



(51) International Patent Classification:
B65B 55/14 (2006.01)

(21) International Application Number:
PCT/US2012/070293

(22) International Filing Date:
18 December 2012 (18.12.2012)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,

HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

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

(54) Title: THERMOSTATIC PACKAGING

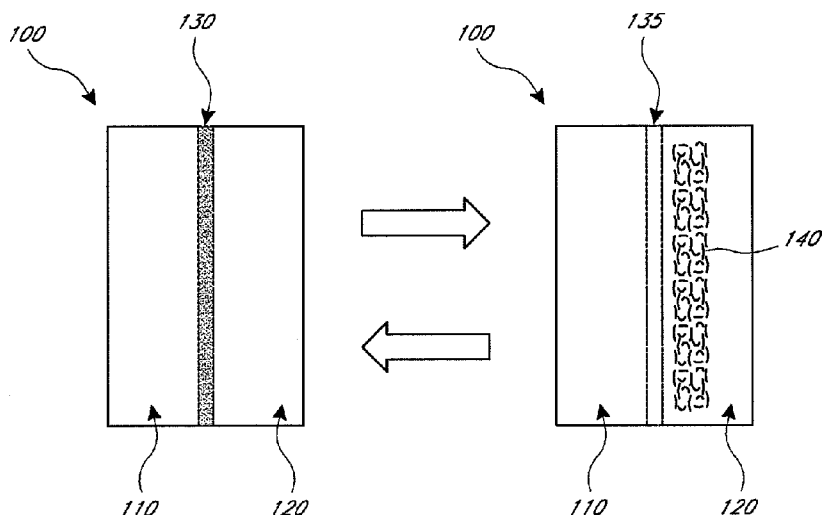


FIG. 1

(57) Abstract: Arrangements and methods for thermostatic packaging are provided herein. In some embodiments, in response to a change in temperature, an endothermic or exothermic reaction can be initiated to counteract the change in temperature.



THERMOSTATIC PACKAGING

Technical Field

[0001] Embodiments provided herein relate generally to arrangements and apparatuses for thermostatic arrangements, and methods of maintaining and/or controlling a temperature.

Background

[0002] A variety of technologies exist for controlling and/or regulating the temperature of a storage space. Such technologies can be effective in a number of ways. In some situations, a storage space can simply be isolated from its environment, such as with an ice chest, thereby passively regulating the temperature of the storage space. In other situations, a more active temperature regulation can be achieved by employing, for example, a thermostat and cooling system, such as used in a refrigerator.

SUMMARY

[0003] Some embodiments provided herein include a cooling system that includes a first reactant and a second reactant. In some embodiments, the first reactant can endothermically react with the second reactant to absorb heat. In some embodiments, the cooling system can include a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant. In some embodiments, at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant. In some embodiments, at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

[0004] Some embodiments provided herein include a method of regulating a temperature. The method can include providing a cooling system. The cooling system can include a first reactant, a second reactant, and a temperature-responsive divider. In some embodiments, the first reactant can react endothermically with the second reactant. In some embodiments, the temperature-responsive divider positioned between at least a

part of the first reactant from at least a part of the second reactant. The method can include changing a first conformation of the temperature-responsive divider to a second conformation of the temperature-responsive divider upon an increase in temperature, such that the second conformation permits the first reactant, the second reactant, or the first and the second reactant to pass through the temperature-responsive divider such that an endothermic reaction occurs.

[0005] Some embodiments provided herein include a packaging. The packaging can include a first reactant. The packaging can include a second reactant. The packaging can include a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant. In some embodiments, the first reactant can endothermically react with the second reactant to absorb heat. In some embodiments, at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant. In some embodiments, at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

[0006] Some embodiments provided herein include a method of preparing a cooling system. The method can include providing a first reactant and providing a second reactant, such that the first reactant can endothermically react with the second reactant to absorb heat. The method can include providing a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant. In some embodiments, at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant. In some embodiments, at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

[0007] In some embodiments, any one or more of the endothermic devices and/or methods provided herein can be applied to an exothermic arrangement as well, simply by swapping the first and second reactants for reactants that produce an exothermic reaction.

[0008] In some embodiments, a heating system is provided. The heating system can include a first reactant and a second reactant. The first reactant can exothermically react with the second reactant to emit heat. The system can include a

temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant. At a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant. At a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

[0009] In some embodiments a method of regulating a temperature is provided. The method can include providing a heating system. The heating system can include a first reactant and a second reactant, wherein the first reactant can react exothermically with the second reactant. The system can include a temperature-responsive divider positioned between at least a part of the first reactant from at least a part of the second reactant. The method can further include changing a first conformation of the temperature-responsive divider to a second conformation of the temperature-responsive divider upon a decrease in temperature. The second conformation permits the first reactant, the second reactant, or the first and the second reactant to pass through the temperature-responsive divider such that an exothermic reaction occurs.

[0010] In some embodiments a packaging is provided and includes a first reactant and a second reactant. The first reactant can exothermically react with the second reactant to emit heat. A temperature-responsive divider can be positioned between at least some of the first reactant and at least some of the second reactant. At a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant. At a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

[0011] In some embodiments a method of preparing a heating system is provided. The method can include providing a first reactant and providing a second reactant. The first reactant can exothermically react with the second reactant to emit heat. The method can include providing a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant. At a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant. At a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

[0012] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **Fig. 1** illustrates some embodiments of a thermostatic packaging.

[0014] **Fig. 2** is a flow diagram illustrating some embodiments of a method of regulating temperature.

[0015] **Fig. 3** is a drawing illustrating some embodiments of a temperature-responsive divider.

[0016] **Fig. 4** is a flow diagram illustrating some embodiments of a method of preparing a cooling system.

DETAILED DESCRIPTION

[0017] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0018] Some embodiments provided herein relate to temperature regulation. While there are a variety of technologies by which this can be achieved, some embodiments provided herein achieve temperature regulation by at least initially maintaining two or more reactants separate from one another. The two or more reactants are then combined in a temperature dependent manner. In some embodiments, this can be achieved by separating the two or more reactants by a temperature-responsive divider. The divider can open and/or close in response to a change in heat (for example, an increase in heat). The opening of the divider allows the two reactants to mix, allowing for

a subsequent heat altering reaction to occur. For the sake of simplicity, the bulk of the following description focuses on arrangements in which an increase in heat results in the opening of the temperature-responsive divider, which in turn allows the two reactants to interact and produce an endothermic reaction, which lowers the local temperature. However, as outlined herein as well, in some embodiments, the device and/or methods can be arranged so as to provide an exothermic reaction and thereby provide an increase in temperature.

[0019] **Fig. 1** illustrates some embodiments of a section of a thermostatic package **100** that can include aspects of the technology provided herein. The arrangement can include a first reactant **110** and a second reactant **120**. The first reactant can be separated from the second reactant by a temperature-responsive divider **130** that is effectively impermeable to at least one of the two reactants at a first temperature. At a second temperature (either lower or higher than the first), the temperature-responsive divider undergoes a change to form a permeable temperature-responsive divider **135**. The permeable temperature-responsive divider is permeable to at least one of the reactants **135**, such that the reactants interact at a reaction site **140**. In some embodiments, the reaction at the reaction site **140** is endothermic. In some embodiments, the reaction at the reaction site **140** is exothermic.

[0020] In some embodiments, a temperature-responsive divider separates a pair of reactants from each other when the temperature is below a threshold, but permits the reactants to react with each other when the temperature passes above the threshold. In some embodiments, the divider can open mechanically, thus permitting a liquid or gel reactant to pass through pores and/or holes in the temperature-responsive divider. In some embodiments, the hydrophobicity of the divider can change, thus permitting a molecule to pass through depending upon the molecule's hydrophobic properties. Additional options for temperature-responsive dividers are discussed below.

[0021] In some embodiments, the first reactant is one that reacts with the second reactant to produce an endothermic reaction. In some embodiments, the first reactant is one that reacts with the second reactant to produce an exothermic reaction.

[0022] In some embodiments, a temperature-responsive divider is positioned between some (or all) of the first reactant, and some (or all) of the second reactant.

[0023] In some embodiments, at a temperature within an acceptable range, the temperature-responsive divider is effectively impermeable to the first reactant, the second

reactant, or both reactants, such that the reactants do not react with each other. However, at a temperature outside of the acceptable range (which can be any predetermined and/or desired range), the temperature-responsive divider can be permeable to one or both of the first and second reactant, such that these reactants react and allow for the appropriate reaction to occur. The endo- or exothermicity of the reaction can return the temperature to the acceptable range.

[0024] In some embodiments, the method and/or device can be applied in a thermostatic package. The thermostatic package can include any number of arrangements of reactants and/or other parts. In some embodiments, the package can include a first reactant and a second reactant separated by a temperature-responsive divider. An object to be kept cool (or warm) can be placed within and/or adjacent to the packaging, allowing for temperature regulation of the object. In some embodiments, the divider separates a solvent from the first and second reactants.

[0025] Some embodiments of the method of employing this technology can include providing an arrangement of thermostatic packaging as described herein and changing a first, effectively sealed, conformation of a temperature-responsive divider to a second, permeable, conformation upon a change in temperature, such that a pair of reactants as described herein interact with each other, thus consuming (or producing) heat to counteract the change of temperature that initially changed the state of the temperature-responsive divider.

[0026] **Fig. 2** is a flow diagram illustrating some embodiments of a method of regulating a temperature. The method can include providing a cooling system that includes a first reactant and a second reactant. When allowed, the first reactant can react endothermically (or alternatively, exothermically) with the second reactant, however, initially there is a closed temperature-responsive divider positioned between at least a part of the first reactant from at least a part of the second reactant **200**. The method includes changing a first conformation of the temperature-responsive divider to a second conformation of the temperature-responsive divider upon an increase (or decrease) in temperature. The the second conformation permits the first reactant, the second reactant, or the first and the second reactant to pass through the temperature-responsive divider such that an endothermic (or exothermic) reaction occurs **210**. The resulting change in heat from the endothermic (or exothermic) reaction can then be used to cool (or heat) and

volume of space and/or an object **220**. As noted herein, the divider can also be used to separate a solvent from one or both of the reactants as well to the same ends.

[0027] One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods may be implemented in differing order. Furthermore, the outlined steps and operations are only provided as examples, and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

[0028] In some embodiments, the method includes effectively separating the first reactant (and/or solvent) from the second reactant (and/or solvent) at the first temperature. In some embodiments, all or substantially all of the first reactant (and/or solvent) is separated from the second reactant (and/or solvent) at the first temperature. In some embodiments, only a portion of the first reactant (and/or solvent) is separated from the second reactant, and/or only a portion of the second reactant (and/or solvent) is separated from the first reactant (and/or solvent) at the second temperature. Thus, in some embodiments, some basal level of cooling and/or heating can occur, and the change in conformation of the temperature-responsive divider merely increases and/or decreases the extent of the cooling and/or heating by allowing for more of the reactants to interact or less of the reactants to interact. In some embodiments, the first reactant (and/or solvent) is completely separated from the second reactant (and/or solvent) by the temperature-responsive divider until a change in temperature changes the temperature-responsive divider to its reactant permeable state.

[0029] In some embodiments, the method can include changing the conformation of the temperature-responsive divider from a first configuration in which the reactants of a reactant pair are separated by the divider and do not mix (e.g. a “closed” configuration) to a second configuration in which the reactants of the reactant pair can mix (e.g. an “open” configuration).

[0030] In some embodiments, the temperature-responsive divider includes an expandable sheet with slits that are effectively sealed to one or both of the reactants. The method can include straining the expandable sheet so that at least one perforation opens at the slit. In some embodiments, strain can be applied to one axis of the sheet. In some embodiments, strain is applied to two or more axes of the sheet.

[0031] In some embodiments, the conformation of the temperature-responsive divider changes upon a decrease in the local temperature. In some embodiments, the conformation of the temperature-responsive divider is changed when the local temperature is above or below a pre-determined threshold temperature. In some embodiments, for example embodiments in which the reactants are configured to act endothermically, the conformation of the divider changes to permit the reactants to mix when the local temperature exceeds the threshold temperature. In some embodiments, for example embodiments in which the reactants are configured to act exothermically, the conformation changes to permit the reactants to mix when the local temperature is below the threshold temperature. In some embodiments, the threshold temperature is about -10°C, -5°C, -1°C, 0°C, 1°C, 2°C, 3°C, 4°C, 5°C, 6°C, 7°C, 8°C, 9°C, 10°C, 11°C, 12°C, 13°C, 14°C, 15°C, 17°C, 20°C, 22°C, 25°C, 27°C, 30°C, 34°C, 37°C, 40°C, 45°C, or 50°C, including any range above any one of the preceding values and any range between any two of the preceding values. Thus, in some embodiments, when the temperature threshold is crossed, the temperature-responsive divider changes conformation to allow the first and/or second reactants to intermix, changing the local temperature back towards its starting value and thereby maintaining a local temperature within a desired range.

[0032] In some embodiments the method includes changing the local temperature by at least about 0.5°C in response to a change in local temperature, for example at least about 0.5°C, 1°C, 2°C, 3°C, 4°C, 5°C, 6°C, 7°C, 8°C, 9°C, 10°C, 11°C, 12°C, 13°C, 14°C, 15°C, 20°C, 30°C, 40°C, 50°C, 60°C, 70°C, 80°C, 90°C, or 100°C, including any range between any two of the listed values. In some embodiments, for example embodiments in which the reactants are selected to react endothermically, the change in temperature is an increase. In some embodiments, for example embodiments in which the reactants are selected to react exothermically, the change in temperature is a decrease.

[0033] In some embodiments, the opening of the temperature-responsive divider is reversible. Accordingly, in some embodiments, the method includes changing the conformation of the temperature-responsive divider from the second configuration (e.g. an “open” configuration) back to the first configuration (e.g. a “closed” configuration). In some embodiments, the conformation is changed back when the temperature crossed the threshold temperature to its initial temperature.

[0034] In some embodiments, the method includes at least 2 cycles of changing the conformation of the temperature-responsive divider from the second configuration back to the first configuration, for example at least about 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 17, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120, 150, 200, 300, 400, 500, or more cycles. In some embodiments, the temperature-responsive divider is capable of changing its conformation from the open to the closed and/or closed to the open state any number of times, for example, at least about 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 17, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120, 150, 200, 300, 400, 500 or more cycles.

[0035] In some embodiments, the open state of the temperature-responsive divider is maintained as long as the temperature exceeds a threshold level. Thus, the reaction is allowed to occur for as long as required in order to revert the local temperature to a level beneath (or above) the threshold level. Thus, in some embodiments, the system and/or method can be self-regulating so that excessive levels of cooling or heating by the system can be avoided and/or minimized.

[0036] In some embodiments, changing the first conformation of the temperature-responsive divider to the second conformation includes changing the conformation of a temperature-responsive actuator.

[0037] In some embodiments, changing the first conformation of the temperature-responsive divider to the second conformation includes changing at least a portion of the surface of a polymer of the temperature-responsive divider from a hydrophilic state to a hydrophobic state.

[0038] In some embodiments, any divider can be used as a temperature-responsive divider, as long as the divider can transition between impermeable to permeable for one or more of the reactants, in response to a change in temperature. In some embodiments, the divider can transition back to impermeable from its permeable state.

[0039] In some embodiments, a temperature-responsive divider prevents (or reduces or minimizes) reactants from reacting with each other at a first temperature, but allows the reactants to react with each other when the temperature is at a different, second temperature. In some embodiments, for example embodiments in which the arrangement is configured to cool via an endothermic reaction, the second temperature is greater than the first temperature. In some embodiments, for example embodiments in which the

arrangement is configured to heat via an exothermic reaction, the second temperature is less than the first temperature.

[0040] In some embodiments, the temperature-responsive divider can be positioned between at least a portion of one reactant and at least a portion of the other reactant. In some embodiments, the temperature-responsive divider is positioned between all of one reactant, and all of the other reactant. In some embodiments, the temperature-responsive divider is positioned between substantially all of one reactant, and substantially all of the other reactant. In some embodiments, the temperature-responsive divider is positioned between substantially all of one reactant, and only a portion of the other reactant. In some embodiments, the temperature-responsive divider is positioned between only a portion of one reactant, and only a portion of the other reactant. In some embodiments, the temperature-responsive divider is positioned between at least about 70% of each reactant, for example, at least about 70%, 75%, 80%, 85%, 90%, 95%, 97%, 98%, 99%, 99.5%, or 99.9% of each reactant, including any range above any one of the preceding values.

[0041] In some embodiments, the temperature-responsive divider prevents (or reduces or minimizes) the reactants from reacting with each other at the first temperature by being impermeable to one or more of the reactants. In some embodiments, for example embodiments in which each reactant is a liquid, the temperature-responsive divider is impermeable to both reactants at the first temperature but is permeable to one or both at the second temperature. In some embodiments, for example embodiments in which a first reactant is a liquid and a second reactant is a solid, the temperature-responsive divider is impermeable to the first reactant at the first temperature, but permeable at the second temperature. In some embodiments, for example embodiments in which each reactant is a solid, the temperature-responsive divider is impermeable to a solvent that can dissolve one or more of the reactants at the first temperature, but is permeable to the solvent at the second temperature. In some embodiments, a solvent can be used to regulate the reaction indirectly. For example, rather than controlling the physical interaction of the two reactants, in some embodiments, the two reactants can be combined in an inert form, for example as a dried solid mixture, whereby the addition of water solvates both reactants into a form in which an exothermic or an endothermic reaction can occur. Thus, any of the embodiments provided herein can also be configured in a form where the two or more reactants are already combined, but are inert, until a

solvent is added. In such embodiments, the solvent can be kept separated from the premixed reactants by the temperature-responsive divider, and thus, the opening of the temperature sensitive divider will allow for the solvent to dissolve the two reactants and the appropriate change in heat to occur.

[0042] In some embodiments, for example embodiments in which the arrangement is configured to cool a product by initiating an endothermic reaction, the temperature-responsive divider prevents reactants from interacting with each other when the temperature is below a threshold temperature, but allows the reactants to interact with each other when the temperature is above a threshold temperature. In some embodiments, for example embodiments in which the arrangement is configured to heat a product by initiating an exothermic reaction, the temperature-responsive divider prevents reactants from interacting with each other when the temperature is above a threshold temperature, but allows the reactants to interact with each other when the temperature is below a threshold temperature.

[0043] In some embodiments, the temperature-responsive divider allows the reactants to react with each other at the second temperature by being permeable to one or more of the reactants at the second temperature. In some embodiments, for example embodiments in which each reactant is a liquid, the temperature-responsive divider allows the reactants to react with each other at the second temperature by being permeable to all of the reactants at the second temperature. In some embodiments, for example embodiments in which the first reactant is a liquid and the second reactant is a solid or gel, the temperature-responsive divider allows the reactants to react with each other at the second temperature by being permeable to the first reactant. The temperature-responsive divider can be made of any material, for example, rubber and/or elastomer.

[0044] Some embodiments of a temperature-responsive divider **300** are illustrated in **Fig. 3**. As shown in the left side of **Fig. 3**, the body **310** of the temperature-responsive divider can include at least one perforation or slit **320**, which is present in a first conformation of the divider **300**. The perforation or slit does not allow, or only allows an insubstantial amount of, interaction between the reactants. Thus, the divider provides an effective barrier or device for separating the first and second reactants. At a temperature that exceeds a threshold **350**, the divider adopts a second conformation (right-hand side of **Fig. 3**). This conformational change can be spread throughout the body **310**

of the divider so that numerous holes **370** are opened up from the previous perforations or slits **320**. In this arrangement, the holes allow for an interaction between the reactants.

[0045] The perforations or slits/holes can be created and/or modulated in any number of ways. In some embodiments, the temperature-responsive divider can include at least one temperature-responsive actuator **340** which can exist in a first conformation as shown on the left side of **Fig. 3**. In some embodiments, the temperature-responsive divider can also include a fixed end **330**. The presence of the fixed end **330** and the actuator **340** can provide for the opening of the slits **320** to the holes **370**. In some embodiments, the actuator can be made from a temperature sensitive material, such as a memory metal. Thus, in some embodiments, the body of the divider need not be made of a temperature sensitive material, but can be associated and/or controlled by a temperature sensitive material, such that a change in temperature, drives a change in conformation that opens (or makes more open) the slits and/or perforations in the body **310** of the divider **300**. In some embodiments, the body itself can be made from the temperature sensitive material, and thus, a shift in conformation of the body can directly open a slit or perforation.

[0046] In some embodiments, at a temperature **360** that is below a threshold, the temperature-responsive actuator can revert to the first conformation **340**, so that the divider and the perforations also revert to the first conformation **320**.

[0047] In some embodiments, the temperature-responsive divider includes an expandable sheet that includes at least one perforation. In some embodiments, the perforation includes at least one of a slit, a hole, or a flap. The perforation can be effectively impermeable to at least one reactant when the expandable sheet is in a first conformation. In some embodiments, the expandable sheet can be stretched along an axis that is parallel or substantially parallel to the largest diameter of the perforation, thus pinching or squeezing the perforation into a closed or substantially closed conformation. The perforation can become permeable to the first reactant and/or the second reactant when the expandable sheet is relaxed along the same axis, which allows the perforation to open.

[0048] In other embodiments, the opposite arrangement can be employed, namely the expandable sheet can be sealed when in its resting state (not stretched) but when stretched or strained along an axis that is perpendicular or substantially

perpendicular to the largest diameter of the perforation the perforation is pulled open by tensile force.

[0049] In some embodiments, the sheet includes two or more perforations, and each of the perforations is positioned in substantially the same orientation on the sheet. In some embodiments, the perforations of the sheet are substantially parallel to each other.

[0050] In some embodiments, the longest diameter of the perforation is at least about 0.1 micrometers, for example about 0.1, 1, 10, 20, 30, 40, 50, 60, 80, 100, 120, 140, 160, 180, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1500, 1800, 2000, 2500, 3000, 4000, 5000, 6000, 7000, 8000, or 9000 micrometers, including any range above any one of the preceding values and any range between any two of the preceding values..

[0051] In some embodiments, the body of the divider includes at least about 2 perforations, for example, at least about 2, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 2000, 3000, 4000, 5000, 10,000, or 100,000 perforations, including any range above any one of the preceding values and any range between any two of the preceding values. In some embodiments, the body of the divider include perforations at a density of at least about 1 perforation per square centimeter, for example at least about 1, 2, 3, 4, 5, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 20, 22, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 120, 150, 180, 190, 200, 220, 250, 300, 400, 500 600, 700, 800, 900, 1000, 10,000, 100,000, or 1,000,000 perforations per square centimeter, including any range above any one of the preceding values and any range between any two of the preceding values.

[0052] In some embodiments, the body of the divider includes at least one of a rubber, a metal, or an elastomer material. In some embodiments, the body of the divider includes two or more of the listed materials. In some embodiments, the body of the divider includes at least one layer of a first material, and at least one layer of a second listed material, for example at least one layer of a rubber, and at least one layer of an elastomer.

[0053] In some embodiments, interaction of the reactants is controlled by mechanically positioning the expandable sheet in one conformation at a first temperature, and a different conformation at a second temperature. In some embodiments, a temperature-responsive actuator controls the conformation of the expandable sheet. The temperature-responsive actuator can be in tensile communication with the expandable

sheet, such that the temperature-responsive actuator positions the expandable sheet in a first configuration at a first temperature, and a second configuration at a second temperature. In some embodiments, for example when the temperature-responsive divider is configured to permit an endothermic reaction at the second temperature, the second temperature is greater than the first temperature. In some embodiments, for example when the temperature-responsive divider is configured to permit an exothermic reaction at the second temperature, the second temperature is less than the first temperature. In some embodiments, the temperature-responsive actuator positions the expandable sheet in a stretched or strained conformation at a first temperature, and a relaxed conformation at a second temperature. Accordingly, in some embodiments, the temperature-responsive actuator permits at least one reactant to pass through perforations in the expandable sheet at the second temperature, but not at the first temperature.

[0054] In some embodiments, the temperature-responsive actuator includes at least one of a bimetal, a shape-memory metal alloy, and/or a shape memory polymer. In some embodiments, two or more temperature-responsive actuators can be employed. As noted above, in some embodiments, the entire body of the temperature-responsive divider includes at least one of a bimetal, a shape-memory metal alloy, and/or a shape memory polymer

[0055] In some embodiments, the temperature-responsive actuator includes a bimetal. In some embodiments, the temperature-responsive actuator has a first concavity at a first temperature, and a second, opposite concavity at a second temperature. The first concavity can conform the expandable sheet so that the perforations are in a closed position, while the second concavity can conform the expandable sheet so that the perforations are in an open position. **Fig. 3** illustrates an exemplary temperature-responsive actuator having an arched shape **340** at a first temperature or temperature range **360** so that the perforations are closed **320**, and a second, opposite concavity **345** at a second temperature or temperature range **350** so that the perforations **370** are open.

[0056] In some embodiments, the temperature-responsive actuator includes a shape memory metal alloy. The shape memory metal alloy can be configured to remember a first conformation at a first temperature, such that the expandable sheet is in the corresponding first conformation, and the perforations in an open position. The shape memory metal alloy can be configured to remember a second conformation at a second temperature, such that the expandable sheet is in the corresponding second conformation,

and the perforations are in a closed position. In some situations, a single shape memory metal alloy actuator may not generate sufficient force to position a large expandable sheet in a strained or stretched position. Accordingly, some embodiments include an array of at least two or more shape memory metal alloy actuators, for example at least about 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, or 1000 shape memory metal alloy actuators, in which each actuator is in tensile communication with the expandable sheet.

[0057] In some embodiments, the temperature-responsive actuator includes a shape memory polymer. At least one surface of the expandable sheet can be laminated in the shape memory polymer. In some embodiments, the expandable sheet is configured so that the perforations are closed when the sheet is in a first, relaxed conformation, and open when the sheet is in a second, strained conformation (for example, strain perpendicular or substantially perpendicular to the longest diameter of the perforation to distort the perforation to an open state when appropriate). The shape memory polymer can be configured to return to its shape at a second temperature, from any given shape at a first temperature. The shape memory polymer can be applied to the sheet such that the “remembered” or set shape applies strain to the sheet and forces the perforations to open. Accordingly, at a first temperature, the shape memory polymer closely conforms to the shape of the expandable sheet, and the sheet remains closed. However, at a second temperature, the shape memory polymer returns to its set shape and induces the sheet to a strained, open, configuration. In situations in which a shape memory metal alloys might not generate a large enough force to open a large sized sheet, an array of many memory metal alloys can be used to achieve the same result. In some embodiments, shape memory metal alloy memorizes an o-shape above T_{set} , and is attached to all or substantially all of slit parts in **Fig. 3**.

[0058] In some embodiments, a shape memory polymer can be used as the temperature-responsive divider without an additional mechanical actuator. For example, a pore opening structure can be memorized above T_{set} and a rubber sheet having a relatively weak tension towards the closed direction can be laminated with the shape memory polymer. When the temperature rises beyond T_{set} , the shape memory polymer starts returning to the memorized shape, for example, the open hole state pulls against, and overcomes, the force generated from the laminated rubber sheet. When the temperature goes down below T_{set} , the rubber layer pulls it back to the closed state.

[0059] Not all of the embodiments involve the opening and/or closing of perforations. In some embodiments, the temperature-responsive divider includes a polymer membrane. A portion, substantially all, or all of a surface of the polymer membrane can be hydrophilic at the first temperature. That portion can be hydrophilic at a second temperature. In some embodiments, the second temperature is greater than the first temperature. In some embodiments, the polymer is porous. In some embodiments, the polymer includes a temperature-responsive hydrogel. In some embodiments, the polymer can absorb moisture when its surface (or portion thereof) is in a hydrophilic state, and can release moisture when its surface (or portion thereof) is in a hydrophobic state. Thus, the polymer can permit permeation of a reactant (or solvent) in aqueous solution via capillary action when in the hydrophilic state, while prohibiting permeation in the hydrophobic state. In some embodiments, the polymer can absorb a non-polar solution when its surface (or portion thereof) is in a hydrophobic state, and can release the non-polar solution when its surface (or portion thereof) is in a hydrophilic state. Thus, the polymer can permit permeation of a reactant (or solvent) in non-polar solution.

[0060] Thus, rather than employing a gross hole that is opened or closed, some embodiments employ a class of polymers that change the surface characteristic from hydrophilic to hydrophobic with temperature change, for example, N-isopropyl acryl amide. Thermo responsiveness of this type of polymer can be controlled by the combination of copolymer composition with N-isopropyl acryl amide or N-alkyl acryl amide. For example, a copolymer of N-isopropyl acryl amide with diacetone acryl amide, acrylic acid and methylene-bis-acryl amide can be used to form a temperature-responsive hydro gel composition which works between 10 degrees Centigrade and 40 degrees Centigrade.

[0061] In some embodiments, a porous membrane that includes such a polymer can be used as a temperature-responsive divider. Such a polymer can be hydrophilic at T_{set} and absorbs moisture to stop permeation. It can change its surface property to hydrophobic above T_{set} , and can release moisture from the membrane. In some embodiments, a micro porous layer can generate a capillary effect to assist permeation of a reactant into the other reactant. In some embodiments one of the reactants can be attached and/or laminated to the side of the temperature-responsive divider. Such an arrangement can allow the attached and/or laminated reactant to pull liquid from the other side when the divider opens at higher temperature.

[0062] In some embodiments, the polymer includes N-alkyl acryl amide. In some embodiments, the polymer includes N-isopropyl acryl amide. In some embodiments, the polymer includes a copolymer of N-alkyl acryl amide and N-isopropyl acryl amide. Without being bound by any one theory, the responsiveness of the polymer can depend on the ratio of alkyl acryl amide and N-isopropyl acryl amide. In some embodiments, the ratio (weight to weight) of alkyl acryl amide to N-isopropyl acryl amide is about 100:1, 70:1, 50:1, 40:1, 30:1, 20:1, 15:1, 10:1, 7:1, 5:1, 4:1, 3:1, 2:1, 1:1, 1:2, 1:3, 1:4, 1:5, 1:7, 1:10, 1:20, 1:30, 1:40, 1:50, or 1:100, including ranges between any two of the listed values. In some embodiments, the polymer includes a copolymer of N-alkyl acryl amide, di-acetone acryl amide, acrylic acid, and/or methylene-bis-acryl amide.

[0063] In some embodiments, the temperature-responsive divider can change to a configuration that is impermeable to the first reactant, the second reactant, or the first and second reactant upon a return of the temperature-responsive divider to the first temperature. In some embodiments, returning the divider to the impermeable configuration includes closing perforations of an expandable sheet of the divider. In some embodiments, returning the divider to the impermeable configuration includes changing the hydrophobicity of the sheet. In some embodiments, even after the closure of the divider, some amount of the reaction and/or reactants can still be occurring and/or present together.

[0064] In some embodiments, one reactant, or a portion of that reactant is positioned on one side of the temperature-responsive divider, while the other reactant, or a portion of the other reactant, is positioned on another side of the temperature-responsive divider. In some embodiments, for example embodiments in which each reactant is a solid that is soluble in a solvent, both reactants are positioned on the same side of the temperature-responsive divider, and the solvent is positioned on a different side of the temperature-responsive divider. In some embodiments, the solvent is positioned on a side of the temperature-responsive divider that is opposite the side on which the reactants are positioned.

[0065] The selection of the various reactants will depend upon the particular application. In some embodiments, two or more reactants can be selected so that the reaction of the reactants has a cooling (or heating) effect that counteracts a change in temperature within the packaging. Thus, in some embodiments, the reactants can react endothermically with each other. The endothermic reaction can absorb heat. Pairs of

reactants that can react endothermically with each other can include, but are not limited to $\text{H}_2\text{O}/\text{NH}_4\text{NO}_3$, $\text{H}_2\text{O}/\text{NH}_4\text{Cl}$, $\text{NH}_4\text{NO}_3/\text{Urea}$, $\text{H}_2\text{O}/\text{Urea}$, $\text{H}_2\text{O}/\text{Ba}(\text{NO}_3)_2$, citric acid/sodium bicarbonate, $\text{H}_2\text{O}/\text{Xylitol}$, and $\text{H}_2\text{O}/\text{Erythritol}$. In some embodiments, the reactant pair is selected from Table 1 provided in the Examples. Some embodiments include two reactants that react endothermically with each other when combined. Some embodiments include three or more reactants that react endothermically when at least two of the reactants are combined, for example H_2O , NH_4NO_3 , and NH_4Cl . Some embodiments include reactants that react exothermically with each other when combined. Some embodiments include a catalyst.

[0066] The phase of the reactants under the conditions at which the endothermic (or exothermic) reaction begins can impact the ability of the reactants to mix with each other and/or react. For example, if each of a pair of reactants is a liquid at the temperature and pressure at which the temperature-responsive divider allows the reaction to initiate, the reactants can readily intermix. Accordingly, in some embodiments, each of the reactants is a liquid. In some embodiments, for example embodiments in which a gradual intermixing of the reactants is desirable, each of the reactants is a gel, for example a hydrogel. In some embodiments, one reactant is a liquid, and the other reactant is a gel. In some embodiments, one reactant is a liquid, while the other reactant is a solid. In some embodiments, one reactant is a gel, while the other reactant is a solid. In some embodiments, each reactant is a solid that is soluble in a solvent, and beyond the threshold temperature, the temperature-responsive divider allows a solvent to enter into one or more of the areas holding one or more of the reactants and dissolve one or more of the reactants, thus allowing the reactants to combine.

[0067] Optionally, a liquid or gel-phase reactant can be stored in a porous substrate. Thus, in some embodiments, a liquid or gel-phase reactant is stored in a porous sponge-like substrate, or a superabsorbent polymer, for example sodium polyacrylate. In some embodiments the liquid or gel-phase reactant is contained in a sponge-like substrate.

[0068] A solid reactant can react more rapidly if it has a relatively large surface area. Thus, in some embodiments, the solid-phase reactant or reactants include at least one of a fiber, a bead, a powder, or a granular substance. In some embodiments, the solid-phase reactant is fixed onto a high-surface area substrate, for example activated charcoal, porous aluminum, silicate beads, or the like. In some embodiments, the solid-

phase reactant includes xylitol, and is fixed onto calcium silicate, for example to form xylitol-fixed beads.

[0069] In some embodiments, the system includes one or more compartments for the reactants. In some embodiments, the system includes a first compartment configured to contain the first reactant, and a second compartment to contain the second reactant. At least a portion of each compartment is defined by the temperature-responsive divider. In other words, the compartments are at least partially separated from one another by the divider. For example, a first surface of the temperature-responsive divider can provide a surface of the first compartment, while a second surface of the temperature-responsive divider can provide a surface of the second compartment. In some embodiments, the first surface can be opposite the second surface. In some embodiments, the system includes two or more compartments for one of the reactants. In some embodiments, system includes two or more compartments for each of the reactants. In some embodiments, a compartment includes at least one of a sack, a box, a drum, a pouch, a tube, a hopper, or a reservoir. In some embodiments, a compartment has a volume of at least about 0.001 liter, for example at least about 0.001, 0.01, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.9, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 100, or 1,000 liters or more, including any range between any two of the preceding values and any range above any one of the preceding values.

[0070] In some embodiments, the first compartment and second compartment are adjacent to each other. In some embodiments, the first compartment and second compartment are not adjacent, but are in fluid communication with each other. In some embodiments, the first compartment is positioned partially or wholly within the second compartment. In some embodiments, the first compartment is configured to contain the first reactant, and also contains a plurality of second compartments, for example at least about 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 30, 40, 50, 70, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1500, 2000, 2500, 3000, 4000, 5000, 6000, 7000, 8000, or 9000 second compartments, in which each second compartment is a vesicle that includes at least one surface that is defined by a temperature-responsive divider. In some embodiments, each of the plurality of dividers has the same temperature dependence for opening and/or closing. In some embodiments, the temperature dependence for opening and/or closing the different dividers can be different, so that finer degrees of temperature control can be maintained. In some embodiments, the temperature dependence for

opening and/or closing the different dividers can be different, so that higher ranges of temperature control can be obtained. For example, in some embodiments, a first divider will open if the temperature exceeds 30 degrees Centigrade, and a second divider will open if the temperature exceeds 40 degrees Centigrade and a third divider will open if the temperature exceeds 50 degrees Centigrade. In some embodiments, the various reactants on each side of the different dividers can be set so that a stronger (for example, more endothermic reaction) will occur for each of the higher temperature dividers. Thus, in some embodiments, the reactant pair can be matched to the temperature-responsive divider so that opening the divider will allow for a sufficiently endothermic reaction (or exothermic reaction) to occur to return the local environment to the desired temperature, from a temperature sufficient to open the temperature-responsive divider.

[0071] In some embodiments, the arrangement includes a storage compartment. The storage compartment can be configured to contain at least one product to be stored. In some embodiments, the storage compartment is configured to contain at least about 2 products to be stored, for example at least about 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 120, 150, 180, 200, 300, 400, 500, or 1000 products to be stored. In some embodiments, the storage compartment is disposed adjacent to the first reactant, the second reactant, or both. In some embodiments, the storage compartment is partially or wholly surrounded by the first reactant, the second reactant, or both. In some embodiments, the storage compartment is not adjacent to the first or second reactant, but is in thermal communication with the first or second reactant via a thermally conductive material. The storage compartment can be made of any material that will allow an adequate transmission of heat and/or cold from the area of the reaction to the volume of space contained by the storage compartment. In some embodiments, the storage compartment can be made from metal, plastic, various polymers, ceramic, etc. In some embodiments, the storage compartment defines the local environment. Thus, in some embodiments, an increase (or decrease) in temperature in the storage compartment is the change in temperature that drives the opening and/or closing of the temperature-responsive divider. In some embodiments, reaction that results then cools (or heats) at least part of the volume of the storage compartment. In some embodiments, the temperature-responsive divider is in thermal communication with the storage compartment.

[0072] Some embodiments employ the device and/or method as a package product. Such packaging can include any of the embodiments provided herein. In some embodiments, the packaging includes the first reactant and the second reactant. The first reactant can endothermically react with the second reactant to absorb heat. The packaging can include the temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant. In some embodiments, at a first temperature the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant as described herein. At a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant. Of course, exothermic embodiments are also available as noted herein.

[0073] There is no particular limitation on the forms in which the packaging can be provided. In some embodiments, the packaging includes at least one of a pouch, a wrap, a sack, an envelope, a box, a chest, a tray, a carton, a bag, or a shipping container. In some embodiments, the packaging includes at least one compartment as described herein. In some embodiments, the packaging is a passive package, and does not require the use of electricity. In some embodiments, the packaging is one configured for shipment. In some embodiments, the packaging is designed to hold or contain food. In some embodiments, the packaging is designed for long-term storage of a product. In some embodiments, the packaging is designed for storing a pharmaceutical product.

[0074] Some embodiments include methods of preparing a cooling system. Embodiments of such a method are generally outlined in **Fig. 4**. The method can include providing a first reactant **400**. The method can further include providing a second reactant as described herein, such that the reactants can endothermically (or exothermically) react with each other **410**. Of course, initially, the first and second reactants are not undergoing a reaction, but are merely selected such that they are capable of the relevant reaction when combined. The method can further include providing a temperature-responsive divider. The two reactants are arranged such that they can interact when the temperature-responsive divider is in its open state. Various options for their arrangement will depend upon the particular state of the reactants and set up involved, as detailed herein. As outlined herein, in some embodiments, the temperature-responsive divider separates at least a portion of the first reactant from the second reactant at a first

temperature, but at a second temperature, the divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant **420**.

[0075] In some embodiments, the system and/or method can provide a package including two compartments which contain two different reactive chemicals separately in each compartment, a pair of chemicals that can react with each other by endothermic (or exothermic) reaction; and a temperature-responsive divider separating the two compartments when the temperature is low and breaking separation when the temperature rises above the previously set temperature.

[0076] Example pairs of reactants are listed in Table 1. There are various reactant pairs which react endothermically as listed in Table 1. Some embodiments can include any pair of reactants listed in Table 1. Both xylitol-H₂O and erythritol-H₂O are appropriate around food products.

[0077] In some embodiments, reactant A is stored in a hydrogel form. Superabsorbent polymer such as sodium polyacrylates can be used to keep water or a solution containing reactant A (of Table 1).

[0078] In some embodiments, any of the herein described systems and/or methods can function without any external power supply or electricity. In some embodiments, the system structure is simple and need not employ a motor. In some embodiments, the system structure is simple and need not employ a motor. In some embodiments, nontoxic and/or nonhazardous material combinations (such as the two reactants and the divider) can be employed. In some embodiments, all or substantially all of the parts are matured materials. In some embodiments, the temperature sensing aspect of the method or device operates to directly, physically, open a barrier between two reactants.

Examples 1-8:

Cooling arrangements

[0079] A polyethylene cylinder is divided into two compartments by a temperature-responsive divider. Each compartment has a volume of about 1 liter. A reactant pair is provided, one reactant of the pair into each of the two compartments, according to each of the pairings of Table 1. Thus, eight different reactant pairs are placed into eight different cylinders.

Table 1 – Exemplary Groups of Reactants Which Cause Endothermic Reaction

No	Reactant A	Reactant B	Absorbed heat (kcal/mol)	Additional Aspects
1	H ₂ O	NH ₄ NO ₃	6.08	
2	H ₂ O	NH ₄ Cl	3.73	
3	NH ₄ NO ₃	Urea	18.0	Ammonium Nitride is an optional material for non-food application.
4	H ₂ O	Urea	3.7	
5	H ₂ O	Ba(NO ₃) ₂	9.65	Optional material for non-food application.
6	Citric acid	Sodium Bicarbonate		CO ₂ will be generated.
7	H ₂ O	Xylitol	35 kcal/g	Food additives
8	H ₂ O	Erythritol	43 kcal/g	Food additives

[0080] The temperature-responsive divider includes a rubber sheet having a substantially uniform thickness of about 5mm. The rubber sheet includes perforations, each of which is a slit having a length of about 1mm, and each of which is in an effectively parallel orientation to the other slits. The sheet contains the perforations at a density of about 10 perforations per cm². The sheet includes a bimetallic actuator (as shown in **Fig. 3**). The bimetallic actuator is in tensile communication with the sheet along an axis substantially perpendicular to the longest axis of the perforations.

[0081] At temperatures of less than 5 °C, the bimetallic actuator has a concave configuration, and pushes the sheet against a fixed end, such that the sheet is compressed. The perforations stay closed, and the reactants do not react. At temperatures greater than 5 °C, the bimetallic actuator adopts a convex configuration, and stretches the sheet from the fixed end. As the sheet is stretched, the slits open to holes, allowing the first and second reactants to mix and thereby allowing the endothermic reaction to occur.

[0082] When the endothermic reaction occurs, it will lower the local temperature around the cylinders.

Example 9:Cooling arrangement and use thereof

[0083] A pouch containing about 2 liters of NH_4NO_3 fixed onto silicate beads, is separated from a pouch containing 2 liters of H_2O by a temperature-responsive actuator. The pouch is wrapped around poultry carcasses being transported. The temperature-responsive divider is made of a copolymer of alkyl acryl amide and N-isopropyl acryl amide. At temperatures below 2 °C, the surface of the divider is hydrophobic, and substantially no water passes through. At temperatures above 2 °C, the surface of the divider is hydrophilic, and water can pass. The pouch and poultry carcasses are initially at 1 °C, and the surface of the divider remains hydrophobic. During storage, the local temperature increases from 1 °C to 4 °C. The surface of the divider adopts a hydrophobic configuration, and water diffuses through the divider. The water reacts endothermically with the NH_4NO_3 and the local temperature decreases. When the local temperature is below 2 °C again, the divider surface returns to a hydrophobic configuration. Water stops diffusing through the divider, and the endothermic reaction ceases.

Example 10:Cooling arrangement and use thereof

[0084] A double-walled chest contains an inner 5-liter compartment for storing dairy products. The chest also includes an intermediate space within the walls of the chest that is filled with citric acid solid crystalline pellets and sodium bicarbonate pellets intermixed. Substantially no water is present in the intermediate space. The outer wall contains vents for any CO_2 released by the reaction of sodium bicarbonate and citric acid. A 2 liter reservoir of water is separated from the intermediate space containing citric acid and sodium bicarbonate by a temperature-responsive divider. The temperature-responsive divider includes a 3mm-thick elastomer sheet, with 1mm perforations at a density of 2 perforations per cm^2 . The sheet is laminated in shape memory polymer, which is programmed to remember (or revert to a previously determined) shape at temperatures of 6 °C or greater. The memory polymer is laminated onto the sheet so that in its memorized (or previously determined) conformation, the polymer stretches the perforations open. At temperatures of less than 6°C, the memory polymer does not

conform to its memorized shape, and elastic tension of the elastomer pulls the perforations shut.

[0085] The inner compartment is filled with cheese, at a local temperature of 3 °C. As the cheese is transported, the local temperature increases, and eventually increases from 3 °C to 7 °C. When the temperature reaches 7 °C, the shape memory polymer switches from its resting conformation (in which elastic tension of the sheet was sufficient to “pull” the perforations closed), to its memorized conformation (in which the tensile force of the polymer forces the perforations open). The perforations open, allowing water to flow into the intermediate compartment, and solubilize the citric acid, which reacts with sodium bicarbonate endothermically. The endothermic reaction cools the cheese products. CO₂ produced by the reaction is emitted through the vent.

Example 11:

Heating arrangements and use thereof

[0086] A container has an inner 5-liter compartment for storing heated food products, and an intermediate space between the walls is filled with a first exothermic reactant and a second exothermic reactant in dry form. Substantially no water is present in the intermediate space. A 0.5 liter reservoir of water is separated from the intermediate space by a temperature-responsive divider. The temperature-responsive divider includes a 3mm-thick elastomer sheet, with 1mm perforations at a density of 2 perforations per cm². The sheet is laminated in shape memory polymer, which is programmed to remember its shape at temperatures of 20 °C or lower. The memory polymer is laminated onto the sheet, so that in its memorized conformation, the polymer stretches the perforations open. At temperatures of greater than 20 °C, however, the memory polymer does not conform to its memorized shape, and elastic tension of the elastomer pulls the perforations shut.

[0087] The inner compartment is filled with pizza, at a local temperature of 40 °C. As the pizza is transported, the local temperature decrease, and eventually reaches 20 °C. When the temperature reaches 20 °C, the shape memory polymer switches from its non-memorized conformation (in which elastic tension of the sheet was sufficient to “pull” the perforations closed), to its memorized conformation (in which the tensile force of the polymer “pushes” the perforations open). The perforations open, allowing water to

flow into the intermediate compartment, and solubilize the two exothermic reactants, which react exothermically. The exothermic reaction heats the pizza.

[0088] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[0089] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0090] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (*e.g.*, bodies of the appended claims) are generally intended as “open” terms (*e.g.*, the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or

"at least one" and indefinite articles such as "a" or "an" (*e.g.*, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (*e.g.*, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*e.g.*, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*e.g.*, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0091] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0092] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in

the art all language such as “up to,” “at least,” and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0093] From the foregoing, it will be appreciated that various embodiments of the present disclosure have been described herein for purposes of illustration, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

WHAT IS CLAIMED IS:

1. A cooling system comprising:
 - a first reactant;
 - a second reactant, wherein the first reactant can endothermically react with the second reactant to absorb heat; and
 - a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant,
 - wherein at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant, and
 - wherein at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.
2. The cooling system of claim 1, wherein the first reactant contacts a first side of the temperature-responsive divider, wherein the second reactant contacts a second side of the temperature-responsive divider, and wherein the first side is opposite to the second side of the temperature-responsive divider.
3. The cooling system of claim 1, wherein the temperature-responsive divider comprises an expandable sheet comprising at least a perforation, wherein the perforation is impermeable to the first reactant and the second reactant when the expandable sheet is in a first conformation, and wherein the perforation is permeable to the first reactant, the second reactant, or the first reactant and the second reactant when the expandable sheet is in a second conformation.
4. The cooling system of claim 3, wherein the expandable sheet comprises at least one of a rubber, a metal, or an elastomer material.
5. The cooling system of claim 3, wherein the temperature-responsive divider further comprises at least one temperature-responsive actuator in tensile communication with the expandable sheet, wherein the at least one temperature-responsive actuator is configured to position the sheet in the first conformation at the first temperature, and wherein the at least one temperature-responsive actuator is configured to position the sheet in the second conformation at the second temperature, wherein the second temperature is greater than the first temperature.

6. The cooling system of claim 5, wherein the at least one temperature-responsive actuator comprises at least one of a bimetal, a shape-memory metal alloy, or a shape memory polymer.

7. The cooling system of claim 1, wherein the temperature-responsive divider comprises a polymer membrane, wherein at least a portion of a surface of the polymer membrane is hydrophilic at a first temperature, and wherein the portion of the surface of the polymer membrane is hydrophobic at a second temperature, wherein the second temperature is greater than the first temperature.

8. The cooling system of claim 7, wherein the polymer membrane comprises N-isopropyl acryl amide.

9. The cooling system of claim 1, wherein the first reactant and the second reactant comprise a first/second reactant pairing comprising at least one of: $\text{H}_2\text{O}/\text{NH}_4\text{NO}_3$, $\text{H}_2\text{O}/\text{NH}_4\text{Cl}$, $\text{NH}_4\text{NO}_3/\text{Urea}$, $\text{H}_2\text{O}/\text{Urea}$, $\text{H}_2\text{O}/\text{Ba}(\text{NO}_3)_2$, citric acid/sodium bicarbonate, $\text{H}_2\text{O}/\text{Xylitol}$, and $\text{H}_2\text{O}/\text{Erythritol}$.

10. The cooling system of claim 1, wherein at least one of the first reactant and the second reactant comprises a liquid, a gel, or a liquid and a gel.

11. The cooling system of claim 1, further comprising:

a first compartment configured to contain the first reactant; and

a second compartment configured to contain the second reactant, wherein at least a portion of the first compartment is defined by a first surface of the temperature-responsive divider, and wherein at least a portion of the second compartment is defined by a second surface of the temperature-responsive divider.

12. The cooling system of claim 1, further comprising a storage compartment disposed adjacent to the first reactant, the second reactant, or the first and second reactant.

13. The cooling system of claim 1, wherein the temperature-responsive divider can change to a configuration that is impermeable to the first reactant, the second reactant, or the first and second reactant upon a return of the temperature-responsive divider to the first temperature.

14. The cooling system of claim 1, wherein the second temperature is higher than the first temperature.

15. A method of regulating a temperature, the method comprising:

providing a cooling system comprising:

a first reactant;

a second reactant, wherein the first reactant can react endothermically with the second reactant; and

a temperature-responsive divider positioned between at least a part of the first reactant from at least a part of the second reactant; and

changing a first conformation of the temperature-responsive divider to a second conformation of the temperature-responsive divider upon an increase in temperature, wherein the second conformation permits the first reactant, the second reactant, or the first and the second reactant to pass through the temperature-responsive divider such that an endothermic reaction occurs.

16. The method of claim 15, wherein the first conformation effectively separates the first reactant from the second reactant at the first temperature, thereby preventing the first reactant from reacting with the second reactant.

17. The method of claim 15, the method further comprising changing the second conformation of the temperature-responsive divider to the first conformation upon a decrease in the temperature.

18. The method of claim 15, wherein the temperature-responsive divider comprises an expandable sheet that comprises at least one perforation, and wherein changing the first conformation of the temperature-responsive divider to the second conformation of the temperature-responsive divider comprises straining the expandable sheet such that the at least one perforation opens.

19. The method of claim 15, wherein the temperature-responsive divider comprises a bimetal, and wherein changing the first conformation of the temperature-responsive divider to the second conformation of the temperature-responsive divider comprises bending the bimetal.

20. The method of claim 15, wherein the temperature-responsive divider comprises at least one of a shape-memory alloy or a shape memory polymer, and wherein changing the first conformation of the temperature-responsive divider to the second conformation of the temperature-responsive divider comprises changing a shape of the shape-memory alloy or the shape memory polymer.

21. The method of claim 15, wherein the temperature-responsive divider comprises a surface of a polymer, and wherein changing the first conformation of the temperature-responsive divider to the second conformation of the temperature-responsive

divider comprises changing at least a portion of the surface of the polymer from a hydrophilic state to a hydrophobic state.

22. The method of claim 15, wherein the increase in local temperature comprises an increase of at least about 5°C.

23. The method of claim 15, wherein the first reactant and the second reactant comprise a first/second reactant pairing comprising at least one of: H₂O/NH₄NO₃, H₂O/NH₄Cl, NH₄NO₃/Urea, H₂O/Urea, H₂O/Ba(NO₃)₂, citric acid/sodium bicarbonate, H₂O/Xylitol, and H₂O/Erythritol.

24. A packaging comprising:

a first reactant;

a second reactant, wherein the first reactant can endothermically react with the second reactant to absorb heat; and

a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant,

wherein at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant, and

wherein at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

25. A method of preparing a cooling system, the method comprising:

providing a first reactant;

providing a second reactant, wherein the first reactant can endothermically react with the second reactant to absorb heat; and

providing a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant,

wherein at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant, and

wherein at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

26. A heating system comprising:

a first reactant;
a second reactant, wherein the first reactant can exothermically react with the second reactant to emit heat; and
a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant,
wherein at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant, and
wherein at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

27. A method of regulating a temperature, the method comprising:
providing a heating system comprising:

a first reactant;
a second reactant, wherein the first reactant can react exothermically with the second reactant; and
a temperature-responsive divider positioned between at least a part of the first reactant from at least a part of the second reactant; and
changing a first conformation of the temperature-responsive divider to a second conformation of the temperature-responsive divider upon a decrease in temperature, wherein the second conformation permits the first reactant, the second reactant, or the first and the second reactant to pass through the temperature-responsive divider such that an exothermic reaction occurs.

28. A packaging comprising:

a first reactant;
a second reactant, wherein the first reactant can exothermically react with the second reactant to emit heat; and
a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant,
wherein at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant, and

wherein at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

29. A method of preparing a heating system, the method comprising:
- providing a first reactant;
 - providing a second reactant, wherein the first reactant can exothermically react with the second reactant to emit heat; and
 - providing a temperature-responsive divider positioned between at least some of the first reactant and at least some of the second reactant,

wherein at a first temperature, the temperature-responsive divider is impermeable to the first reactant, the second reactant, or the first reactant and the second reactant, and

wherein at a second temperature, the temperature-responsive divider is permeable to the first reactant, the second reactant, or the first reactant and the second reactant.

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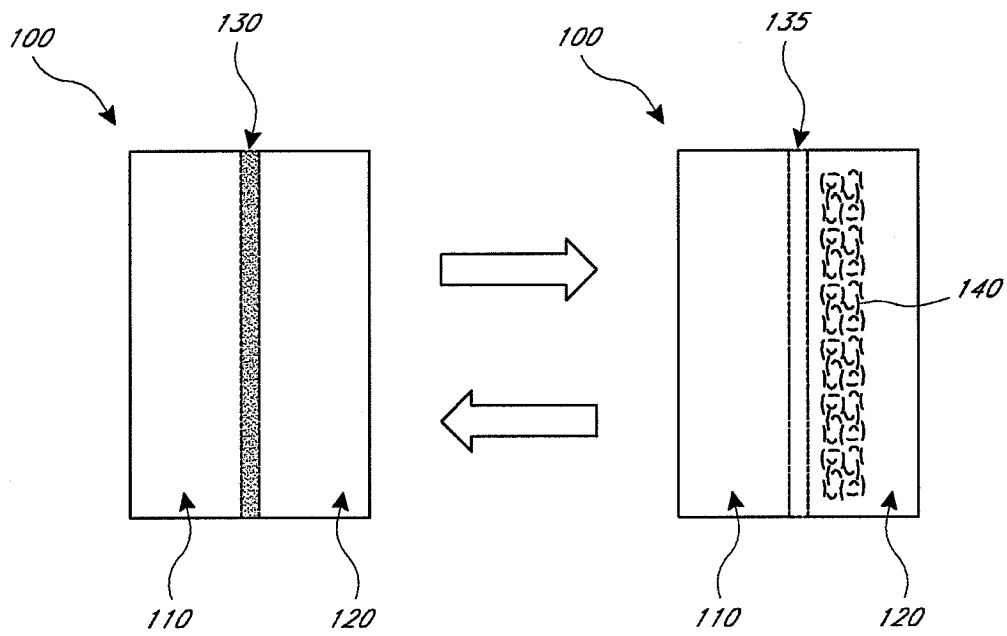
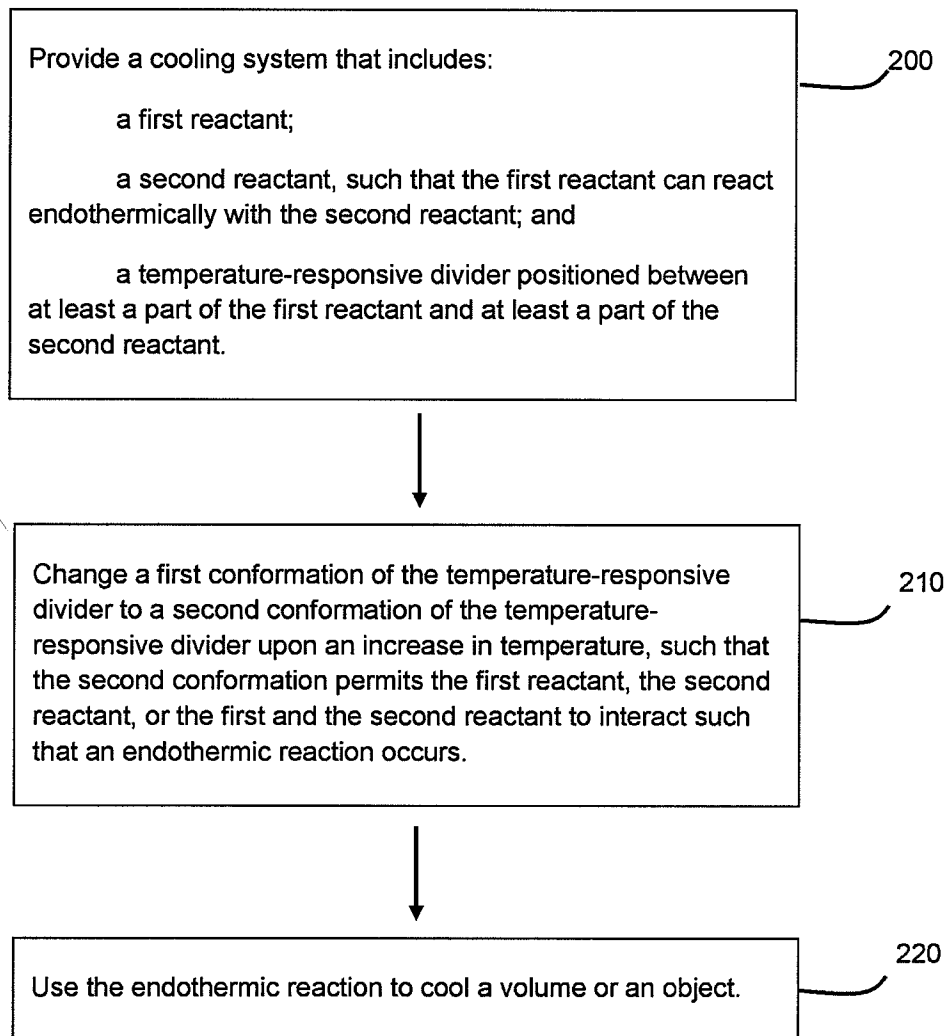


FIG. 1

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FIGURE 2

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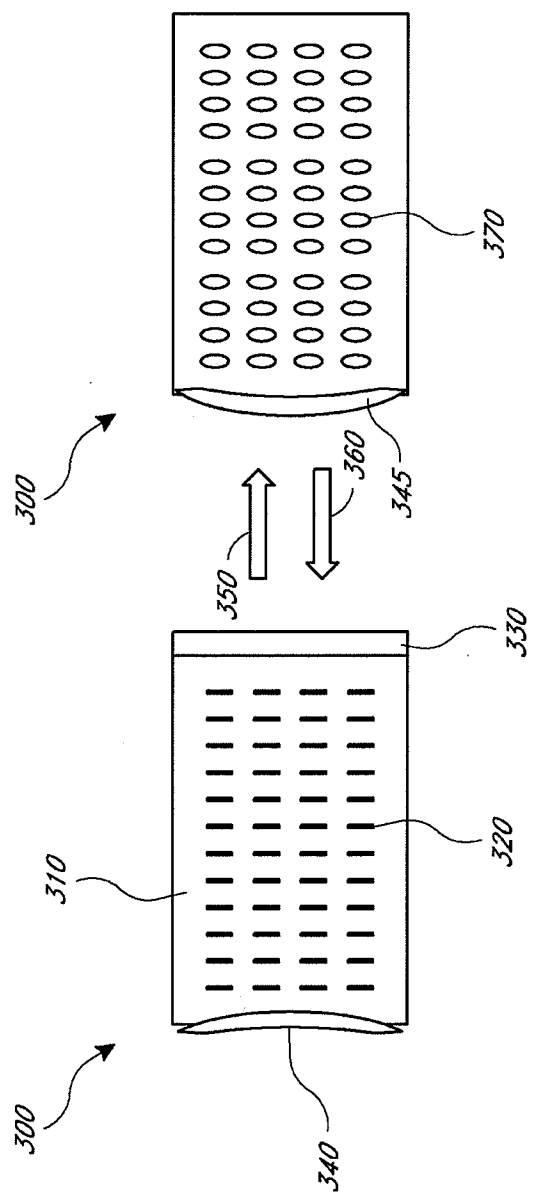
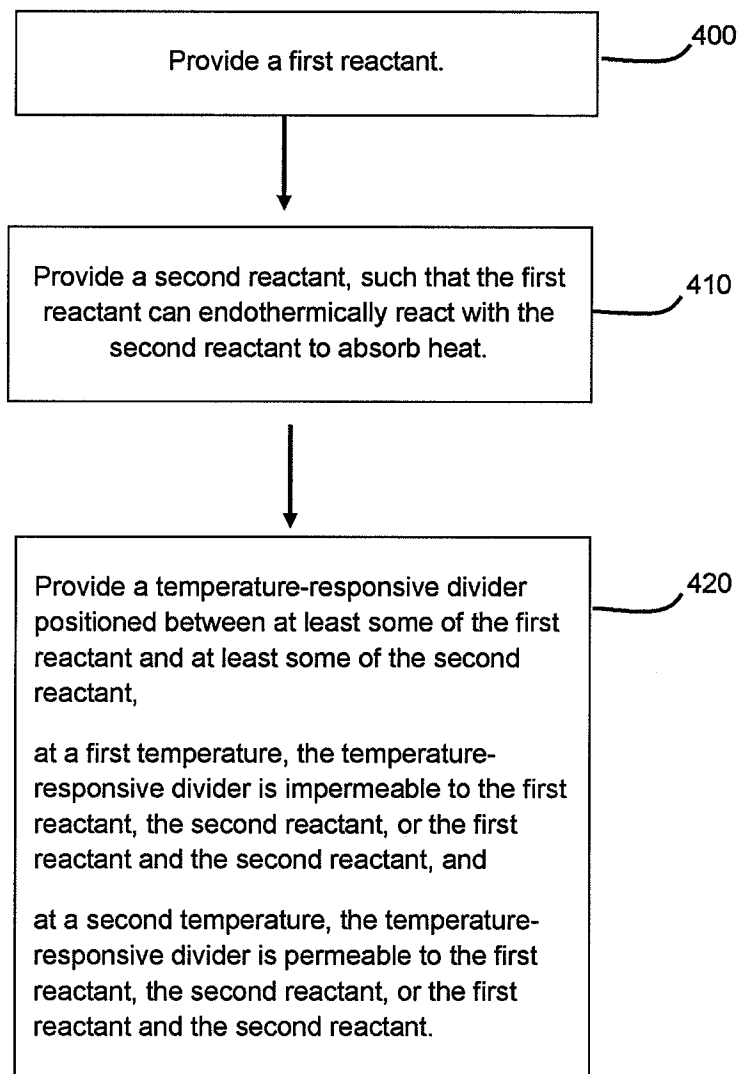


FIG. 3

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FIGURE 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/70293

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - B65B 55/14 (2013.01) USPC - 53/440 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC(8) -- B65B 55/14 (2013.01) USPC -- 53/440 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched IPC(8) -- B65B 55/14; B65B; F28D; G01K; A23J (2013.01) USPC -- 53/440, \$, 116/\$, 126/\$ Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PubWest (PGPB,USPT,USOC,EPAB,JPAB); Patbase; USPTO; Espacenet; Google Scholar -- BARRIER BI-METAL ENDOTHERM* EXOTHERM* IMPERMEAB\$ LIQUID MEMBRANE PACKAG* PERFORAT\$ PERMEAB\$ REACTANT SHAPE MEMORY TEMPERATURE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2003/0000517 A1 (Joseph et al.) 02 January 2003 (02.01.2003) Figs 6,9,10,13,14; para [0002]; [0047]; [0049]; [0050]; [0056]; [0060]; [0071]; [0079];	1-29
Y	US 2008/0282962 A1 (Petrakis) 20 November 2008 (20.11.2008) Figs 1, 2A,4,8,9,27,28,38to43; para [0163]; [0167]; [0175]; [0177]; [0179]; [0189]; [0213]; [0217]; [0219]; [0239]; [0242];	1-29
Y	US 5,929,214 A (Peters et al.) 27 July 1999 (27.07.1999) col 5, ln 14-42; col 6, ln 50-58	7,8,21
A	US 2011/0132611 A1 (Rytlewski et al.) 09 June 2011 (09.06.2011) para [0013]; [0015]; [0016]; [0022]	1-29
A	US 2004/0131838 A1 (Serra et al.) 08 July 2004 (08.07.2004) para [0034]; abstract	1-29
A	US 2004/0109720 A1 (Gruenbacher et al.) 10 June 2004 (10.06.2004) Fig 1; Fig 2; para [0074]; [0080]	1-29
A	BG 106064 A (Mitev) 30 April 2003 (30.04.2003) abstract	1-29
☐ Further documents are listed in the continuation of Box C. ☐		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 05 FEBRUARY 2013 (05.02.2013)		Date of mailing of the international search report 26 FEB 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774