Title: A SOLVENT-ACTIVATED REACTOR

High product(s) yield

Products Diffuse

(57) Abstract: A reactor for an in-situ production of a chemical product in high yield are presented. The reactor, which may be placed in a main solvent, includes a core and a reactor wall around the core. The reactor wall allows controlled permeation of the main solvent to the core. The core contains a reactant that reacts to produce a target product upon being contacted by a main solvent.

The target product leaves the reactor at a controlled rate. Because the amount of the main solvent that permeates into the reactor is controlled, a high concentration of the reactant is maintained inside the reactor, resulting in a higher yield of the desired chemical product than if the reactants were directly added to the body of main solvent.
A SOLVENT-ACTIVATED REACTOR

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RELATED APPLICATION

This patent application claims the benefit, under 35 U.S.C. § 119(e), of U.S. Provisional Application Serial No. 60/588,442 filed on July 16, 2004, the content of which is incorporated herein by reference.

FIELD OF INVENTION

This invention relates generally to an oxidizing compound and more particularly to an oxidizing compound that is stabilized for storage.

BACKGROUND

Oxidizers are commonly used to effectively destroy organic and inorganic contaminants. Some of the typical applications of oxidizers include treatment of water systems and inactivation of bacteria and viruses in various media.

Although oxidizers are used in numerous applications, there are also applications where they are not used even though their utility is well established. The reason these oxidizers are not used often relates to their instability during storage. Oxidizers such as hypochlorous acid and peracids, for example, could be used in more applications than the disinfection applications that they are already used in if their stability can be improved. The problem with some of these powerful oxidizers such as hypochlorous acid and peracids is that their activity level tends to decrease during storage. Since the effectiveness of the oxidizers in various applications depends on their concentrations, activity levels, and the level of demand on the oxidizer as measured by its oxidation reduction potential (ORP), a reduction in the activity level of the oxidizers impedes their performance in the various applications. Thus, even if an oxidizer is initially highly effective, the effectiveness decreases during storage.
A few methods are currently used to get around this storage problem. One of these methods, which is the point-of-use generation method or the in-situ method, is desirable because it eliminates the need for prolonged storage. However, on a practical level, these point-of-use generation methods are not widely employed because they require expensive equipment and specialized expertise. Other in-situ generation methods involve adding the reagents to the water to produce the target product. However, when doing this, significant dilution of reagents as well as competing reactions impede the level of conversion to the target product.

Sometimes, the reagents are coated to provide a barrier between the reagents and the environmental elements, thereby making the reagents easier to store and use in formulations. The coatings are designed so that when they are combined with water, they dissolve and rapidly release the reagents. Silicates, for example, are widely used in laundry detergent applications. In the alkaline condition induced by the laundry formulation, the silicate coating rapidly dissociates and releases the encased additives into the bulk water. There are also instances where a highly hydrophobic coating such as a wax or slow-dissolving coating is used for time-release purposes. These cases operate on the basis of a mechanism similar to the mechanism of the silicate coating in that the outer coating material quickly dissolves to expose the enclosed material to the solvent in the environment, at which point chemical reaction starts.

Various bleaching and oxidizing compositions have been made to enhance the performance in an application. Such enhancement is desirable because the generally effective hydrogen peroxide donors such as percarbonate, perborate, and persulfate-based additives do not remove stubborn stains from clothing. To enhance their bleaching ability under the conditions that are typical to the application (e.g., laundry water), precursors are added to induce formation of a more effective bleaching agents (e.g., tetraacetyl-ethylenediamine (TAED)) in-situ. However, this addition of bleaching agent precursors has its disadvantages. For example, high concentrations of additives are needed to achieve effective results, increasing both the cost and inconvenience.

Another way of enhancing peroxygen compounds’ performance is to make them more stable, thus allowing long-term storage. Sometimes, the peroxygen compounds and the formulations they are used in are coated to enhance storage stability. These coatings,
however, do not always dissolve quickly and therefore increase the time it takes for the peroxoxygen compound to become effective. One of the ways to allow long-term storage of oxidizers such as potassium monopersulfate and chlorine is to store them in packages or bags. The packages or bags are designed to dissolve in water, so that they can be directly thrown into a body of water. Although the use of bags provides for easy application in large scale or macro applications, their utility is limited in that they can be used only for applications of a certain scale.

A method of stabilizing reactive components for storage without compromising or limiting their performance during usage is desired.

SUMMARY

In one aspect, the invention is a reactor that generates a target product when placed in contact with a main solvent. The reactor includes a reactor wall forming a reactor space, and a core in the reactor space. The reactor wall allows a controlled permeation of the main solvent into the reactor space. The core includes a reactant that, upon contacting the main solvent, starts a chemical reaction in the reactor space to generate the target product. The reactor wall allows the target product to leave the reactor space at a predetermined rate, thus releasing the target product into the main solvent.

In another aspect, the invention is a method of making a reactor that generates a target product when placed in contact with a main solvent. The method entails preparing a core containing a reactant and forming a reactor wall around the core. The reactant, upon contacting the main solvent, generates the target product through a chemical reaction. The reactor wall allows a controlled permeation of the main solvent into the reactor space where the chemical reaction occurs. The target product leaves the reactor space at a predetermined rate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGs. 1A, 1B, and 1C are schematic illustrations of the reactor wall during a reaction.
FIGs. 2A, 2B, 2C, and 2D show different stages of a reactor undergoing a reaction.

FIG. 3 is a schematic illustration that the reactor of the invention may be used to form various target products.

FIGs. 4A, 4B, 4C, 4D, 4E, and 4F show a micro-reactor for generation of multiple target products under acid catalyzed conditions.

FIGs. 5A and 5B illustrate a micro-reactor for generation of multiple target products under neutral to alkaline pH using stable polyester membrane reactor coating.

FIG. 6 shows the stability of PMPS in various alcohols which can be used to form suspensions or binders for formation of the core.

FIG. 7 shows the increase in viscosity provided by Carbopol® used to alter the rheology of the solution.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The invention is particularly applicable to generation and release of oxidizers that have bleaching, biocidal, or virucidal properties and it is in this context that the invention will be described. It will be appreciated, however, that the reactor, the method of making the reactor, and the method of using the reactor in accordance with the invention has greater utility and may be used for any other target product(s). Although the main solvent is described as water for clarity of illustration, the invention is not so limited.

“Reactor space” is a space that is defined by the outline of a reactor, and includes the space surrounded by the reactor wall, the reactor wall itself, and any pores or channels in the reactor wall. A “main solvent,” which is described as water in this disclosure although it is not so limited, may be any solvent that dissolves the reactant(s) in the core. A “non-solvent” is a carrier and void producing volatile liquid in which the polymer or coating material used in forming the reactor wall is insoluble. The term is also used to describe a liquid in which the oxidizer and/or oxidizable substance is insoluble. A solvent and a non-solvent that are used together are miscible.

“Amphipathic” is intended to mean that a molecule has a polar and a nonpolar domain.

A “polymer,” as used herein, includes a copolymer.
A “critical level” is a predetermined amount of the target product that is generated by the chemical reaction in the reactor. The critical level may be, but does not have to be, defined by pH level. When the reactor wall “disintegrates,” it could collapse due to a pressure difference between the inside and the outside of the reactor, dissolve in the main solvent, or come apart and dissipate due to forces applied by the movement in the main solvent. A membrane is a solid porous material. A plasticizer is a compound that alters the pliability and/or the hygroscopicity of the polymer. A “surrogate” describes the various acid, salt, and derivative forms of a particular compound. “Water,” as used herein, is not limited to pure water but can be an aqueous solution.

To maximize the yield in a chemical reaction, it is usually preferable to start with high concentrations of reactants because the molar concentrations of the reactants determine the rate of reaction and the subsequent product yield. Therefore, adding reactants to a large body of water to be treated is not an effective way to generate the desired product in-situ. Adding the reactants to the water lowers the reactant concentrations, and the resulting conversion of the reactants to the desired product(s) is generally poor. Another factor to be considered is the side reactions. When generating an agent in-situ, the oxidizer reactant is often consumed in reactions other than those desired for the in-situ production of the target product. Therefore, adding the reactants to the water to be treated results in more reagent requirements, longer reaction time, and/or an overall decreased yield of the target product.

Furthermore, the chemical environment, such as pH, can adversely affect the in-situ production of the target product. For example, reactions that are acid catalyzed are not supported in alkaline conditions such as laundry wash water. By isolating the reactants and controlling the conditions inside the reactor, efficient generation of the target product(s) occurs regardless of the conditions external to the reactor.

When an oxidizer, such as potassium monopersulfate (PMPS), is added to water to convert sodium chloride to hypochlorous acid through a hypohalite reaction, the conversion or yield is dependent on the molar concentrations of the reactants. As described above, however, adding a given amount of reactants to a large volume of water yields poor conversion to the target product. Furthermore, potassium monopersulfate is highly reactive with organic chemical oxygen demand (COD). Thus, upon being exposed
to the bulk solution, the PMPS reacts with the COD and further reduces the concentration of PMPS that is available to induce the hypohalite reaction.

The invention is based on the concept that a high yield can be maintained by controlling the rate at which the reactants are exposed to water. More specifically, if the reactants were first exposed to a small volume of water and allowed to react to generate the target product, a high yield of the target product can be obtained because the reactant concentrations will be high. Then, the target product can be exposed to a larger volume of water without compromising the yield. The rate at which the reactants are exposed to water has to be such that the target product is generated in high-yield before more water dilutes the reactants. The invention controls the reactants’ exposure to water by coating the reactants with a material that allows water to seep in and reach the reactants at a controlled rate.

Depending on the embodiment, the invention may be a reactor that is stable enough for storage and useful for generating high yields of products in-situ, product including oxidizers, biocides, and/or virucidal agents. A “soluble reactor” has walls that dissolve in the main solvent after the reaction has progressed beyond a certain point such that the concentration of the target product is equal to or greater than a predetermined critical level. The soluble reactor is stable when dry. When mixed with a main solvent (e.g., water), however, the coating material that forms the outer wall of the soluble reactor allows the solvent to slowly seep into the inside of the reactor and react with the core. The core of the soluble reactor contains one or more reactants that, when combined with the main solvent, react to generate a target product. Since the concentrations of the reactants are high within the soluble reactor, a high yield of the target product is achieved inside the reactor. After the generated amount of the target product reaches a critical level, the coating material dissolves or dissipates, releasing the target product into the bulk solvent body.

In some embodiments, the reactor of the invention is a “micro-reactor” having a diameter or width in the range of 10 – 2000 μm. However, the reactor is not limited to any size range. For example, the reactor may be large enough to be referred to as a pouch. A single reactor may be both a micro-reactor and a soluble reactor at the same time. Furthermore, a reactor may have a soluble wall and a non-soluble wall.
The reactor of the invention includes a core and a reactor wall surrounding the core. There may be additional layers, such as a protective layer for shielding the core from the environmental elements. The core contains an oxidizer reactant, an oxidizable reactant, or both. The reactor wall has a lower solubility than the reactants in the core or the target product that is produced in the reactor. The reactor wall controls the diffusion of water into the reactor and restricts the diffusion of reaction components out of the reactor. The rate at which water seeps into the reactor and the rate at which the target product leaves the reactor are controlled through the porosity of the reactor wall.

The invention includes a method of preparing a reactor, wherein the reactor produces high concentrations of one or more target products that are different from the reactants enclosed in the reactor. The method of the invention allows the production of compositions that are stable for storage and, upon activation by contact with the solvent, produce a different composition in a high yield. It is the intent of the disclosure to illustrate exemplary methods of use for the various compositions.

FIGs. 1A, 1B, and 1C are schematic illustrations of the reactor wall 10 of a reactor 100 during a reaction. As shown in FIG. 1A, the reactor wall 10 is initially substantially solid, forming an reactor space 12 where reactants (not shown) can be placed. When the reactor wall 10 encounters water, it slowly forms cracks or fissures 14 in the reactor wall 10, as shown in FIG. 1B. The water seeps into the reactor 100 through the fissures 14, dissolves at least some of the reactants in the reactor space 12, and triggers a chemical reaction. Aside from the fissures 14, the reactor wall 10 remains substantially intact while the reactants react inside the reactor space 12 to generate the target product. However, once the reaction progresses to a critical level, the reactor wall 10 dissolves, as illustrated in FIG. 1C by the thinning of the reactor wall 10. The reactor wall 10 eventually dissipates into the water, releasing the target product into the body of water.

Details about the composition of the reactor wall 10 are provided below.

One way to control the timing of the disintegration of the reactor wall is to select a reactor wall 10 whose solubility is a function of pH. In this case, the critical level is a certain pH level where the reactor wall 10 becomes soluble. If the solubility of the reactor wall 10 is impaired by the pH of the internal and/or the external solution, and the
pH of the internal solution changes as the reaction in the reactor space 12 progresses, the reactor wall 10 will not become soluble until a certain pH is reached in the reactor (i.e., the reaction has progressed to a certain point). The reactions may occur in the reactor space 12 or along the inner surfaces of the reactor wall 10.

FIGs. 2A, 2B, 2C, and 2D show different stages of the reactor 100 undergoing a reaction. The reactor 100 has a core 20 in the reactor space 12. When in storage, the reactor wall 10 is intact and protects the core 20 from various environmental elements, as shown in FIG. 2A. When the reactor 100 is placed in the liquid to be treated, the reactor wall 10 begins to form the fissures 14 and the core 20 begins to dissolve, as shown in FIG. 2B. When dissolved, the components that form the core 20 become reactive and a chemical reaction begins. Since the amount of the water that permeates into the reactor space 12 is small, the components that form the core 20 (i.e., the reactants) remain high in concentration. As the chemical reaction progresses, the reactant concentration decreases, as shown by the decreasing size of the core 20 in FIG. 2C. When the concentration of the desired target product becomes high, the reactor wall 10 begins to disintegrate and the target product diffuses out of the reactor wall 10 into the water outside the reactor, as shown in FIG. 2D.

The reactant in the core may contain an oxidizing agent, such as a peroxygen compound. The peroxygen compound may be, for example, monopersulfate, percarbonate, perborate, peroxyphthalate, sodium peroxyde, calcium peroxyde, magnesium peroxyde, or urea peroxyde. As for the "oxidizable reactant," which may also be present in the core, it usually reacts with the oxidizer reactant to produce one or more target products. The target products may include an oxidizer that is different from the oxidizer reactant. In some embodiments, the oxidizable reactant is a catalyst that is not consumed during its reaction with the oxidizer reactant. However, in some other embodiments, the oxidizable reactant is altered and consumed by the reaction with the oxidizer reactant.

FIG. 3 is a schematic illustration that the reactor 100 may be used with any suitable reactions including but not limited to reactions that produce hypohalite, haloimide, dioxirane, hydroxyl radicals, percarboxylic acids, or chlorine dioxide. The reactor is useful for producing one or more of hypochlorous acid, hypochlorite, chlorine
gas, hypobromous acid, hypobromite, bromine gas, N-halo-succinimide, N-halo-
sulfamate, N-bromo-sulfamate, dichloro-isocyanuric acid, trichloro-isocyanuric acid, 5,5
dihalo dialkyl hydantoin, Hydroxyl radicals, oxygen radicals, peracids, and chlorine
dioxide, and releasing the product into a body of water.

REACTOR CORE

1) Reactants

Reactants are selected to induce the formation of the desired product(s). When
determining the ratio of reactants, consideration should be given to the desired ratio of
products. Single species generation of agent is achieved with proper optimization of
reagent ratios.

High conversion of reactants and good stability of products is achieved by adding
stabilizers and/or pH buffering agents to the mixture of reactants. For example, to
produce N-haloimides such as N-chlorosuccinimide, N-succinimide is added to a mixture
containing PMPS and NaCl. Also, an organic acid (e.g., succinic acid) and/or inorganic
acids (e.g., monosodium phosphate) may be applied to ensure that the pH of the reactant
solution is within the desired range for maximum conversion to the haloimide.

The core includes reactants that, upon dissolution, induce the in-situ generation of
the desired target product(s). For example, where the desired target product is a
bleaching/oxidation agent, the reactant may be a peroxyn compound such as a
persulfate, inorganic peroxide, alkyl peroxide, and aryl peroxide. The core can be formed
into any useful size and shape, including but not limited to a granule, nugget, wafer, disc,
briquette, or puck. While the reactor is generally small in size (which is why it is also
referred to as the micro-reactor), it is not limited to any size range.

2) Binders

Binders are compounds that are used to combine the components in the core and
hold them together, at least until they are coated, to provide a homogenous mixture of
reactants throughout the core. Binders may not be necessary in some embodiments.

Many different types of compounds can be used as binders including polymers with
hydrophobic and/or hydrophilic properties (e.g. polyoxyethylene alcohol, fatty acid
esters, polyvinyl alcohol, fatty acids (e.g. myristic acid), alcohols (myristic alcohol), and polysaccharides such as chitosan, chitin, hydroxypropyl cellulose, hydroxypropyl methylcellulose and the like. The function of the binder is to provide an agglomerating effect without adding an undesirable amount of moisture so as to cause the reactants to dissociate and start reacting. In cases where solvent recovery apparatus is available during manufacturing, binder solvents can be used to promote better distribution of the binder as long as the solubility of the reactants in the binder solvent is low.

The binder may be a rheology-altering polymer/copolymer such as Carbopol® sold by BFGoodrich that is a family of polymer/copolymers comprised of high molecular weight homo- and copolymers of acrylic acid crosslinked with a polyalkenyl polyether. Rheology-altering polymers allow a wide range of core components to be combined by incorporating a non-solvent in the core. Either the oxidizer reactant or the oxidizable reactant is insoluble in the non-solvent. The presence of the non-solvent prevents activation of the components in the core, whereby the rheology-altering component binds the core components to provide a homogenous mixture. Depending on the embodiment, the non-solvent may become a part of the final composition, be partially removed, or be removed altogether. Since the non-solvent is usually not water, the final product may contain volatiles although it is substantially free of water (moisture). Sometimes, moisture may be used to enhance the formation of the agglomerate. However, in such cases, at least the oxidizer reactant should be coated to prevent its dissociation, the moisture should be well-distributed and used sparingly, and any moisture should be completely removed before long-term storage.

3) **Fillers**

Fillers can be used or altogether omitted depending on the type of processing and the requirements of the use of the final product. Fillers are typically inorganic compounds such as various metal alkali salts and oxides, zeolites and the like. The fillers can enhance distribution of moisture when water is employed to enhance agglomeration.

4) **pH Buffers**
A pH buffer, which is an optional component of the core, provides a source of pH control within the reactor. Even when alkaline water from laundry wash is used to dissolve the core, the pH buffers provide effective adjustment and control of the pH within the desired range to induce the desired reactions inside the reactor. PH buffers can be inorganic (e.g. sodium bisulfate, sodium pyrosulfate, mono-, di-, tri- sodium phosphate, polyphosphates, sodium bicarbonate, sodium carbonate, boric acid and the like). Organic buffers are generally organic acids with 1-10 carbons such as succinic acid.

5) Stabilizers

Stabilizers are added when N-hydrogen donors are applied to generate N-haloimides in-situ. Examples of stabilizers include but are not limited to N-succinimide, N-sulfamate, isocyanuric acid, and the like. When stabilization is not required to generate these compounds, they can be omitted.

6) Examples

Where the target product is dioxirane, the oxidizer reactant is one of potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, and a Caro’s acid precursor. The Caro’s acid precursor is a combination of a peroxide donor (e.g., urea peroxide, calcium peroxide, magnesium peroxide, sodium peroxide, potassium peroxide, perborate, perphosphate, persilicate, and percarbonate) and a sulfuric acid donor (e.g., sodium bisulfate and pyrosulfate and a sulfuric acid donor). In addition to the oxidizer reactant, the core may also include an organic compound containing carbonyl groups (C=O) to produce dioxirane. Preferably, the organic compound has 3-20 carbons. The core composition may be 10-80 wt.% oxidant and 0.5-20 wt.% carbonyl donor such as aldehydes, ketones, and carboxylic acids. If a binder or a filler is used, each of these components does not make up more than 50 wt.% of the core. If a pH buffer is used, it does not exceed 30 wt.% of the pH buffer. Dioxirane formation is typically most efficient around neutral pH.

Where the target product is a peroxycarboxylate, it can be produced with a core that includes an oxidizer reactant such as urea peroxide, calcium peroxide, magnesium
peroxide, sodium percarbonate, sodium perborate, persulfate(s), monopersulfate, persilicate, perphosphate, sodium peroxide, lithium peroxide, potassium peroxide, or permanganate. The core may also include a carboxylic acid donor such as acetic acid in the form of sodium acetate. Another example is inclusion of tetraacetyl-ethylene diamine (TAED) with the peroxide donor for production of peracid in alkaline conditions. The core composition is about 10-80 wt.% oxidizer reactant and about 1-40 wt.% carboxyl group donor. Optionally, a binder, a filler, and a pH buffer may be added to the core but they cannot make up more than 50, 50, and 30 wt.% of the core, respectively. The core is at least 50 wt.% solids. The molar ratios are optimized and addition of pH buffers is employed in the core composition before coating. Upon dilution with water, the core dissolves and produces a ready source of peracetic acid in high yield.

Where the target product is a hypohalite, the reactant in the core may be potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, or a Caro’s acid precursor. The Caro’s acid precursor is a combination of a peroxide donor (urea peroxide, calcium peroxide, magnesium peroxide, sodium peroxide, potassium peroxide, perborate, perphosphate, persilicate, and percarbonate) and a sulfuric acid donor (sodium bisulfate and pyrosulfate). The core is about 10-80 wt.% oxidizer reactant and about 0.5-20 wt.% halogen donor. Optionally, a binder, a filler, and a pH buffer may be added to the core but they cannot make up more than 50, 50, and 30 wt.% of the core.

Where the target product is an N-haloamine, the reactant may be a potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, or a Caro’s acid precursor. The core may also include a monovalent metal salt, a divalent metal salt, or a trivalent metal salt, as well as an N-hydrogen donor capable of reacting with hypo-halite to generate the target product and a chlorate donor. The composition of the core is about 10-80 wt.% reactant, 0.5-20 wt.% a halogen donor, and 2-50 wt.% stabilizer. Optionally, a binder, a filler, and a pH buffer may be added to the core but they cannot make up more than 50, 50, and 30 wt.% of the core, respectively.

Where the target product is chlorine dioxide, the core composition is about 10-80 wt.% reactant, about 0.5-20 wt.% halogen donor, and about 0.5 – 15 wt.% chlorite donor. In one embodiment, the reactant in the core may be potassium persulfate, sodium
persulfate, ammonium persulfate, potassium monopersulfate, permanganate, or a Caro’s acid precursor. The halogen donor may be, for example, a mono-valent or di-valent metal salt. The chlorate donor may be sodium chlorate.

In another embodiment, the reactant is urea peroxide, calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate, persulfate(s), monopersulfate, persilicate, perphosphate, sodium, lithium, or potassium peroxide. A halogen donor and a chlorate donor such as sodium chlorate, potassium chlorate, lithium chlorate, magnesium chlorate, and calcium chlorate may be included in the core.

In either embodiment, the binder, the filler, and the pH buffer may be used optionally, but not in amounts more than 50, 50, and 30 wt.% of the core, respectively.

Where the target product is a hydroxyl radical, the core composition may be about 10-80 wt.% reactant, about 0.001-10 wt.% a transition metal, and about 1-30 wt.% pH buffer. In addition, a binder and a filler may be used. However, each of the binder and the filler is preferably not present in an amount exceeding 50 wt.% of the core. The reactor in the core may be urea peroxide, calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate, persulfate(s), monopersulfate, persilicate, perphosphate, sodium, lithium, permanganate, or potassium peroxide. The transition metal is a chelating agent selected from a group consisting of trisodium pyrophosphate, tetrasodium diphosphate, sodium hexametaphosphate, sodium trimetaphosphate, sodium triopolyphosphate, potassium triopolyphosphate, phosphonic acid, di-phosphonic acid compound, tri-phosphonic acid compound, a salt of a phosphonic acid compound, ethylene diamine-tetra-acetic acid, gluconate, or another ligand-forming compound.

Hydroxyl radical may be produced with a reactor that contains a metal catalyst. The metal catalyst may be contained in the core, coated on the core, or included in the reactor wall, for example in the pores on the membrane. The metal catalyst may be Cu (II), Mn (II), Co (II), Fe (II), Fe (III), Ni (II), Ti (IV), Mo (V), Mo (VI), W (VI), Ru (III), or Ru (IV). Upon dilution with water the composition releases peroxide. Under neutral to acidic conditions is converted to hydroxyl radicals upon reaction with the catalyst. The catalyst remains unaltered.

7) Core Configurations
Generally, the core composition is broken down as about 10–80 wt.% oxidizer reactant and about 1-20 wt.% oxidizable reactant, although there may be exceptions, as described above. The entire core is at least about 50 wt.% solids.

There are different configurations in which the core can be prepared, depending on the types of equipment available, the core composition, and the solubility characteristics of the core components.

A first configuration is a layered configuration wherein the different components form discrete layers. In this configuration, the oxidizable reactant is separated from the oxidizer reactant by a layer of a third component. This can be accomplished, for example, by spray coating or adding components in separate mixing stages, such as in a fluidized bed drier, to produce separate layers. When using this method, controlled diffusion rates through the reactor coating is achieved to ensure that adequate reaction internal to the reactor happens prior to diffusion of the target product(s). The diffusion rates can be further controlled by arranging the layers such that the most soluble component makes up the innermost layer of the core.

A second configuration is a homogeneous core. In this configuration, the core components and the binder are combined and mixed to form a homogenous core. The binder can be any one or more of the compounds mentioned above, and one or both of the oxidizer reactant and the oxidizable reactant are immiscible with the binder. The mixing can be carried out in a blender/mixer, agglomerator, or a fluidized bed device. If there is moisture in the core, it can be either dried to remove any final moisture. If non-solvents are used to enhance agglomeration, moisture is removed even if other residual volatiles may remain. Alcohols, for example, which are compatible with potassium monopersulfate and can be formed into a gel or virtual solid by adding rheology modifiers like Carbopol®, may remain. Thus, although there may be volatile components in the final composition, the core is substantially free of moisture. Any reference to “drying” during processing the reactor refers to the removal of water, and does not necessarily imply that all volatiles are removed.

A third configuration includes a solution or gel. A slurry is prepared by suspending the core components in a solution or gel. The agent(s) used to suspend the components must have properties such that either one or both of the oxidizer reactant and
the oxidizable reactant are immiscible in the solution or gel. The agents used as solution or gel can be either removed or can remain as part of the final core product.

The descriptions of various components and examples of said components are not meant to limit the invention. Other unspecified compounds that perform the same function are considered within the scope of the invention.

8) Producing the Core

The core is first produced by using any or a combination of suitable conventional equipment and techniques. Regardless of the equipment or technique, an effective amount of reactants are distributed within the reactor core. The term “effective distribution” is defined by the core’s ability to generate the target product(s) when exposed to water. The components comprising the core can be fed into a mixer/densifier using high, moderate or low shear such as those sold under the trade names “LOdige CB30” or “LOdige CB30 Recycler,” a granulator such as those sold under the trade names “Shugi Granulator” and “Drais K-TTP 80”. In some cases, a binder can be combined to enhance core formation. The core components can also be fed into the mixer or agglomerator at separate stages as to form layers thereby separating the oxidizer reactant from the oxidizable reactant. This is relevant when moisture addition is involved in the processing. However, when solvents or binders are used in which at least one of the oxidizer reactant and the oxidizable reactant are immiscible, the core components can be combined in one single stage or in multiple stages.

Furthermore, a spray-drying tower can be used to form a granular core by passing a slurry of components through the spray drier. The reactants and other components that make up the core are fed as a slurry to a fluidized bed or a moving bed drier, such as those sold under the trade name “Eischer Wyss.” When using a fluidized bed or a moving bed drier, care must be taken to consider the solubility and reactivity of the components in the core. For example, a halide donor combined directly to the PMPS in a moist environment will give off chlorine gas. To prevent this chlorine emission, the PMPS may first be coated to prevent direct contact between the halide and moisture. Alternatively, an intermediate solvent may be used to shield the PMPS from the moisture. The intermediate solvent is selected such that either the coated PMPS or the halide salt is
insoluble or have poor solubility (i.e., alcohols). A binder that is un-reactive with the oxidizer reactant can be combined into the core either before or during the spray drying or spray graining process to enhance agglomeration without compromising oxidizer activity.

In another aspect of the invention, the core components are combined in an alcohol solution that is thickened with a rheology modifier, and then dried in a spray drier, fluidized drier, or the like. This alcoholic gel improves the long-term storability of reactants such as PMPS by further preventing the reactants from coming into contact with water. More details about the alcoholic gel is provided in a copending U.S. Patent Application No. 10/913,976 filed on August 6, 2004, which is entitled “Storing a Composition in an Alcoholic Gel.” The combining of the reactant components may be done in-situ during the fluidizing process. Alternatively, the components may be combined externally in a granulator, densifier, agglomerator, or the like prior to the fluidizing process.

Spray graining layers of core components is another way of preventing direct contact between the oxidizer reactant and precursors such as halides that may induce the production of halogen gas. This method is useful when membrane-based coatings are applied as described herein. The membrane-based coating sufficiently suppresses diffusion of the dissolved components through the pores due to osmotic pressure.

Molecular diffusion is sufficiently slow to allow for the reactants to dissolve and react prior to diffusion of the produced agent(s).

The oxidizer reactant of the core can be coated with an aqueous solution or slurry of the components that make up the remainder of the core while suspended in a fluidized drier system. The resulting core composition can be either dried and removed from this stage of the process, agglomerated while in the fluidized bed drier, or removed and further mixed using equipment such as the mixer/densifier discussed above.

To further enhance the processing options and maintain the activity of the oxidizer reactant, the oxidizer reactant may be coated independently of other core components to enhance its processing survivability. The coating material may include inorganic as well as organic materials such as alkali metal salts, polysaccharides, etc. The coating must have sufficient solubility when exposed to the environmental
conditions inside the reactor. For example, alkali metals salts such as magnesium carbonate function as anti-caking agents for PMPS and enhance the oxidizer's processing survivability. However, when exposed to an acidic environment, the alkali rapidly dissolves, exposing the PMPS. Chitosan is another example of a coating that improves the product’s process survivability and hygroscopicity. Under normal storage conditions, when exposed to acidic conditions and in particular organic acids, the polymer becomes very hydrophilic and rapidly dissolves exposing the PMPS. This condition can be exploited by including organic acid donors such as succinic acid into the core composition when using chitosan-coated PMPS.

Multiple oxidizers can be generated by altering the ratio of core components. Combining reactants to produce N-chlorosuccinimide, hypochlorous acid, and chlorine dioxide can provide synergistic effects from one product by using multiple mechanisms of oxidation.

Examples of oxidizable reactants consumed or altered in the reaction with the oxidizer include but are not limited to: halogen donors such as NaCl and NaBr, organic carboxylic acids having from 1-10 carbons and at least 1-carboxylic acid (COO-) group such as citric acid or acetic acid donors, ketones, and aldehydes. Examples of oxidizable substances not consumed or altered in the reaction are: transition metal donors such as iron or copper salts or bound by chelants.

**COATING MATERIAL FOR THE REACTOR WALL**

After the reactants are selected, the coating material for encapsulating the reactants is selected. With proper selection of coating material based on its solubility in water, water permeates through the coating and activates the reactants inside by dissolving them. At the same time, the reactants are contained within the walls of the coating and not allowed to diffuse out through the coating until the reaction has progressed beyond a critical point. By restricting the diffusion of reactants, their respective molar concentrations inside the coating remain high, increasing the yield of the agents.

The pores and other openings in the reactor wall allow the target product to migrate out of the reactor. Initially, osmotic pressure on the reactor wall increases,
thereby squeezing in the main solvent into the reactor. A controlled permeation of the target product from the inside of the reactor occurs to prevent the reactor wall from rupturing. This permeation is enhanced by the gas(es) often produced during the chemical reaction in the reactor. The rate of permeation both into and out of the reactor is controlled by the size and the number of the pores in the reactor wall.

Two properties are desirable in the coating material: 1) it allows for adequate permeation of water to dissolve the reactants in the core, thereby triggering a chemical reaction inside the reactor, and 2) it acts as a barrier for preventing the reactants from diffusing out to the water body before the reaction has progressed enough to have generated a predetermined level of the desired target product. Both of these properties depend on the solubility of the coating material, which in turn may depend on the surrounding conditions (e.g., pH, solvent type). Thus, the elements surrounding conditions should be taken into consideration when choosing the coating material.

1) Silicate-based Coating Material

Examples of coating material include silicates, silicones, polysiloxane, and polysaccharides including chitosan and chitin. The silicate-based coating material may be something that contains silicate, such as metasilicate, borosilicate, and alkyl silicate.

How suitable a particular coating material is for a given application depends on the surrounding conditions. For example, silicate coatings are well established for providing a barrier film of protection to percarbonates and other bleaching agents used in laundry detergents but do not always make a reactor. In laundry detergents, the inclusion of bleach precursors such as tetraacetyl-ethylenediamine or nonanoyl-oxybenzene sulfonate to enhance the bleaching performance in low temperatures is common. The hydrolysis of the precursors requires alkaline pH conditions. In such applications, due to the hydrolysis requirements and peroxxygen chemistry, the internal and external solution used to dissolve the reactants is high in pH. The silicate coating is soluble under alkaline conditions, and the integrity of the reactor wall is compromised. The coating dissociates rapidly, without acting as a reactor. In this case, the benefit of the high reaction yield is not achieved.
Silicates provide for a simple and inexpensive reactor coating when used in lower pH applications or formulations that result in internal acidic pH conditions that sustain the integrity of the reactor wall. This usefulness of silicates remains uncompromised even if the external conditions are alkaline in pH, such as in the case of laundry water. 

Silica solubility is poor at low pH. At lower pH, silica remains colloidal and forms a colloidal gel. When monopersulfate (MPS) and a source of chloride such as NaCl are encased within a coating of silicate such as sodium silicate, then added to water, the water permeates through fissures and cracks in the coating and dissolves the reactants. The resulting low pH (<5) from the dissolving MPS suppresses the dissolution rate of the surrounding silica, and the silica remains as a colloidal gel.

Inside the space enclosed by the silica gel coating, the concentration of reactants remains high and the resulting reactions produce high yields of chlorine gas. Upon diffusion of the reactants and the chlorine into the surrounding water, hypochlorous acid and hypochlorite ions form as a function of the water’s pH. The resulting conversion to the target product is therefore much higher when the pH inside the reactor is low and the reactor wall remains undissolved. With the inclusion of N-succinimide, it is now possible to produce N-chlorosuccinimide with the slow-diffusing chlorine gas. pH buffers can be added to further ensure efficacy based on application requirements. In alkaline pH conditions such as laundry bleaching, the elevated pH will not allow for generation of the N-chlorosuccinimide. By sustaining the integrity of the reactor, the internal conditions of the reactor are such that the reactions are successfully carried out. The target product is efficiently generated and released.

2) Polymer Surfactant Coating Material

In some embodiments, the reactor wall is made of a generally hydrophobic substance that includes hydrophilic constituents. A mixture of hydrophobic and hydrophilic substance is applied to the core and dried. Upon addition of water, the hydrophilic component dissolves and the hydrophobic polymer remains intact, forming a porous shell around the core. Water permeates through the pores to reach the core and trigger a chemical reaction. Then, eventually, after the product concentration reaches the
critical level, the hydrophobic substance dissolves. More details about this coating process are provided below.

Applications where alkaline pH aquatic conditions are achieved or increased control of diffusion rates is desired can utilize hydrophobic coatings combined with hydrophilic agents. This hydrophobic coating material may be useful with an alkaline-pH aquatic environment where the silicate coating is ineffective as a reactor. As mentioned above, hydrophobic coatings may possess hydrophilic portions, such as some hydrophilic functional groups inherent in the polymer structure. However, the hydrophobic coatings have a hydrophobic backbone that limits their solubility substantially, thereby allowing them to effectively function as a reactor by maintaining the integrity of the reactor walls until the reaction inside has progressed beyond a critical point. This critical point may be defined by a condition such as the pH of the solution inside the reactor or the concentration of the target product.

Examples of hydrophobic polymers include but are not limited to polyoxyethylene alcohols such as R(OCH₂CH₂)ₙOH, CH₃(CH₂)ₙ(OCH₂CH₂)ₙOH, and polyoxyethylene fatty acid esters having the general formula RCOO(CH₂CH₂O)ₙH, RCOO(CH₂CH₂O)ₙOCR, oxirane polymers, polyethylene terephthalates, polyacrylamides, polyurethane, latex, epoxy, and vinyl, cellulose acetate. Suitable hydrophilic components include but are not limited to: polycarboxylic acids such as polymaleic acid, polyacrylic acid, and nonionic and anionic surfactants such as ethoxylated or sulfonated alkyl and aryl compounds.

The non-solvent is generally hydrophilic and is removed after the application of the coating to leave voids and channels. The amphipathic agent is used to combine the polymer coating with the hydrophilic non-solvent. The resulting coat is usually microporous but the process may be altered to form macro-porous voids and channels. The ratio of solvent to non-solvent as well as non-solvent selection can be adjusted to provide varying degrees of pore size, distribution, and symmetry.

Polysiloxane emulsified in water using water-soluble surfactants provides for an effective coating in pH-sensitive applications. The emulsion is applied to the composition's core (i.e., to the reactants) and then dried, as is performed in the application of the silicates. However, when exposed to water, the hydrophilic component
dissociates, forming pores in the hydrophobic polysiloxane coating. The water then permeates into the reactor dissolving the core and activating the reactants. The reactions produce the desired target products in high yield, and these target products act on the bulk body of water when the reactor wall dissolves. Due to the high chemical stability of the polysiloxane, the integrity of the reactor coating remains uncompromised in alkaline pH conditions.

3) Membrane

In another embodiment, the reactor wall 10 is a hydrophobic and porous membrane. A second coating can be applied to improve the shelf life in high-humidity storage conditions. To further improve on the diffusion rates by providing for a controlled porosity and pore symmetry, the hydrophobic components such as cellulose acetate can be dissolved in a solvent and combined with a non-solvent that is amphipathic or has a hydrophilic functionality. After forming the coating, both the solvent and non-solvent are removed (e.g., evaporated) leaving a coat with specific porosity. The porosity can be altered by controlling the ratio and types of non-solvent and solvent to the hydrophobic component. For example, addition of ethanol into a mixture of acetone/water-magnesium perchlorate (solvent/non-solvent mixture) produces asymmetrical pores. “Solvents” have the ability to dissolve the hydrophobic polymer while being soluble in the non-solvent.

The hydrophobic component can be any number of thermoplastics and fiber forming polymers or polymer precursors, including but not limited to polyvinyl chloride, polyacrylonitrile, polycarbonate, polysulfone, cellulose acetates, polyethylene terephthalates, and a wide variety of aliphatic and aromatic polyamides, and polysiloxane. Using this coating technology, a membrane with controlled porosity is produced. Representative synthetic polymers include polyphosphazines, poly(vinyl alcohols), polyamides, polycarbonates, polyalkylenes, polyacrylamides, polyalkylene glycols, polyalkylene oxides, polyalkylene terephthalates, polyvinyl ethers, polyvinyl esters, polyvinyl halides, polyvinylpyrrolidone, polyglycolides, polysiloxanes, polyurethanes and copolymers thereof. Other suitable polymers include, but are not limited to, methyl cellulose, ethyl cellulose, hydroxypropyl cellulose, hydroxypropyl
methyl cellulose, hydroxybutyl methyl cellulose, cellulose acetate, cellulose propionate, cellulose acetate butyrate, cellulose acetate phthalate, carboxymethyl cellulose, cellulose triacetate, cellulose sulfate sodium salt, poly(methyl methacrylate), poly(ethyl methacrylate), poly(butyl methacrylate), poly(isobutyl methacrylate), poly(hexyl methacrylate), poly(isodecyl methacrylate), poly(lauryl methacrylate), poly(phenyl methacrylate), poly(methyl acrylate), poly(isopropyl acrylate), poly(isobutyl acrylate), poly(octadecyl acrylate) polyethylene, polypropylene, poly(ethylene glycol), poly(ethylene oxide), poly (ethylene terephthalate), polyvinyl acetate), polyvinyl chloride, poly styrene, polyvinyl pyrrolidone, and polyvinylphenol. Representative bioerodible polymers include polylactides, polyglycolides and copolymers thereof, poly(ethylene terephthalate), poly(butyl acid), poly(valeric acid), poly(lactide-co-caprolactone), poly[lactide-co-glycolide], polyanhydrides, polyorthoesters, blends and copolymers thereof.

More specifically, cellulose acetate phthalate such as CA-398-10NF sold by Eastman Chemical Company may be used as the coating material. Under low pH conditions like those previously described for production of N-chlorosuccinimide, the coating remains stable. However, when the core components are depleted, the higher pH (>6.0) dissolves the coating. The porosity can be controlled by dissolving the cellulose in a solvent, then adding an effective amount of non-solvent. After application of the coating, the solvent and non-solvent are removed via evaporation, leaving behind a membrane with a distinct porosity. The porosity can be further altered in symmetry, number of pores, and size of pores by altering the coating components and processing. For example, a decrease in solvent to polymer (S/P) ratio, an increase in nonsolvent/solvent (N/S) ratio, an increase in nonsolvent/polymer (N/P) ratio in the casting solution composition, and a decrease in the temperature of the casting solution tend to increase the average size of the pores on the surface of resulting membranes. Further, an increase in S/P ratio in the casting solution composition, and an increase in the temperature of the casting solution, tend to increase the effective number of such pores on the membrane surface.

Some applications may benefit from a membrane that provides a long term treatment with antimicrobial agents. After the core is extruded, the membrane coating is
formed by either directly applying a film-forming membrane and evaporating off any solvents (including water) and non-solvent in the membrane. Alternatively, after the core is extruded, the phase inversion process may be used to produce long fibrous micro-reactors that can be woven or combined with woven materials. The membrane formation process will now be described.

To further improve the stability of the formed polymer membrane, an alloy component can be incorporated into the membrane to form an alloyed reactor wall membrane. For example, addition of poly(phenylene oxide dimethyl phosphonate) to cellulose acetate on a 1:1 w/w mixture can increase membrane tolerance from a pH of <8 to a pH of 10-10.7 for extended usage. An alloying compound is typically an organic component that is combined with the primary hydrophobic component that enhances the polymer membrane's chemical and/or thermal stability. The alloying compound can also be a cross-linking agent such as triflic acid with phosphorous pentoxide, trifluoromethansulfonate, etc., or a plasticizer.

In some embodiments, a cross-linking agent that enhances the structural integrity and rigidity with a polymer precursor such as styrene is included in the reactor wall. Styrene, a cross-linking agent such as divinylbenzene, a solvent, and non-solvent are mixed and applied to form an effective film, followed by the step of initiating polymerization by applying a persulfate or activating peroxide solution before removing the solvent and non-solvent by evaporative drying. The persulfate may be applied during the removal of the solvent and non-solvent, in situ. After the drying, a plastic coating layer having a micro- or macro-porous structure with substantially improved rigidity and strength is obtained.

A plasticizer may also be used to increase the pliability as well as alter the hygroscopicity of the membrane coating.

Alloying compounds such as plasticizers and cross-linking agents may be incorporated into the reactor wall to further improve its structural integrity and/or stability across different temperature and pH ranges. As stated above, the alloying component can also be a cross-linking agent such as triflic acid with phosphorous pentoxide, trifluoromethansulfonate, and the like.
4) Multiple Reactor Walls

A single reactor may contain more than one reactor wall. For example, a silicate-coated-core can be further treated with a second coating of chitosan to improve its fluidity and hygroscopic properties. Upon exposure to a bulk quantity of water, the chitosan is dissolved and the silica-coated reactor is exposed. Also, where enhanced storage stability is required, such as high humidity exposure, a secondary coating that enhances the hygroscopicity of the reactor-encased composition may be applied. The invention is not limited to a specific number of reactor wall. Examples of dual-reactor embodiments are provided below. Reactors may also be prepared with more than two layers of reactor walls, depending on the application.

4) Forming the reactor wall

The coating material may be applied to the core in the form of an aerosol, a liquid, an emulsion, a gel, or a foam to form the reactor wall. The preferred form of coating depends on the composition of the coating being applied, the application equipment, and conditions. The coating generally comprises from 0.2 to 5% of the total weight of the micro-reactor. However, the actual amount of membrane coating can vary based on the size of the reactor, porosity and the like.

In one aspect, the invention is a method of producing the reactor described above, and also a method of using the reactor to treat an aquatic system. The invention is a method of generating high yields of oxidizers, biocides and/or virucidal agents in-situ by using the reactor that is described above. The reaction in the reactor is triggered when the reactor is exposed to the body of water that is to be treated by the products of the reaction.

The core that is formed as described above is coated with an effective amount of coating material. The “effective amount” of coating takes into consideration the solubility characteristics of the coating under the conditions in the application so as to ensure that the structural integrity of the reactor remains sufficiently intact until such time as the reactants have been depleted. The coating material may be applied by using any effective means of distributing the coating material over the surface of the core, such as spray coating in a fluidized bed, or applying a foam or liquid containing the coating material.
and mixing. Then, the coated composition is dried by using an effective means of drying, such as a fluidized drier or a tray drier, rotary drier and the like.

Once the core has been produced, the coating is effectively applied in the form of liquid, foam, gel, emulsion and the like. The coating can be applied by aerosol, spray, immersion and the like. The coating may be applied with a mechanical mixing device such as a blender/mixer, then dried using any number of batch or continuous drying techniques such as tray driers, rotary driers, fluidized bed driers, and the like. The preferred technique is to accomplish coating and drying in a continuous fluidized bed drier. The fluidized bed drier can incorporate multiple stages of drying to apply multiple applications of coating, perform different steps in the coating process (i.e., coating, polymerization, evaporation) and the like under continuous or batch processing. Generally, the product temperature during the coating process should not exceed 100 °C and preferably 70 °C. During membrane coating, the application of the coating should occur at <50 °C and preferably <30 °C depending on the solvent and non-solvent that are used.

The order of application, evaporation, drying, etc. of the coating material varies based on the types of polymers, solvents, non-solvents and techniques used to produce the porous membrane. For example, a cellulose acetate membrane is effectively applied by first dissolving the cellulose polymer in a solvent, then adding a non-solvent such as water and magnesium perchlorate to produce the gel. The gel is coated on the core by spraying or otherwise applying a thin film of gel onto the surface of the core, then evaporating the solvent and the volatile components of the non-solvent.

A polyamide membrane can be produced by using the method that is commonly referred to as the “phase inversion process.” The phase inversion process includes dissolving a polyamide in a solvent such as dimethyl sulfoxide to form a gel, applying the gel to form a thin film, then applying the non-solvent to coagulate the polymer. Then, the solvent and non-solvent are evaporated.

**Example 1**

This example illustrates the generation of N-chlorosuccinimide using the invention, and explains its utility.
Conventionally, laundry bleaching utilizes liquid or dry chlorine bleaching agents for white fabrics and peroxycarboxylic compounds such as percarbonate for colored fabrics. To further improve the removal of colored stains, precursors are incorporated into the laundry detergents to produce peracids (e.g., peracetic acid) in-situ. The effectiveness of these treatments is based on factors such as contact time, temperature, concentration, types of stains, demand for oxidants in the water, and the like. Generally, the effectiveness of treating color stains and in many cases stains on white fabrics is limited. Thus, additional treatment steps are commonly employed to successfully remove the stains, as illustrated in the published application WO9923294.

This published application discloses a multi-step process to improve the effectiveness of stain removal, wherein one of the steps employs dioxirane.

By utilizing the reactor, a combination of agents, each with its own selective order of reactions, may be employed in one step. The synergistic effect of combined treatments substantially improves performance in stain removal without the problems associated with high dosages of single indiscriminate treatments, such as bleaching of colors and fabric decomposition.

Set-in protein based stains are difficult to treat due to their insoluble composition. Peroxycarboxylic compounds and peracids are effective at decomposing the soluble components that increase the COD of the wash water. However, the efficiency of the reactions (gms oxidant/gm COD) needs to be considered for bleaching efficacy. By selecting reactant components based on their reaction selectivity, the efficacy of the bleaching process is improved.

The difficulty in selecting and applying the components is a result of their storage stability, ability to formulate, and condition (chemistry) requirements for in-situ generation. For example, acid catalyzed reactions are not well suited for the alkaline conditions experienced in laundry wash water.

By employing the reactor of the invention, the issues of stability, formulation, and in-situ generation are addressed. Lower levels of highly selective agents can be produced in-situ that carry out specific tasks. For example, N-chlorosuccinimide is very effective at decomposing tryptophan peptide bonds that bind the high molecular weight (water insoluble) proteins. N-chlorosuccinimide may be generated using a core that includes a
halogen donor such as NaCl and an oxidizer such as potassium monopersulfate, persulfates, or peroxyphthalate. The halogen donor and the oxidizer will produce hypohalite (OCI). With the pH suppressed to <6.0, chlorine gas results as an equilibrium product of the halogen species. Including a N-hydrogen donor such as N-succinimide, isocyanuric acid, 5,5-alkylhydantoin, or N-sulfamate, a stable antimicrobial agent is produced such as N-chlorosuccinimide as in the case of N-succinimide reacting with chlorine gas.

When decomposition occurs, smaller water-soluble byproducts are produced. The carbon based compounds are readily oxidized by oxygen-based oxidizers such as dioxirane, peracids or chlorine dioxide. Hydroxyl radicals further enhance decomposition of these compounds and significantly improve the rate of decomposition by hydrogen cleavage, radical formation, and autocatalytic decomposition.

The result of utilizing selective chemistry minimizes the amount of reactants that is required while maximizing bleaching efficacy. Resistant stains that otherwise survive non-chlorine bleach detergent blend are effectively cleaned without the damage resulting from higher concentrations, direct contact with ready to use bleaching agents, and use of indiscriminate bleaching agents. It also provides for an easy single-step application.

EXAMPLE 2

The reactor of the invention may be used to generate multiple target products by customizing the reactions and selecting the reactants for a specific application. For example, in bleaching processes, combining dioxirane and peracids with residual PMPS provides for multiple mechanisms of oxidation and bleaching. In antimicrobial applications, combining chlorine dioxide with residual hypohalite and/or haloimide provides for a broad-spectrum inactivation of microorganisms and enhanced efficacy over single species applications. This example illustrates the generation of peracetic acid and dioxirane using an acidic reactor environment.

FIGs. 4A, 4B, 4C, 4D, 4E, and 4F show a reactor 30 for generation of multiple target products under acid catalyzed conditions. The target products include peracetic acid, which is most efficiently produced under low pH, and dioxirane, which is most efficiently produced under neutral-pH conditions. As shown in FIG. 4A, the reactor 30
includes a core 32, a silicate coating 34, an alkali salt coating 36, and a cellulose triacetate membrane 38. The core 32 includes PMPS (the oxidizer reactant), ketone, percarbonate, and acetate.

The reactor 30 is multi-layered. The silicate coating 34 forms an inner reactor, and the cellulose triacetate membrane forms the outer reactor that contains the inner reactor. The inner reactor generates the peracetic acid and the outer reactor generates the dioxirane. By forming the core 32 with an acidic oxidizer reactant such as PMPS, a hydrogen peroxide donor (e.g., percarbonate), an acetic acid donor (e.g., sodium acetate), and a carbonyl donor (e.g., dihydroxyacetone, ketone) in one reactor (e.g., silicate coating), surrounding the reactor with an effective dose of alkali salt (e.g., sodium carbonate), and coating the alkali salt coating 36 with yet a second reactor coating such as a cellulose triacetate membrane 38, the reactor 30 maximizes the generation of peracetic acid and dioxirane.

FIG. 4B shows that upon contacting water, pores form in the cellulose triacetate membrane 38. Moisture permeates the cellulose membrane 38 through the pores and dissolves some of the alkali salt coating 36 and hydrolyzes the silicate coating 34. The silicate coating 34 (colloidal gel), which forms the wall of the inner reactor, allows for moisture to permeate and reach the core 32. Once the moisture permeates to the core, the reactants in the core are activated, creating an acidic condition (FIG. 4C). As shown in FIG. 4C, the activated reactants dissociate, shrinking the core 32 and reducing the pressure inside the reactor 30. Since the cellulose triacetate membrane 38 has pores, the silica coating 34 supports the cellulose membrane 38. Peracetic acid, residual PMPS, and carbonyl donor (e.g., ketone) are generated by the reaction in the inner reactor (FIG. 4C). Because the cellulose membrane 38 is micro-porous, the rate at which the peracetic acid, the residual PMPS, and the carbonyl donor diffuse out of the reactor 30 is limited.

As the peracetic acid, the residual PMPS, and the carbonyl donor from the inner reactor pass into the alkali salt coating 36 as shown by an arrow 39, the rise in pH induces the generation of dioxirane by activating a PMPS-carbonyl donor reaction (FIG. 4D). The peracetic acid, dioxirane, and residual PMPS diffuse through the porous cellulose triacetate membrane 38. The raised pH collapses the silicate coating 34, which then decomposes. Without the silicate coating 34 to provide extra support against the
osmotic pressure difference between the inside and the outside of the reactor 30, the cellulose triacetate membrane 38 also collapses (FIG. 4E). After collapsing, the cellulose-based cellulose triacetate membrane 38 dissipates (FIG. 4F) and the reactor 30 is gone.

As illustrated above in FIG. 4A, a reactor may contain multiple sub-reactors (e.g., an inner reactor and an outer reactor) with each sub-reactor generating a specific target product. When generating multiple target products, the target product combinations are selected such that they can be generated under the same conditions.

Example 3

This example illustrates the generation of peracetic acid and dioxirane in a neutral to alkaline reactor environment.

FIGs. 5A and 5B illustrate a reactor 40 for generation of multiple target products under neutral to alkaline pH using stable polyester membrane reactor coating 48. The target products include peracetic acid and dioxirane. As described above, PMPS can be combined with organics containing carbonyl groups (e.g., ketone, aldehyde, carboxylic acid) to produce dioxirane. Dioxirane formation is most efficient around neutral pH. As FIG. 5A shows, the reactor 40 includes a core 42, a silicate coating 44, and the polyester membrane 48. In the example shown in FIG. 5A, the core contains PMPS, a carbonyl donor (ketone in this case), a percarbonate, an acetate, and a pH buffer.

Moisture permeates the polyester membrane 48 through the pores in the membrane and hydrolyzes a silicate coating 44 to form a colloidal gel. The silicate coating 44, which forms the wall of the inner reactor, allows for moisture to permeate and reach the core 42. Once the moisture permeates to the core, the reactants in the core are dissolved to form an alkaline condition (FIG. 5B). Tetraacetyl-ethylenediamine (TAED) and PMPS react to produce peracid in high yield in an alkaline condition. The alkaline condition activates a PMPS-carbonyl donor reaction and generates dioxirane. As the reactants dissociate through a chemical reaction, the core 42 decreases in size. Eventually, the osmotic pressure difference between the inside and the outside of the reactor 40 collapses the reactor 40 (not shown).
EXPERIMENTAL DATA

1) Test 1

A 500 ml sample of distilled water was treated with 0.5 grams of 4.8 % A.O. potassium monopersulfate (PMPS) and 1.3 grams of N-succinimide. The solution pH was increased to pH 10.13 using K₂CO₃. Immediately, 0.5 grams of NaCl was added and the solution was vigorously mixed using a magnetic stirrer for 5-minutes. A 25 ml sample was removed and 3 ml of 0.1-molar EDTA solution was added to neutralize any residual PMPS. The solution pH was 8.2 when DPD reagent was immediately added, producing a faint pink color.

The solution was titrated with a thiosulfate solution whereby 0.6 ppm of chlorine based oxidizer was detected. The result of Test 1 illustrated that producing hypohalites and subsequent haloimides in alkaline conditions does not have any significant advantages or benefits.

2) Test 2

A 500 ml sample of distilled water was treated with 0.5 grams 4.8 % A.O. potassium monopersulfate (PMPS), 1.0 grams succinic acid, and 1.3 grams of N-succinimide. The solution pH was measured at pH 3.65. 0.5 grams of NaCl was added, and the solution was vigorously mixed using a magnetic stirrer for 5-minutes. During the reaction period, no chlorine odor was detected. A 25 ml sample was removed and 3 ml of 0.1-molar EDTA solution was added to neutralize any residual PMPS. The DPD reagent was added producing a bright pink color.

The solution was titrated with thiosulfate solution whereby 20.4 ppm of chlorine based oxidizer was detected. The results of Test 2 shows that the same concentrations of reactants under acid conditions efficiently generated 20.4 ppm of N-chlorosuccinimide and/or hypohalite. The lack of chlorine odor and bleaching of the DPD reagent indicates the predominant components was stabilized chlorine in the form of N-chlorosuccinimide.

3) Test 3

A N-chlorosuccinimide generating micro-reactor was produced by combining: 15.15 wt% PMPS, 15.15 wt% NaCl, 30.30 wt% succinic acid, and 39.39 wt% N-
succinimide. The combination was placed in a grinder until they formed a fine dusty powder. A solution of 95% ethanol and 5% isopropyl alcohol was treated with 1% Carbopol® to produce a thick gel. 10 grams of gel was added to 100 grams of the fine powder and slowly mixed until the components agglomerated into granules. The granules were transferred to a fluidized drier, whereby they were fluidized while sustaining an exit air temperature of about 65 °C. A solution of 30 wt% metasilicate was applied by supplying an aerosol spray into the fluidized stream of granules. A coating made up approximately 2.5 wt% of the total. The granules where allowed to continue drying until the water had been sufficiently removed.

A 500 ml of DI water was treated with K₂CO₃ to raise the pH to 10.58. 3.64 grams of the stated micro-reactors was added to the solution and vigorously mixed for 7 minutes. Periodically the solution was checked to see if the core of the reactor had dissolved, and a solution of dissolved K₂CO₃ was added to sustain the pH >10.0. It took approximately 5 minutes to dissolve substantially all of the core of the reactors. An additional 2 minutes of mixing was provided.

A 25 ml sample was removed and 3 ml of 0.1-molar EDTA solution was added to neutralize any residual PMPS. The DPD reagent was immediately added producing a bright pink color. The solution was titrated with thiosulfate solution whereby 12.8 ppm of chlorine based oxidizer was detected. The results of Test 3 show that even when the bulk water conditions do not favor generation of N-chlorosuccinimide and hypohalites, the reactor of the invention provided a condition that achieved a 63% conversion.

By further regulating diffusion rates utilizing micro-porous membrane coatings and/or multiple coatings, rather than the macro-porous like that achieve with silicate, still higher conversions are to be expected.

4) Results of Comparative Experiments

FIG. 6 shows the stability of potassium monopersulfate in various alcohols which can be used to form suspensions or binders in the core. As stated above, alcohols may be used to aggregate PMPS into the core, for example when the core is of the homogeneous configuration. The alcohol may be formed into a gel or converted into an almost-solid form by adding rheology modifiers like Carbopol®. FIG. 6 graphically summarizes the
active oxygen (A.O.%) level in compositions prepared with different alcohols as a function of time (days in storage). The control group did not include any alcohol, and showed a drop in the active oxygen level after 14 days, from 4.41 % to 4.4 %. In contrast, PMPS stored in isopropyl alcohol (IPA) and ethyl alcohol (EA) showed an increase in the active oxygen level. The PMPS stored with methyl alcohol (MA) showed a significant drop in the active oxygen level in the first week of storage, but then recovered during the second week to match the overall active oxygen level drop of the control group. Although there was alcohol in the tested compositions, their core is substantially free of moisture. FIG. 6 suggests that a core made using EA or IPA may be most effective for stabilizing PMPS.

FIG. 7 shows the increase in viscosity provided by Carbopol® used to alter the rheology of the solution. More specifically, the plot of FIG. 7 shows viscosity as a function of Carbopol® resin concentration in water. As shown, the viscosity of a medium (e.g., alcoholic gel) can be increased and controlled by adjusting the Carbopol concentration.

The reactor has far-reaching applications. Reactants such as PMPS and NaCl are quite stable when dry but once moisture is added and reactions are triggered, an agent with a completely different set of properties may be produced. The reactor allows for a stable point-of-use product with easy application. The fact that the reaction is triggered by moisture allows for a wide range of applications since the reactor remains stable until some type of liquid, such as water or urine, contacts the composition. The contaminated liquid that is to be treated is what activates the reactor to generate and release target products for treatment. When the released target products are oxidizers, they treat the bulk liquid by controlling bacteria, viruses and various organic and inorganic contaminants.

The benefits of the invention are broad in nature. The reactors, or the micro-reactors, provide storage stable, and safe to use bleaching agents and antimicrobial agents in a ready to use form. This technology greatly enhances the utility of the agents. For example, the agents can be combined with laundry detergents and provide one or multiple bleaching agents to provide a synergistic effect from a single or multiple reactors in the
formulation. The micro-reactors can be impregnated into wipes whereupon contact with moisture, release powerful anti-microbial agents. Further still, the micro-reactors can be combined with other additives to provide for anti-microbial capabilities such as animal storage, feed, and cleaning facilities. Further still, the micro-reactors provide for convenient generation of anti-microbial agents for use in home and institutional applications as cleansers or diluted with water as a spray or aerosol. The micro-reactors also allow for applications where the products are suspended in a gel for easy application such as in medical or cleaning applications. Yet still, micro-reactors can generate multiple agents from one reactor, or be combined with multiple reactors each generating its own agent(s) to provide a combined effect to the bleaching or antimicrobial application.

One benefit of the invention is to control the reactor chemistry as to maximize the concentration of reactants in an environment conducive to forming the target products. For example, N-chlorosuccinimide generation is best performed under acidic conditions where chlorine gas and/or hypochlorous acid are readily available. In applications such as laundry bleaching, generation of N-chlorosuccinimide is less than optimal because the alkaline pH (generally >9.0) is not well suited for producing N-chlorosuccinimide. By producing N-chlorosuccinimide in a contained space inside the reactor and controlling the diffusion rate of product and reactants out of the reactor, the conditions that are conducive to high conversion rates and yields are sustained. Thus, the yield is maximized prior to the product’s being releasing into the alkaline bleaching environment of the wash-water. Similar characteristics are true of the various oxidizers produced by reacting reagents to generate more powerful oxidants in-situ. Conditions such as pH, concentrations of reactants, and minimizing oxidizer demand such as that found in the bulk wash-water must be controlled to maximize conversion of the reactants and the yield of the target product. Utilizing granules of oxidizers incorporating precursors that require acid catalyzed reactions into alkaline wash water and high demand deplete in-situ efficacy.

The above description of the coating materials is not intended to limit the invention. In other chemical applications, such as where solvents are organic, a suitable coating may be selected to accomplish the desired effect while providing sufficient
resistance to decomposition or dissipation prior to carrying out the function of a reactor. While the foregoing has been with reference to a particular embodiment of the invention, it will be appreciated by those skilled in the art that changes in this embodiment may be made without departing from the principles and spirit of the invention.
What is claimed is:

1. A reactor that generates a target product when placed in contact with a main solvent, the reactor comprising:
   - a reactor wall forming a reactor space, the reactor wall allowing a controlled permeation of the main solvent into the reactor space; and
   - a core in the reactor space, wherein the core includes a reactant that, upon contacting the main solvent, starts a chemical reaction in the reactor space to generate the target product, and wherein the reactor wall allows the target product to leave the reactor space at a predetermined rate.

2. The reactor of claim 1, wherein the reactor wall disintegrates when the concentration of the target product in the main solvent outside of the reactor is equal to or greater than a predetermined level.

3. The reactor of claim 1, wherein the reactor wall disintegrates when the generated amount of the target product is equal to or greater than the critical level.

4. The reactor of claim 1, wherein the reactor wall contains a silicate-based material.

5. The reactor of claim 1, wherein the reactor wall contains a polymer and a surfactant.

6. The reactor of claim 1, wherein the reactor wall is a porous membrane.

7. The reactor of claim 1, wherein the reactor wall is a first reactor and the reactor space is a first reactor space, further comprising a second reactor wall formed around the core to form a second reactor space.

8. The reactor of claim 1, wherein the target product is dioxirane, the core comprising:
about 10-80 wt.% an oxidant;
about 0.5-20 wt.% a carbonyl donor;
about 0-50 wt.% a binder;
about 0-50 wt.% a filler; and
about 0-30 wt.% a pH buffer, wherein the core is > about 50 wt.% solids.

9. The reactor of claim 8, wherein the reactor wall comprises a coating material that allows a polar solvent to permeate into the reactor space while restricting diffusion of the reactant and the target product out of the reactor space, the coating material having a lower solubility in the main solvent than the oxidant and the target product.

10. The reactor of claim 9, wherein the core is a homogeneous agglomeration of components.

11. The reactor of claim 9, wherein the coating material is a silicate-based material.

12. The reactor of claim 9, wherein the coating material comprises one or both of a polymer and a surfactant.

13. The reactor of claim 9, wherein the reactor wall is a porous membrane.

14. The reactor of claim 9 further comprising a soluble layer formed around the core, wherein the soluble layer contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.

15. The reactor of claim 14, wherein the soluble layer is formed between the core and the reactor wall.
16. The reactor of claim 14, wherein the soluble layer is formed around the reactor wall.

17. The reactor of claim 9, wherein the reactor space is a first reactor space and the reactor wall is a first wall, further comprising a second wall formed around the core to form the second reactor space having a pH level that is different from a pH level of the first reactor space.

18. The reactor of claim 17, wherein the second reactor is one of a silicate based material, a combination of a polymer and a surfactant, or a porous membrane.

19. The reactor of claim 17, wherein the chemical reaction is a first chemical reaction, and wherein a second chemical reaction occurs in the second reactor space to produce the target product.

20. The reactor of claim 17, wherein the second wall is formed around the first wall.

21. The reactor of claim 17, wherein the second wall is formed between the core and the first wall.

22. The reactor of claim 17 further comprising a layer positioned between the first wall and the second wall, the layer containing one or more of a pH buffer, a stabilizer, and a reactant.

23. The reactor of claim 9, wherein the reactor wall comprises a combination of a polymer and an alloying compound.

24. The reactor of claim 8, wherein the core is shaped into a particle, granule, nugget, wafer, disc, briquette, and puck.
25. The reactor of claim 8, wherein the reactant is at least one of potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, and a Caro's acid precursor.

26. The method of claim 25, wherein the Caro’s acid precursor is a combination of a peroxide donor and a sulfuric acid donor.

27. The method of claim 26, wherein the peroxide donor is one of urea peroxide, calcium peroxide, magnesium peroxide, sodium peroxide, potassium peroxide, perborate, perphosphate, persilicate, and percarbonate, and wherein the sulfuric acid donor is one of sodium bisulfate and pyrosulfate.

28. The method of claim 8, wherein the carbonyl donor has 3-20 carbons and at least one carbonyl group.

29. The reactor of claim 1, wherein the target product is percarboxylic acid, the core comprising:
   about 10-80 wt.% an oxidant;
   about 1-40 wt.% a carboxyl group donor;
   about 0-50 wt.% a binder;
   about 0-50 wt.% a filler; and
   about 0-30 wt.% a pH buffer, wherein the core is > about 50 wt.% solids.

30. The reactor of claim 29, wherein the reactor wall comprises a coating material that allows a polar solvent to permeate into the reactor space while restricting diffusion of the reactant and the target product out of the reactor space, the coating material having a lower solubility in the main solvent than the oxidant and the target product.

31. The reactor of claim 29, wherein the core is a homogeneous agglomeration of components.
32. The reactor of claim 29, wherein the reactor wall comprises a silicate-based material.

33. The reactor of claim 29, wherein the reactor wall comprises one or both of a polymer and a surfactant.

34. The reactor of claim 29, wherein the reactor wall is a porous membrane.

35. The reactor of claim 29 further comprising a soluble layer formed around the core, wherein the soluble layer contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates

36. The reactor of claim 35, wherein the soluble layer is formed between the core and the reactor wall.

37. The reactor of claim 35, wherein the soluble layer is formed around the reactor wall.

38. The reactor of claim 29, wherein the reactor space is a first reactor space and the reactor wall is a first wall, further comprising a second wall formed around the core to form the second reactor space having a pH level that is different from a pH level of the first reactor space.

39. The reactor of claim 38, wherein the second reactor is one of a silicate based material, a combination of a polymer and a surfactant, or a porous membrane.

40. The reactor of claim 38, wherein the chemical reaction is a first chemical reaction, and wherein a second chemical reaction occurs in the second reactor space to produce the target product.
41. The reactor of claim 38, wherein the second wall is formed around the first wall.

42. The reactor of claim 38, wherein the second wall is formed between the core and the first wall.

43. The reactor of claim 38 further comprising a layer positioned between the first wall and the second wall, the layer containing one or more of a pH buffer, a stabilizer, and a reactant.

44. The reactor of claim 29, wherein the reactor wall comprises a combination of a polymer and an alloying compound.

45. The reactor of claim 29, wherein the core is one of a particle, granule, nugget, wafer, disc, briquette, and puck.

46. The reactor of claim 29, wherein the reactant is one of urea peroxide, calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate, persulfate(s), monopersulfate, persilicate, perphosphate, sodium peroxide, lithium peroxide, potassium peroxide, and permanganate.

47. The reactor of claim 29, wherein the reactant is a first reactant, and wherein the carboxyl group donor is a second reactant having 1-20 carbons and a carboxylic acid functional group.

48. The reactor of claim 29, wherein the pH buffer is an organic acid having 1-10 carbons and a carboxyl functional group.

49. The reactor of claim 29, wherein the pH buffer is an inorganic acid.
50. The reactor of claim 1, wherein the target product is a hypohalite, the core comprising:
   about 10-80 wt.% an oxidant;
   about 0.5-20 wt.% a halogen donor;
   about 0-50 wt.% a binder;
   about 0-50 wt.% a filler; and
   about 0-30 wt.% a pH buffer, wherein the core is > about 50 wt.% solids.

51. The reactor of claim 50, wherein the reactor wall comprises a coating material that allows a polar solvent to permeate into the reactor space while restricting diffusion of the reactant and the target product out of the reactor space, the coating material having a lower solubility in the main solvent than the oxidant and the target product.

52. The reactor of claim 50, wherein the core is a homogeneous agglomeration of components.

53. The reactor of claim 50, wherein the reactor wall comprises a silicate-based material.

54. The reactor of claim 50, wherein the reactor wall comprises one or both of a polymer and a surfactant.

55. The reactor of claim 50, wherein the reactor wall is a porous membrane.

56. The reactor of claim 50 further comprising a soluble layer formed around the core, wherein the soluble layer contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.
57. The reactor of claim 56, wherein the soluble layer is formed between the core and the reactor wall.

58. The reactor of claim 56, wherein the layer is formed around the reactor wall.

59. The reactor of claim 50, wherein the reactor wall is a first wall, further comprising a second wall formed around the core to provide support for the reactor wall.

60. The reactor of claim 59, wherein the second reactor is one of a silicate based material, a combination of a polymer and a surfactant, or a porous membrane.

61. The reactor of claim 59, wherein the second wall is formed around the first wall.

62. The reactor of claim 59, wherein the second wall is formed between the core and the first wall.

63. The reactor of claim 59 further comprising a layer positioned between the first wall and the second wall, the layer containing one or more of a pH buffer, a stabilizer, and a reactant.

64. The reactor of claim 50, wherein the reactor wall comprises a combination of a polymer and an alloying compound.

65. The reactor of claim 50, wherein the core is one of a particle, granule, nugget, wafer, disc, briquette, and puck.

66. The reactor of claim 50, wherein the reactant is at least one of potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, and a Caro's acid precursor.
67. The method of claim 66, wherein the Caro’s acid precursor is a combination of a peroxide donor and a sulfuric acid donor.

68. The method of claim 67, wherein the peroxide donor is one of urea peroxide, calcium peroxide, magnesium peroxide, sodium peroxide, potassium peroxide, perborate, perphosphate, persilicate, and percarbonate, and wherein the sulfuric acid donor is one of sodium bisulfate and pyrosulfate.

69. The reactor of claim 1, wherein the target product is an N-halo-amine, the core comprising:

- about 10-80 wt.% an oxidant;
- about 0.5-20 wt.% a halogen donor;
- about 2-50 wt.% stabilizer;
- about 0-50 wt.% a binder;
- about 0-50 wt.% a filler; and
- about 0-30 wt.% a pH buffer, wherein the core is > about 50 wt.% solids.

70. The reactor of claim 69, wherein the reactor wall comprises a coating material that allows a polar solvent to permeate into the reactor space while restricting diffusion of the reactant and the target product out of the reactor space, the coating material having a lower solubility in the main solvent than the oxidant and the target product.

71. The reactor of claim 69, wherein the core is a homogeneous agglomeration of components.

72. The reactor of claim 69, wherein the reactor wall comprises a silicate-based material.
73. The reactor of claim 69, wherein the reactor wall comprises one or both of a polymer and a surfactant.

74. The reactor of claim 69, wherein the reactor wall is a porous membrane.

75. The reactor of claim 69 further comprising a soluble layer formed around the core, wherein the soluble layer contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.

76. The reactor of claim 75, wherein the layer is formed between the core and the reactor wall.

77. The reactor of claim 75, wherein the layer is formed around the reactor wall.

78. The reactor of claim 69, wherein the reactor space is a first reactor space and the reactor wall is a first wall, further comprising a second wall formed around the core to form the second reactor space having a pH level that is different from a pH level of the first reactor space.

79. The reactor of claim 78, wherein the second reactor is one of a silicate based material, a combination of a polymer and a surfactant, or a porous membrane.

80. The reactor of claim 78, wherein the chemical reaction is a first chemical reaction, and wherein a second chemical reaction occurs in the second reactor space to produce the target product.

81. The reactor of claim 78, wherein the second wall is formed around the first wall.
82. The reactor of claim 78, wherein the second wall is formed between the core and the first wall.

83. The reactor of claim 78 further comprising a layer positioned between the first wall and the second wall, the layer containing one or more of a pH buffer, a stabilizer, and a reactant.

84. The reactor of claim 69, wherein the reactor wall comprises a combination of a polymer and an alloying compound.

85. The reactor of claim 69, wherein the core is one of a particle, granule, nugget, wafer, disc, briquette, and puck.

86. The reactor of claim 69, wherein the reactant is one of potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate and Caro’s acid precursors.

87. The reactor of claim 86, wherein the reactant is a first reactant, the core further comprising a second reactant that is one of a monovalent metal salt, a divalent metal salt, and a trivalent metal salt.

88. The reactor of claim 86, wherein the core further comprises an N-hydrogen donor capable of reacting with hypo-halite to generate the target product.

89. The reactor of claim 69, wherein the core further comprises a chlorate donor.

90. The reactor of claim 69, wherein the pH buffer is an organic acid having 1-10 carbons and a carboxyl functional group.

91. The reactor of claim 69, wherein the pH buffer is an inorganic acid.
92. The reactor of claim 1, wherein the target product chlorine dioxide, the core comprising:
   about 10-80 wt.% an oxidant;
   about 0.5-20 wt.% a halogen donor;
   about 0.5 – 15 wt.% chlorite donor;
   about 0-50 wt.% a binder;
   about 0-50 wt.% a filler; and
   about 0-30 wt.% a pH buffer, wherein the core is > about 50 wt.% solids.

93. The reactor of claim 92, wherein the reactor wall comprises a coating material that allows a polar solvent to permeate into the reactor space while restricting diffusion of the reactant and the target product out of the reactor space, the coating material having a lower solubility in the main solvent than the oxidant and the target product.

94. The reactor of claim 92, wherein the core is a homogeneous agglomeration of components.

95. The reactor of claim 92, wherein the reactor wall comprises a silicate-based material.

96. The reactor of claim 92, wherein the reactor wall comprises one or both of a polymer and a surfactant.

97. The reactor of claim 92, wherein the reactor wall is a porous membrane.

98. The reactor of claim 92 further comprising a soluble layer formed around the core, wherein the soluble layer contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.
99. The reactor of claim 92, wherein the soluble layer is formed between the core and the reactor wall.

100. The reactor of claim 92, wherein the soluble layer is formed around the reactor wall.

101. The reactor of claim 92, wherein the reactor space is a first reactor space and the reactor wall is a first wall, further comprising a second wall formed around the core to form the second reactor space having a pH level that is different from a pH level of the first reactor space.

102. The reactor of claim 101, wherein the second reactor is one of a silicate based material, a combination of a polymer and a surfactant, or a porous membrane.

103. The reactor of claim 101, wherein the chemical reaction is a first chemical reaction, and wherein a second chemical reaction occurs in the second reactor space to produce the target product.

104. The reactor of claim 101, wherein the second wall is formed around the first wall.

105. The reactor of claim 101, wherein the second wall is formed between the core and the first wall.

106. The reactor of claim 101 further comprising a layer positioned between the first wall and the second wall, the layer containing one or more of a pH buffer, a stabilizer, and a reactant.

107. The reactor of claim 92, wherein the reactor wall comprises a combination of a polymer and an alloying compound.
108. The reactor of claim 92, wherein the core is one of a particle, granule, nugget, wafer, disc, briquette, and puck.

109. The reactor of claim 92, wherein the reactant is one of potassium, sodium, ammonium persulfate, potassium monopersulfate, permanganate and a Caro’s acid precursor.

110. The reactor of claim 109, wherein the halogen donor is a mono-valent or di-valent metal salt.

111. The reactor of claim 109, wherein the core further comprises a chlorate donor.

112. The reactor of claim 92, wherein the pH buffer comprises an organic acid having 1-10 carbons and a carboxyl functionality.

113. The reactor of claim 92, wherein the pH buffer comprises an inorganic acid.

114. The reactor of claim 92, wherein the reactant is one of urea peroxide, calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate, persulfate(s), monopersulfate, persilicate, perphosphate, sodium, lithium, potassium peroxide.

115. The reactor of claim 114, wherein the core further comprises a chlorate donor.

116. The reactor of claim 1, wherein the target product is a hydroxyl radical, the core comprising:
about 10-80 wt.% an oxidant;
about 0.001-10 wt.% a transition metal;
about 0-50 wt.% a binder;
about 0-50 wt.% a filler; and
about 1-30 wt.% a pH buffer, wherein the core is > about 50 wt.% solids.

117. The reactor of claim 116, wherein the reactor wall comprises a coating material that allows a polar solvent to permeate into the reactor space while restricting diffusion of the reactant and the target product out of the reactor space, the coating material having a lower solubility in the main solvent than the oxidant and the target product.

118. The reactor of claim 116, wherein the core is a homogeneous agglomeration of components.

119. The reactor of claim 116, wherein the reactor wall comprises a silicate-based material.

120. The reactor of claim 116, wherein the reactor wall comprises one or both of a polymer and a surfactant.

121. The reactor of claim 116, wherein the reactor wall is a porous membrane.

122. The reactor of claim 116 further comprising a soluble layer formed around the core, wherein the soluble layer contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polycarboxyamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.

123. The reactor of claim 122, wherein the soluble layer is formed between the core and the reactor wall.
124. The reactor of claim 122, wherein the soluble layer is formed around the reactor wall.

125. The reactor of claim 116, wherein the reactor space is a first reactor space and the reactor wall is a first wall, further comprising a second wall formed around the core to form the second reactor space having a pH level that is different from a pH level of the first reactor space.

126. The reactor of claim 116, wherein the second reactor is one of a silicate based material, a combination of a polymer and a surfactant, or a porous membrane.

127. The reactor of claim 126, wherein the chemical reaction is a first chemical reaction, and wherein a second chemical reaction occurs in the second reactor space to produce the target product.

128. The reactor of claim 126, wherein the second wall is formed around the first wall.

129. The reactor of claim 126, wherein the second wall is formed between the core and the first wall.

130. The reactor of claim 125 further comprising a layer positioned between the first wall and the second wall, the layer containing one or more of a pH buffer, a stabilizer, and a reactant.

131. The reactor of claim 116, wherein the reactor wall comprises a combination of a polymer and an alloying compound.

132. The reactor of claim 116, wherein the core is one of a particle, granule, nugget, wafer, disc, briquette, and puck.
133. The reactor of claim 116, wherein the reactant is one of urea peroxide, calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate, persulfate(s), monopersulfate, persilicate, perphosphate, sodium, lithium, permanganate, and potassium peroxide.

134. The reactor of claim 116, wherein the transition metal is a chelating agent selected from a group consisting of trisodium pyrophosphate, tetrasodium diphosphate, sodium hexametaphosphate, sodium trimetaphosphate, sodium tripolyphosphate, potassium tripolyphosphate, phosphonic acid, di-phosphonic acid compound, tri-phosphonic acid compound, a salt of a phosphonic acid compound, ethylene diamine-tetra-acetic acid, gluconate, or other ligand forming compound.

135. The reactor of claim 116, wherein the pH buffer is an organic acid having 1-10 carbons and at least one carboxyl functional group.

136. The reactor of claim 116, wherein the pH buffer is an inorganic acid.

137. The reactor of claim 116 further comprising a metal catalyst in the core.

138. The reactor of claim 137, wherein the metal catalyst is selected from a group consisting of: Cu (II), Mn (II), Co (II), Fe (II), Fe (III), Ni (II), Ti (IV), Mo (V), Mo (VI), W (VI), Ru (III), and Ru (IV).

139. The reactor of claim 137, wherein the metal catalyst is coated on the core.

140. The reactor of claim 137 further comprising a non-solvent component in the reactor wall, wherein the metal catalyst is combined with the non-solvent component of the membrane coating, whereby removal of the volatile non-solvent component results in formation of channels and pores that are lined with the metal catalyst.
141. A method of making a reactor that generates a target product when placed in contact with a main solvent, the method comprising:

preparing a core containing a reactant that, upon contacting the main solvent, generates the target product through a chemical reaction; and

5 forming a reactor wall around a reactor space such that the reactor space contains the core, the reactor wall allowing a controlled permeation of the main solvent into the reactor space wherein the chemical reaction occurs in the reactor space, and wherein the target product leaves the reactor space at a predetermined rate.

142. The method of claim 141 further comprising forming the reactor wall such that the reactor wall disintegrates when the concentration of the target product in the main solvent outside of the reactor is equal to or greater than a predetermined level.

143. The method of claim 141 further comprising forming the reactor wall such that the reactor wall disintegrates when the concentration of the target product is equal to or greater than the critical level.

144. The method of claim 141, wherein the reactant is an oxidizer.

145. The method of claim 141, wherein preparing the core comprises mixing and agglomerating core components.

146. The method of claim 145 further comprising adding a binder to the core.

147. The method of claim 145 further comprising drying the agglomerated core components simultaneously with the forming of the reactor wall.

148. The method of claim 145 further comprising drying the agglomerated core components before the forming of the reactor wall.
149. The method of claim 141, wherein forming the reactor wall comprises applying a coating material in the form of a liquid, gel, suspension, or foam.

150. The method of claim 141, wherein forming the reactor wall comprises:

dissolving a silicate-based material in a silicate solvent to form a silicate solution;

and applying the silicate solution to the core.

151. The method of claim 141, wherein forming the reactor wall comprises:
combining a hydrophobic polymer, a hydrophilic component, and an amphipathic component to form an emulsion; and coating the core with the emulsion.

152. The method of claim 151 further comprising removing the hydrophilic component to form pores in the reactor wall.

153. The method of claim 141, wherein forming the reactor wall comprises forming a porous membrane.

154. The method of claim 153, wherein the porous membrane comprises a polymer, a solvent, and a non-solvent.

155. The method of claim 154, wherein polymer is hydrophobic, further comprising:
forming a mixture of the polymer and the solvent;
coating the core with the mixture to form a mixture layer; and applying the non-solvent on the mixture layer.

156. The method of claim 154, wherein the forming of the porous membrane comprises:
dissolving the polymer in the solvent to form a polymer solution;
adding the non-solvent to the polymer solution to form a polymer mixture; and
coating the core with the polymer mixture.

157. The method of claim 156, wherein the non-solvent is soluble in the
solvent, further comprising adjusting a porosity of the membrane by varying an amount
of the non-solvent.

158. The method of claim 154 further comprising removing portions of the
solvent and non-solvent.

159. The method of claim 158 further comprising combining the non-solvent
with a metal catalyst so that the metal catalyst remains on the reactor wall after the
removing of the non-solvent.

160. The method of claim 158, wherein the removing comprises evaporating.

161. The method of claim 154 further comprising combining the polymer with
an additive, wherein the additive is one of an alloying agent, a cross-linking agent, and a
plasticizer.

162. The method of claim 154, wherein the reactor wall comprises a
hydrophobic polymer precursor, a cross-linking agent, a solvent, and a non-solvent, and
wherein the forming of the reactor wall comprises:
applying a coating material on the core to form a film;
coating the film with an effective amount of oxidizer to induce polymerization
between the polymer precursor and the cross-linking agent to form the reactor wall;
forming pores in the reactor wall by removing the solvent and the non-solvent.

163. The method of claim 141 further comprising forming a soluble layer
around the core, wherein the soluble layer contains at least one of a silicate, a cellulose,
chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.

164. The method of claim 163 further comprising forming the soluble layer between the reactor wall and the core.

165. The method of claim 163 further comprising forming the soluble layer around the reactor wall.

166. The method of claim 141, wherein the reactor wall is a first reactor wall, further comprising forming a second reactor wall that supports the first reactor wall.

167. The method of claim 166 further comprising forming an intermediate layer between the first reactor wall and the second reactor wall, wherein the intermediate layer contains one or more of a pH buffer, a stabilizer, or a reactant for the chemical reaction.

168. The method of claim 141, wherein the target product is dioxirane, and wherein preparing the core comprises:

- combining an oxidant in an amount of about 10-80 wt.% of the core, one or more carbonyl donors in an amount of about 0.5-20 wt.% of the core, a binder in an amount of about 0-50 wt.% of the core, a filler in an amount of about 0-50 wt.% of the core, and a pH buffering agent in an amount of about 0-30 wt.% of the core such that at least about 50 wt.% of the core is solids.

169. The method of claim 168, wherein preparing the core comprises mixing core components to produce an agglomerate.

170. The method of claim 168 further comprising:

- drying the core; and

- coating the core with one of: a silicate-based material, a mixture of a polymer and a surfactant, and a porous membrane.
171. The method of claim 168, wherein the reactor wall, upon contact with a polar solvent, allows the solvent to permeate into the reactor space while restricting a diffusion of the reactant and the target product out of the reactor.

172. The method of claim 168, wherein a solubility of the reactor wall in the main solvent is lower than a solubility of the oxidant and the solubility of the target product in the main solvent.

173. The method of claim 168, wherein the reactant is at least one of potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, and a Caro’s acid precursor.

174. The method of claim 173, wherein the Caro’s acid precursor is one of a peroxide donor and a sulfuric acid donor.

175. The method of claim 174, wherein the peroxide donor is one of urea peroxide, calcium peroxide, magnesium peroxide, sodium peroxide, potassium peroxide, perborate, perphosphate, persilicate, and percarbonate, and wherein the sulfuric acid donor is one of sodium bisulfate and pyrosulfate.

176. The method of claim 173, wherein the reactant is an oxidizer reactant, the core further comprising an oxidizable reactant having 3-20 carbons and at least one carbonyl group.

177. The method of claim 141, wherein the target product is percarboxylic acid, and wherein preparing the core comprises:

- combining an oxidant in an amount of about 10-80 wt.% of the core, one or more carboxyl group donors in an amount of about 1-40 wt.% of the core, a binder in an amount of about 0-50 wt.% of the core, and a filler in an amount of about 0-50 wt.% of the core.
core, and a pH buffering agent in an amount of about 0-30 wt.% of the core, such that at least about 50 wt.% of the core is solids.

178. The method of claim 177, wherein preparing the core comprises mixing core components to produce an agglomerate.

179. The method of claim 177 further comprising:

drying the core; and

coating the core with one of: a silicate-based material, a mixture of a polymer and a surfactant, and a porous membrane.

180. The method of claim 177, wherein the reactor wall, upon contact with a polar solvent, allows the solvent to permeate into the reactor space while restricting a diffusion of the reactant and the target product out of the reactor.

181. The method of claim 177, wherein a solubility of the reactor wall in the main solvent is lower than a solubility of the oxidant and the solubility of the target product in the main solvent.

182. The method of claim 177, wherein the reactant is one of urea peroxide, calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate, persulfate(s), monopersulfate, persilicate, perphosphate, sodium peroxide, lithium peroxide, permanganate, and potassium peroxide.

183. The method of claim 177, wherein the reactant is a first reactant, the one or more of the carboxyl group donors include a second reactant having 1-20 carbons and a carboxylic acid functional group.

184. The method of claim 141, wherein the target product is hypohalite and wherein preparing the core comprises:
combining an oxidant in an amount of about 10-80 wt.% of the core, a halogen donor in an amount of about 0.5-20 wt.% of the core, a binder in an amount of about 0-50 wt.% of the core, a filler in an amount of about 0-50 wt.% of the core, and a pH buffering agent in an amount of about 0-30 wt.% of the core such that at least about 50 wt.% of the core is solids.

185. The method of claim 184, wherein preparing the core comprises mixing core components to produce an agglomerate.

186. The method of claim 184 further comprising applying a film around the core, wherein the film contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polycrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.

187. The method of claim 184, wherein the reactor wall, upon contact with a polar solvent, allows the solvent to permeate into the reactor space while restricting a diffusion of the reactant and the target product out of the reactor.

188. The method of claim 184, wherein a solubility of the reactor wall in the main solvent is lower than a solubility of the oxidant and the solubility of the target product in the main solvent.

189. The method of claim 184, wherein forming the reactor wall comprises: mixing an alloying compound with a coating material to form an alloyed mixture; and depositing the alloyed mixture on the core.

190. The method of claim 189, wherein the alloying compound is a cross-linking agent.

191. The method of claim 184, wherein forming the reactor wall comprises:
drying the core; and

wherein forming the reactor wall further comprises applying a film around the core, wherein the film contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.

192. The method of claim 191, wherein the depositing of the coating material is performed after the core is dry.

193. The method of claim 184 further comprising shaping a core in a preselected size and shape.

194. The method of claim 184, wherein the reactant is at least one of potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, and a Caro’s acid precursor.

195. The method of claim 141, wherein the target product is an N-halo-amine and wherein preparing the core comprises:

combining an oxidant in an amount of about 10-80 wt.% of the core, a halogen donor in an amount of about 0.5-20 wt.% of the core, a stabilizer in an amount of about 2-50 wt.% of the core, a binder in an amount of about 0-50 wt.% of the core, a filler in an amount of about 0-50 wt.% of the core, and a pH buffering agent in an amount of about 0-30 wt.% of the core such that at least about 50 wt.% of the core is solids.

196. The method of claim 195, wherein preparing the core comprises mixing core components to produce an agglomerate.

197. The method of claim 195 further comprising:

drying the core; and

coating the core with one of: a silicate-based material, a mixture of a polymer and a surfactant, and a porous membrane.
198. The method of claim 195, wherein the reactor wall, upon contact with a polar solvent, allows the solvent to permeate into the reactor space while restricting a diffusion of the reactant and the target product out of the reactor.

199. The method of claim 195, wherein a solubility of the reactor wall in the main solvent is lower than a solubility of the oxidant and the solubility of the target product in the main solvent.

200. The method of claim 195, wherein forming the reactor wall comprises: mixing an alloying compound with a coating material to form an alloyed mixture; and depositing the alloyed mixture on the core.

201. The method of claim 200, wherein the alloying compound is a cross-linking agent.

202. The method of claim 195, wherein forming the reactor wall further comprises applying a film around the core, wherein the film contains at least one of a silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides, polyvinylalcohols, polyethylene glycols, their respective surrogates.

203. The method of claim 202, wherein the depositing of the coating material is performed after the core is dry.

204. The method of claim 195 further comprising forming the core in a preselected size and shape.

205. The method of claim 195, wherein the reactant is one of potassium persulfate, sodium persulfate, ammonium persulfate, potassium monopersulfate, permanganate, and Caro’s acid precursors.
206. The method of claim 195, wherein the halogen donor is one of a monovalent metal salt, divalent metal salt and a trivalent metal salt.

207. The method of claim 195, wherein the core further comprises an N-hydrogen donor capable of reacting with hypo-halite to generate the target product.

208. The method of claim 141, wherein the target product is chlorine dioxide and wherein preparing the core comprises:

combining an oxidant in an amount of about 10-80 wt.% of the core, a halogen donor in an amount of about 0.5-20 wt.% of the core, a chlorite donor in an amount of about 0.5-15 wt.% of the core, a binder in an amount of about 0-50 wt.% of the core, a filler in an amount of about 0-50 wt.% of the core, and a pH buffering agent in an amount of about 0-30 wt.% of the core such that at least about 50 wt.% of the core is solids.

209. The method of claim 208, wherein preparing the core comprises mixing core components to produce an agglomerate.

210. The method of claim 208 further comprising:

drying the core; and

coating the core with one of: a silicate-based material, a mixture of a polymer and a surfactant, and a porous membrane.

211. The method of claim 208, wherein the reactor wall, upon contact with a polar solvent, allows the solvent to permeate into the reactor space while restricting a diffusion of the reactant and the target product out of the reactor.

212. The method of claim 208, wherein a solubility of the reactor wall in the main solvent is lower than a solubility of the oxidant and the solubility of the target product in the main solvent.
213. The method of claim 208, wherein forming the reactor wall comprises:
mixing an alloying compound with a coating material to form an alloyed mixture;
and
depositing the alloyed mixture on the core.

214. The method of claim 213, wherein the alloying compound is a cross-
linking agent.

215. The method of claim 208, wherein forming the reactor wall further
comprises applying a film around the core, wherein the film contains at least one of a
silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides,
polyvinylalcohols, polyethylene glycols, their respective surrogates.

216. The method of claim 215, wherein the applying of the film is performed
after the core is dry.

217. The method of claim 208 further comprising shaping a core in a
preselected size and shape.

218. The method of claim 208, wherein the reactant is one of urea peroxide,
calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate,
persulfate(s), monopersulfate, persilicate, perphosphate, sodium, lithium, potassium
peroxide, and permanganate.

219. The method of claim 208, wherein the halogen donor is one of a
monovalent or divalent metal salt.

220. The method of claim 141, wherein the target product is hydroxyl radicals
and wherein preparing the core comprises:
combining an oxidant in an amount of about 10-80 wt.% of the core, transition
metal in an amount of about 0.001-10 wt.% of the core, a binder in an amount of about 0-
50 wt.% of the core, a filler in an amount of about 0-50 wt.% of the core, and a pH buffering agent in an amount of about 1-30 wt.% of the core such that at least about 50 wt.% of the core is solids.

221. The method of claim 220, wherein preparing the core comprises mixing core components to produce an agglomerate.

222. The method of claim 220 further comprising:

drying the core; and

coating the core with one of: a silicate-based material, a mixture of a polymer and a surfactant, and a porous membrane.

223. The method of claim 222, wherein the film comprises a metal catalyst for the chemical reaction.

224. The method of claim 223 further comprising:

combining the metal catalyst with a non-solvent component to generate a catalyst mixture;

applying the catalyst mixture on the core to form the reactor wall; and

removing the non-solvent component, leaving pores in the reactor wall including the metal catalyst.

225. The method of claim 220, wherein the reactor wall, upon contact with a polar solvent, allows the solvent to permeate into the reactor space while restricting a diffusion of the reactant and the target product out of the reactor.

226. The method of claim 220, wherein a solubility of the reactor wall in the main solvent is lower than a solubility of the oxidant and the solubility of the target product in the main solvent.
227. The method of claim 220, wherein forming the reactor wall comprises:

mixing an alloying compound with a coating material to form an alloyed mixture;

and

depositing the alloyed mixture on the core.

228. The method of claim 227, wherein the alloying compound is a cross-
linking agent.

229. The method of claim 220, wherein forming the reactor wall further

comprises applying a film around the core, wherein the film contains at least one of a
silicate, a cellulose, chitin, chitosan, polymaleic acid, polyacrylic acid, polyacrylamides,
polyvinylalcohols, polyethylene glycols, their respective surrogates.

230. The method of claim 228, wherein the applying the film is performed after
the core is dry.

231. The method of claim 220 further comprising shaping a core in a
preselected size and shape.

232. The method of claim 220, wherein the reactant is one of urea peroxide,
calcium peroxide, magnesium peroxide, sodium percarbonate sodium perborate,
persulfate(s), monopersulfate, persilicate, perphosphate, sodium, lithium, and potassium
peroxide.

233. The method of claim 220, wherein the transition metal is a chelating agent
selected from a group consisting of trisodium pyrophosphate, tetradsodium diphosphate,
sodium hexametaphosphate, sodium trimetaphosphate, sodium tripolyphosphate,
potassium tripolyphosphate, phosphonic acid, di-phosphonic acid compound, tri-
phosphonic acid compound, a salt of a phosphonic acid compound, ethylene dianine-
tetra-acetic acid, gluconate, or other ligand forming compound.
234. The method of claim 220 further comprising adding a metal catalyst to the reactor, wherein the metal catalyst is one of Cu (II), Mn (II), Co (II), Fe (II), Fe (III), Ni (II), Ti (IV), Mo (V), Mo (VI), W (VI), Ru (III), and Ru (IV).
Low pH Acetate Conversion

PMPS Ketone Percarbonate Acetate

Fig 4A
Moisture Contact
Osmotic Pressure Builds

Coating dissolved
Micro-porous
Membrane exposed

Alkali Salt Dissolves

Silicate- Hydrolyzes
Colloidal Gel forms

Core Dissolves
Dioxirane/PAA/PMPS
Diffuse – molecular diffusion
Colloidal Gel
Osmotic Pressure
Collapses membrane
PAA/Dioxirane/PMPS
Solution excreted
Neutral to Alkaline pH Precursor Conversion

Fig 5A