrade, with the ionic liquid acting as a solvent for the cellulose, so that it causes the active component to thereby be released.

**[0027]** In certain embodiments, an additional susceptor material that facilitates heating of the encapsulated material when subjected to such radiation may be incorporated into the encapsulated material. Such materials may include various metals (iron, copper, aluminum, etc.), graphite, carbon black, etc. Combinations of such materials may also be used. Such materials may be used as particles that are dispersed or incorporated within the encapsulating material component or active component. In certain embodiments, they may be dispersed within the dissolved cellulose solution prior to regenerating the cellulose material. Examples of various susceptor materials and their use are described in U.S. Patent Application Publication No. US2008/0149335A1, which is herein incorporated by reference in its entirety for all purposes.

**[0028]** The encapsulated materials may be of different sizes and shapes. The particle size of the encapsulated materials may vary depending upon the components being used and their purpose and use. As an example, however, the particle size of the encapsulated materials may range from about 3mm to about 20mm. The configurations and shapes may also vary, such as spherical, oblong, oval, cylindrical, etc.

**[0029]** The encapsulated materials may be used in a treatment fluid that is introduced into a subterranean formation through a wellbore, such as those used in hydrocarbon production. The treatment fluid may be an aqueous fluid, such as fresh water, city water, river water, lake water, pond water, flow back water, produced water, re-used water, sea water, salt solutions or brines, although the treatment fluid may include other fluids, aqueous or non-aqueous.

**[0030]** The treatment fluid may include other components as well, which may or may not react or otherwise interact with the active component of the encapsulated material. The treatment fluids incorporating the encapsulating materials may have a variety of compositions, applications and uses. The treatment fluid may be a hydraulic fracturing fluid, an acid fracturing fluid, an acid diverting fluid, a matrix acidizing fluid, a sandstone acidizing fluid, a sand control treatment fluid, a wellbore consolidation treatment fluid, a cementing treatment fluid, a drilling fluid, a water control fluid, a remediation treatment fluid, or any other well treatment fluid where a chemical reaction or a chemical or physical process takes place that may utilize an encapsulated material.

**[0031]** In certain applications, the treatment fluid may include a viscosifying agent or agents, such as hydratable polymers or viscoelastic surfactants (VES). The treatment fluid may also contain other components, which may be encapsulated with the encapsulating materials of the invention or with other encapsulating materials. The other components may also be non-encapsulated. Non-limiting examples of materials and components that may be included with the treatment fluid include sand, fibers, proppant, crosslinkers, crosslinker activators, oxygen scavengers, crosslinker delaying agents, breakers, pH buffers, iron control agents, clay control agents, scale control additives, fine control additives, friction reducers, biocides, flow back additives, pH buffers, gas components, etc.

**[0032]** The amount of encapsulated material used in the treatment fluid will depend upon the treatment being performed, the amount of material for which the active component is to react or interact, etc.

**[0033]** The release of the active component from the encapsulated material can be achieved in a variety of ways. In certain embodiments, however, this is accomplished through the use of electromagnetic radiation. In particular, microwave radiation having a frequency of from about 300 MHz to about 300 GHz, more particularly from about 1GHz to about 100 GHz may be used. Generators of such radiation or microwaves can be provided downhole, such as on a drilling strings, cables, coiled tubing, etc. Examples of providing electromagnetic and microwave radiation downhole are described, for instance, in U.S. Patent No. 4,678,034; U.S. Patent Application Publication Nos. US2008/0149335A1 and US2010/0186955A1; and WO2009/143061A2, each of which is herein incorporated by reference in its entirety for all purposes. Thus, by locating the encapsulated materials (with or without additional susceptors) of the invention downhole within the subterranean formation at the desired location and time and subjecting the encapsulated material to electromagnetic energy, the encapsulating component can be degraded to facilitate the release of the active component into the formation. The electromagnetic radiation may be microwave radiation and may have a frequency of from about 300 MHz to about 300 GHz, more particularly from about 1GHz to about 100 GHz.

**[0034]** Alternative release mechanisms may also be employed. These may include merely subjecting the encapsulated materials to environmental temperatures where the encapsulating material will degrade. Physical crushing or mechanical breaking of the encapsulating material may also facilitate release of the active component, such as may occur during hydraulic fracturing. Chemical degradation of the encapsulating material may also be employed by introducing a chemical capable of degrading the encapsulating material either contemporaneously with the encapsulating material within the treatment fluid or prior or subsequent to its introduction. Enzymes may be used as one particular type of degrading compound that may be employed with the cellulose encapsulating materials. The enzymes may be cellulases, which may be cellulases themselves, hemi-cellulases, endo-cellulases or exo-cellulases. The enzymes may also be proteases. Combinations of different enzymes may also be used. The enzymes may be used in an amount to facilitate degrading of the encapsulating material. Combinations of all of the above-described release mechanisms may also be employed with the encapsulated materials.

**[0035]** The following examples serve to further illustrate the invention.

## EXAMPLES

### Examples 1

**[0036]** Strips of cellulose cotton filter paper, available from Whatman, Inc., Piscataway, New Jersey, were placed in a beaker of [EMIM]OAc as the ionic liquid. The mixture was placed in a microwave oven and subjected to three 5-second pulses of microwaves. After the third pulse, the cellulose material had substantially dissolved. Figure 1 shows the degree of dissolution of the cellulose strips after each microwave pulse.

### Examples 2

**[0037]** Cellulose powder was dissolved in [EMIM]OAc ionic liquid in a beaker by mixing the powder in the IL with a spatula and subjecting the mixture to three microwave pulses of 5 seconds, 3 seconds and 3 seconds, respectively. After the third microwave pulse the cellulose was substantially dissolved in the ionic liquid.

**[0038]** The liquid cellulose/IL solution was then added dropwise with a syringe to cold deionized water. As soon as the droplets contacted the water, the droplets hardened immediately with the IL coated or entrapped within the cellulosic membrane.

**[0039]** With the regenerated cellulose particles immersed in water, the water containing the immersed particles was microwaved. The cellulose particles released the entrapped IL, indicating that the IL incorporated with the cellulose particles had re-dissolved the cellulose. Figure 2 shows the cellulose particles before and after microwaving in water.

**Examples 3**

**[0040]** Using a cellulose/IL solution as prepared in Example 2, beads of polylactic acid (PLA) were suspended in the solution. The beads were then removed from the solution and immersed in cold water, thus forming PLA beads encapsulated in the regenerated cellulose. The encapsulated PLA materials were then microwaved in water. The cellulose encapsulating material dissolved in the water leaving the released PLA beads remaining undissolved in the water. Figure 3 shows the encapsulated PLA beads before and after being microwaved in water.

**[0041]** While the invention has been shown in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes and modifications without departing from the scope of the invention. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

## CLAIMS

I claim:

1. A method of treating a subterranean formation penetrated by a wellbore, comprising:

introducing into the wellbore an encapsulated material comprising an encapsulating component formed from a regenerated ionic-liquid-dissolved compound and an active component that is encapsulated by the encapsulating component; and

allowing the encapsulating material to release the active component into the formation.

2. The method of claim 1, wherein:

the regenerated ionic-liquid-dissolved compound is a cellulose material.

3. The method of claim 1, wherein:

allowing the encapsulated material to release the active component includes subjecting the encapsulated material to electromagnetic energy.

4. The method of claim 1, wherein:

the encapsulated material further comprises a susceptor.

5. The method of claim 4, wherein:

the susceptor is selected from at least one of a metal, graphite, and carbon-black.

6. The method of claim 1, wherein:

the active component is selected from at least one of a breaker, an emulsifier, a cross-linking agent, an acid, a base, an oxidizer, an acid precursor, and a base precursor.

7. The method of claim 1, wherein:

allowing the encapsulating material to release the active component into the formation includes subjecting the encapsulated material to at least one of temperatures, mechanical forces, and degrading materials that facilitate degrading of the encapsulating component.

8. A method of treating a subterranean formation penetrated by a wellbore, the method comprising:

introducing into the wellbore an encapsulated material comprising an encapsulating component formed from a regenerated ionic-liquid-dissolved cellulose and an active component that is encapsulated by the encapsulating component; and

allowing the encapsulating material to release the active component into the formation.

9. The method of claim 8, wherein:

allowing the encapsulated material to release the active component includes subjecting the encapsulated material to electromagnetic energy.

10. The method of claim 8, wherein:

the encapsulated material further comprises a susceptor.

11. The method of claim 10, wherein:

the susceptor is selected from at least one of a metal, graphite, and carbon-black.

12. The method of claim 8, wherein:

the active component is selected from at least one of a breaker, an emulsifier, a cross-linking agent, an acid, a base, an oxidizer, an acid precursor, and a base precursor.

13. The method of claim 8, wherein:

allowing the encapsulating material to release the active component into the formation includes subjecting the encapsulated material to at least one of temperatures, mechanical forces, degrading materials sufficient to degrade the encapsulating component.

14. A method of treating a subterranean formation penetrated by a wellbore, the method comprising:

introducing into the wellbore an encapsulated material comprising an encapsulating component and an active component that is encapsulated by the encapsulating component, the encapsulating component being degradable when subjected to electromagnetic radiation having a frequency of from about 300 MHz to about 300 GHz; and then

subjecting the encapsulated material to electromagnetic energy in the frequency range of from about 300 MHz to about 300 GHz to degrade the encapsulating component and facilitate the release the active component into the formation.

15. The method of claim 14, wherein:

the encapsulating component is formed from a regenerated ionic-liquid-dissolved compound.

16. The method of claim 15, wherein:

the regenerated ionic-liquid-dissolved compound is a regenerated ionic-liquid-dissolved cellulose material.

17. The method of claim 14, wherein:

the encapsulated material further comprises a susceptor.

18. The method of claim 17, wherein:

the susceptor is selected from at least one of a metal, graphite, and carbon-black.

19. The method of claim 14, wherein:

the active component is selected from at least one of a breaker, an emulsifier, a cross-linking agent, an acid, a base, an oxidizer, an acid precursor, a base precursor.

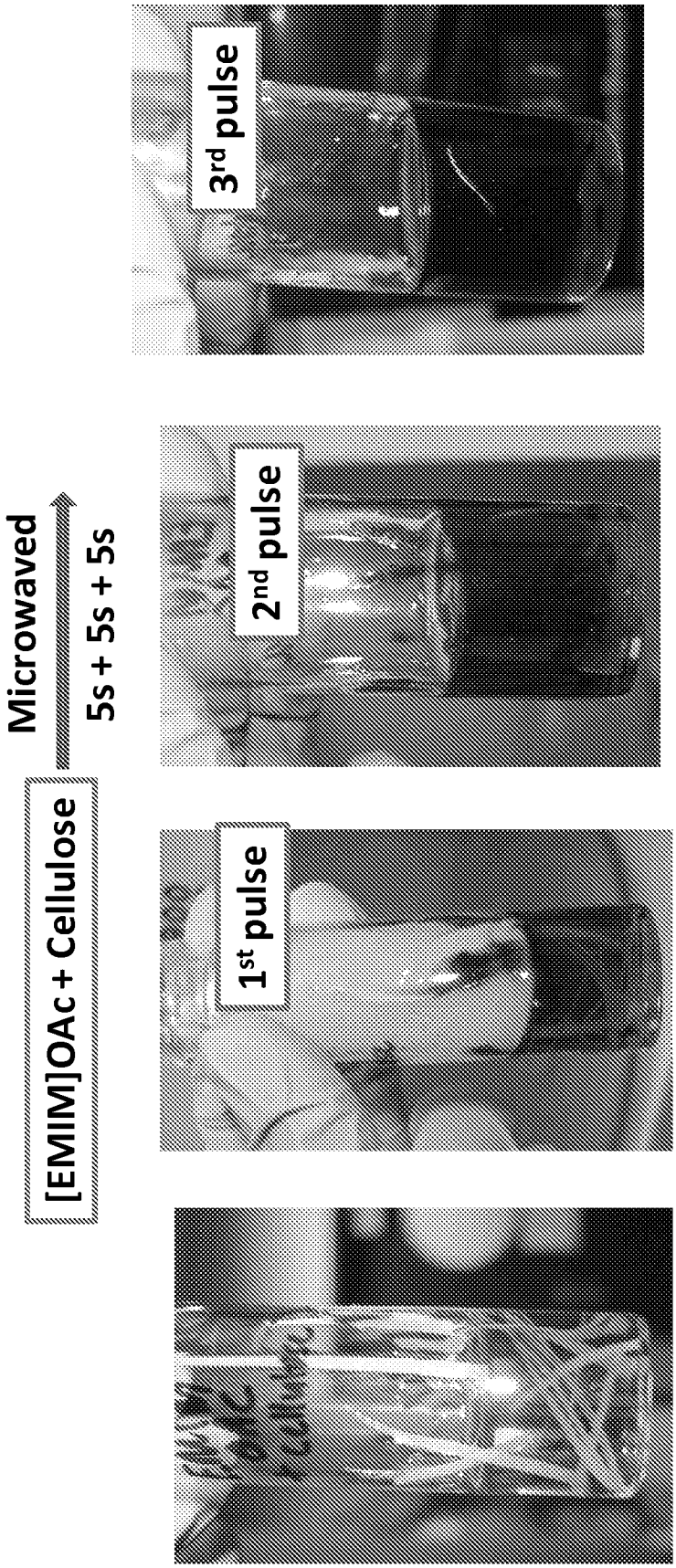
[EMIM]OAc + Cellulose
Microwaved
5s + 5s + 5s
1st pulse
2nd pulse
3rd pulse

FIGURE 1

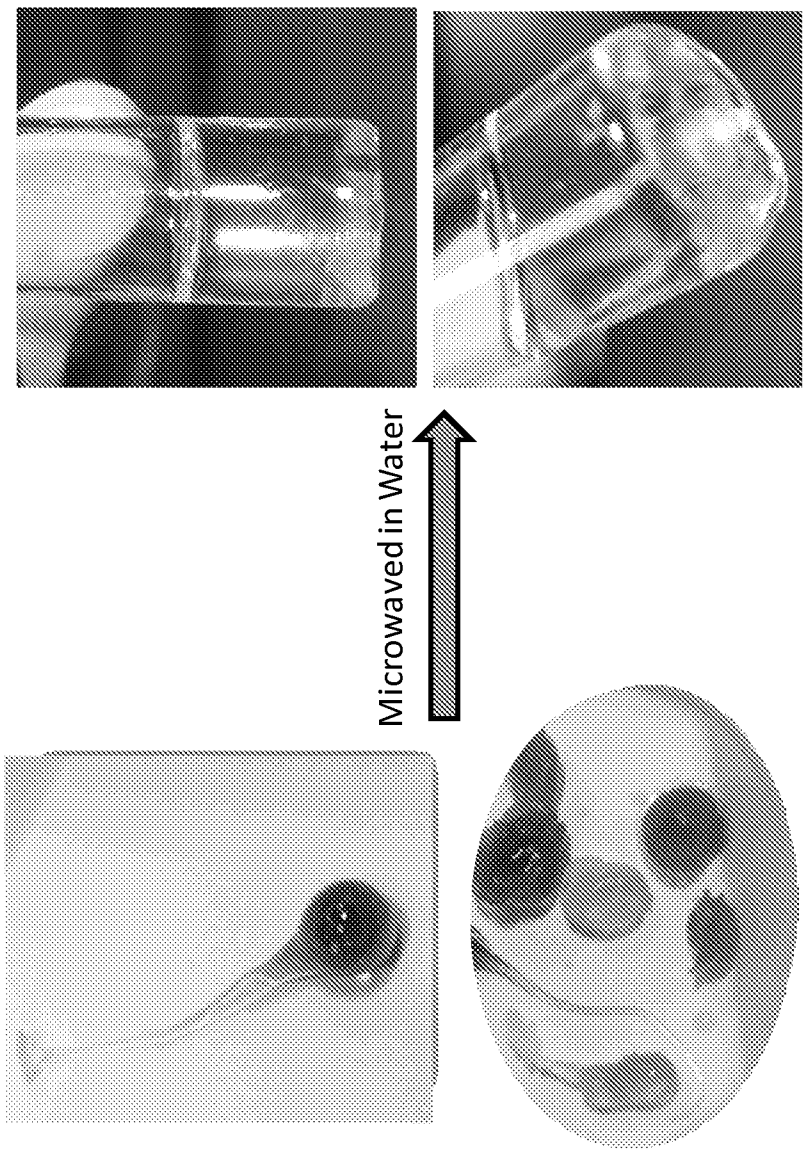


FIGURE 2

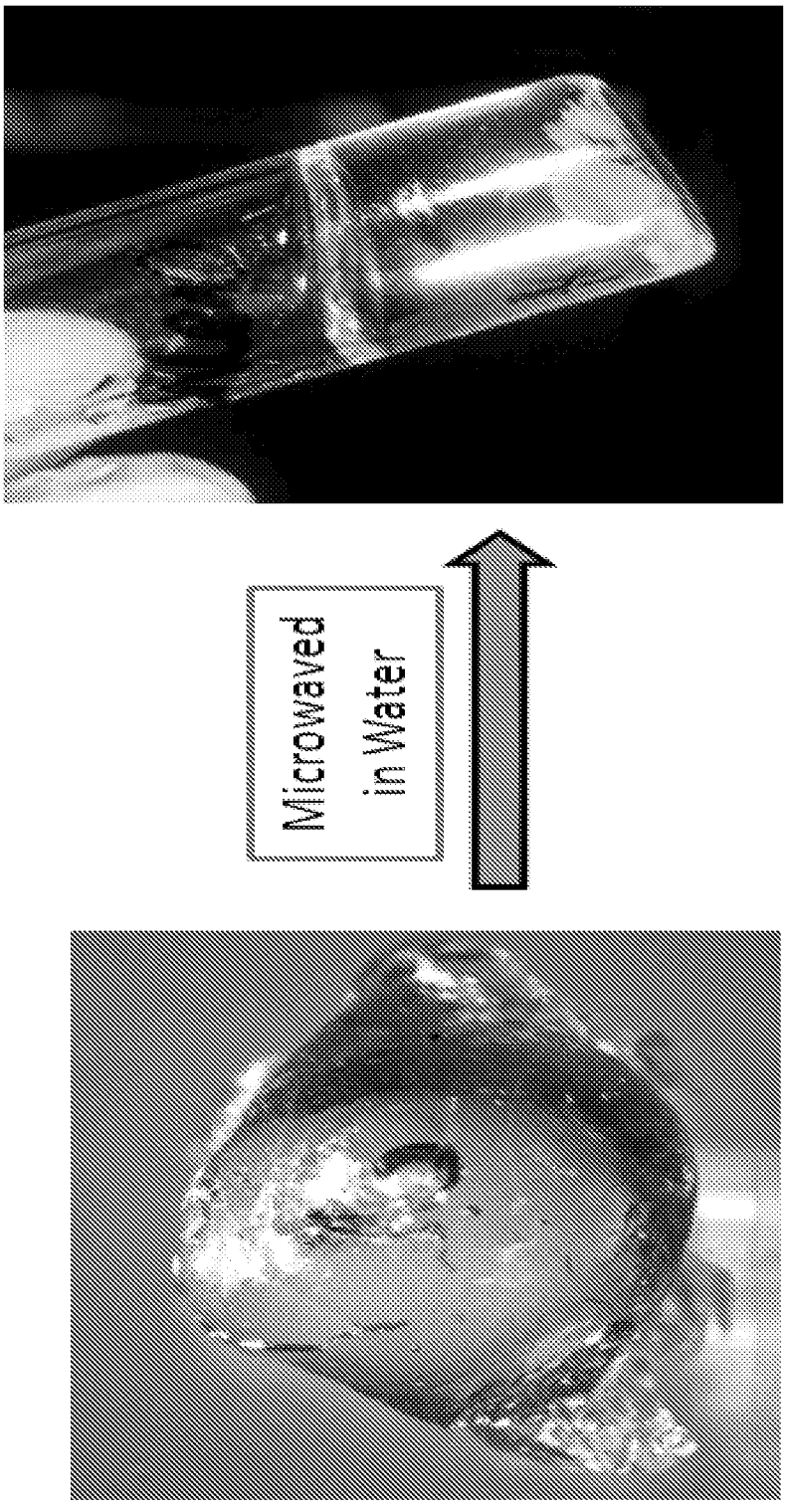


FIGURE 3

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/US 2012/043020

A. CLASSIFICATION OF SUBJECT MATTER ***E21B 43/22*** *(2006.01)*
***C09K 8/92*** *(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)

C09K 8/00-8/94, E21B 21/00-21/14, 33/00-33/138, 43/00-43/32

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)

PatSearch (RUPTO internal), Esp@cenet, PAJ, USPTO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2008/0149335 A1 (JESSE LEE) 26.06.2008, par. [0007], [0016], [0024], [0028], [0030]-[0032], [0038], [0040], [0044], [0045], [0050] | 1-19 |
| Y | US 2009/0044942 A1 (BJ SERVICES COMPANY) 19.02.2009, par. [0002], [0011], [0017], [0019], [0031], [0032], [0062], [0068], [0069] | 1-19 |
| A | US 4919209 A (DOWELL SCHLUMBERGER INCORPORATED) 24.04.1990, col. 1, lines 5-10, col. 3, lines 45-50, claim 2 | 1-19 |
| A | CA 1221822 A (GRANTED TO AMOCO CORPORATION) 19.05.1987, abstract | 1-19 |
| A | US 2002/0055439 A1 (BENTLEY J. PALMER et al.) 09.05.2002, par. [0007], [0023], [0033] | 1-19 |

☐ Further documents are listed in the continuation of Box C. ☐ 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 document 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 |
|---|---|
| 23 August 2012 (23.08.2012) | 20 September 2012 (20.09.2012) |
| Name and mailing address of the ISA/ FIPS<br>Russia, 123995, Moscow, G-59, GSP-5,<br>Berezhkovskaya nab., 30-1<br><br>Facsimile No. +7 (499) 243-33-37 | Authorized officer<br>T. Melnikova<br><br>Telephone No. 499-240-25-91 |

Form PCT/ISA/210 (second sheet) (July 2009)

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/US 2012/043020

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Two claimed groups of inventions (claims 1, 8, and 14) have no the same or respective special technical features.

The special technical feature of group I (claims 1 and 8) is using a regenerated ionic-liquid-dissolved compound.

The special technical feature of group II (claim 14) is degrading of the encapsulating component when subjected to electromagnetic radiation having a frequency of from about 300 MHz to about 300 GHz.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.