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(54) SELF-COOLING CONTAINERS AND WRAPS

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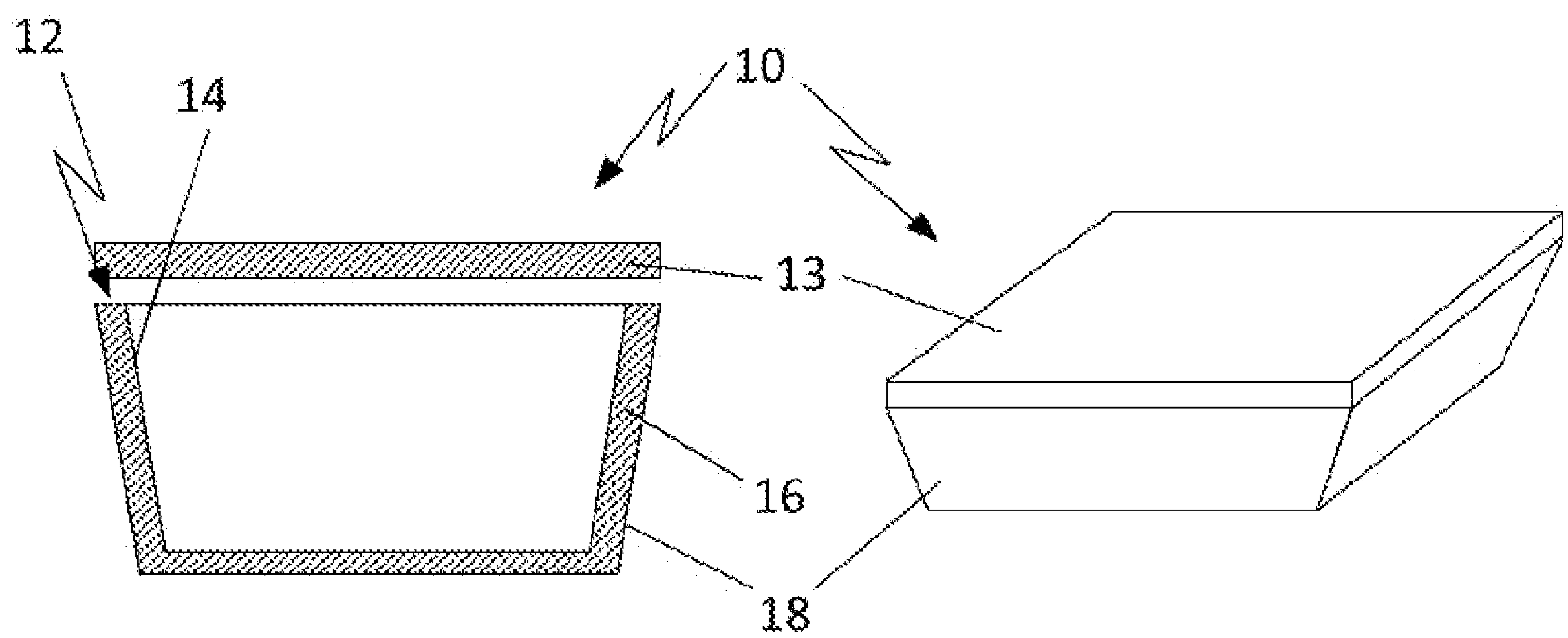
(57) **ABSTRACT**

Self-cooling materials, such as food containers for transporting perishable food items, and methods for producing and using the materials are disclosed. The materials include a reactant adapted to produce an endothermic reaction upon hydration of the reactant by ambient water vapor.



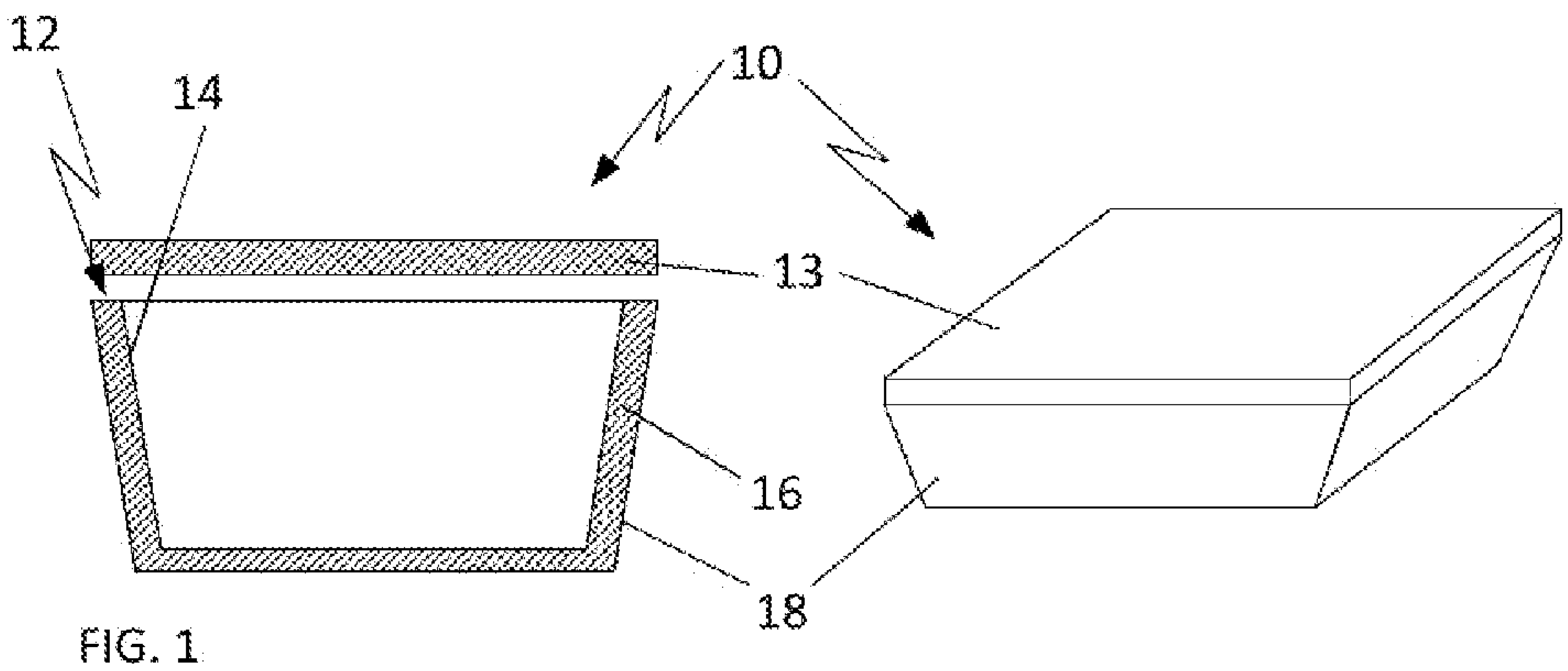


FIG. 1

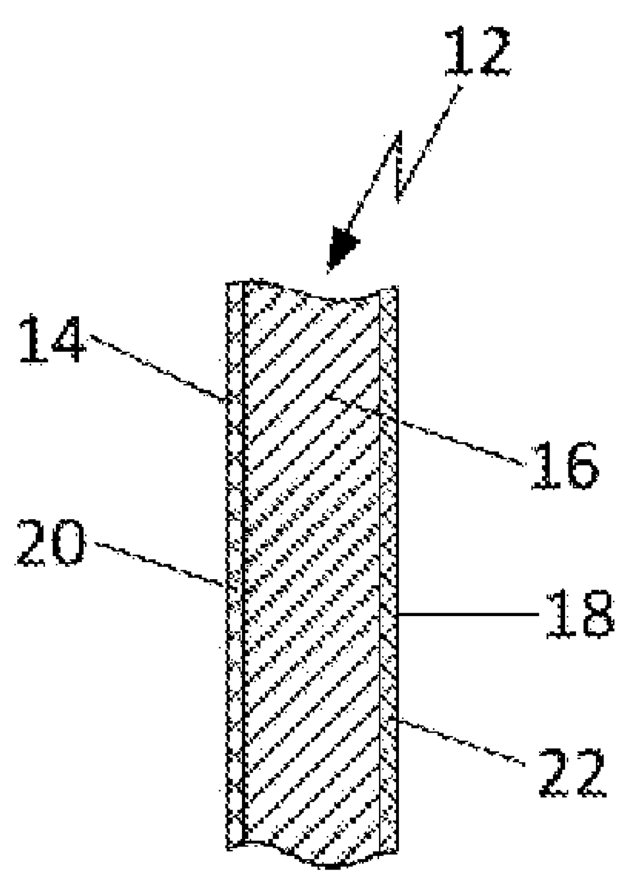


FIG. 2

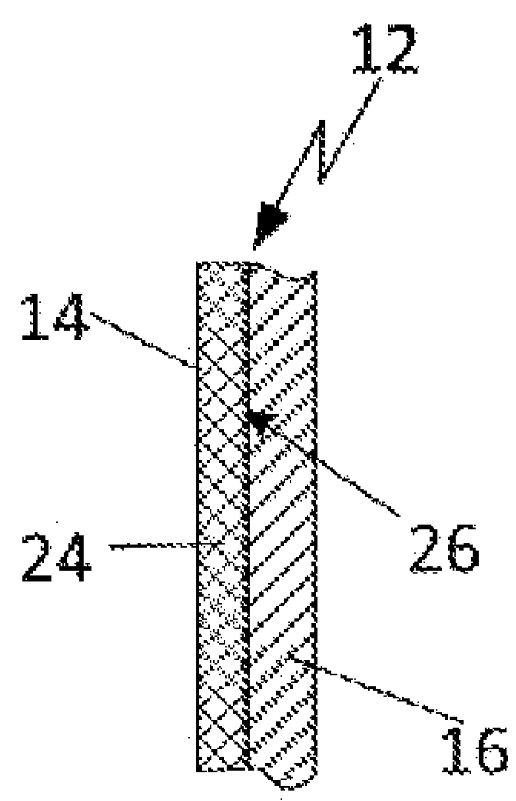


FIG. 3

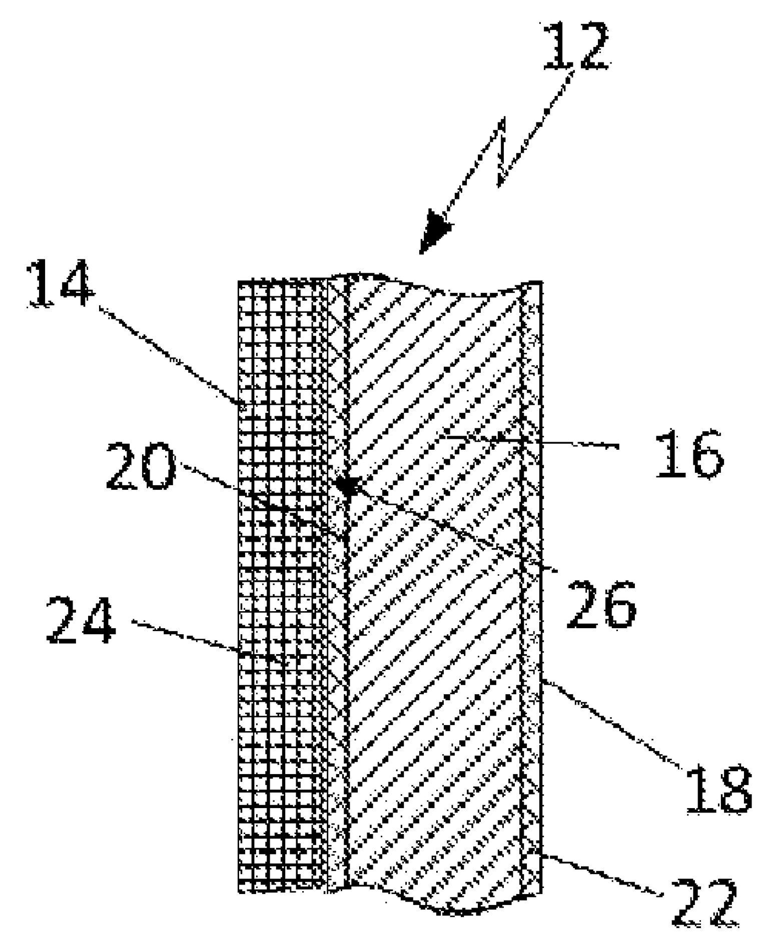


FIG. 4

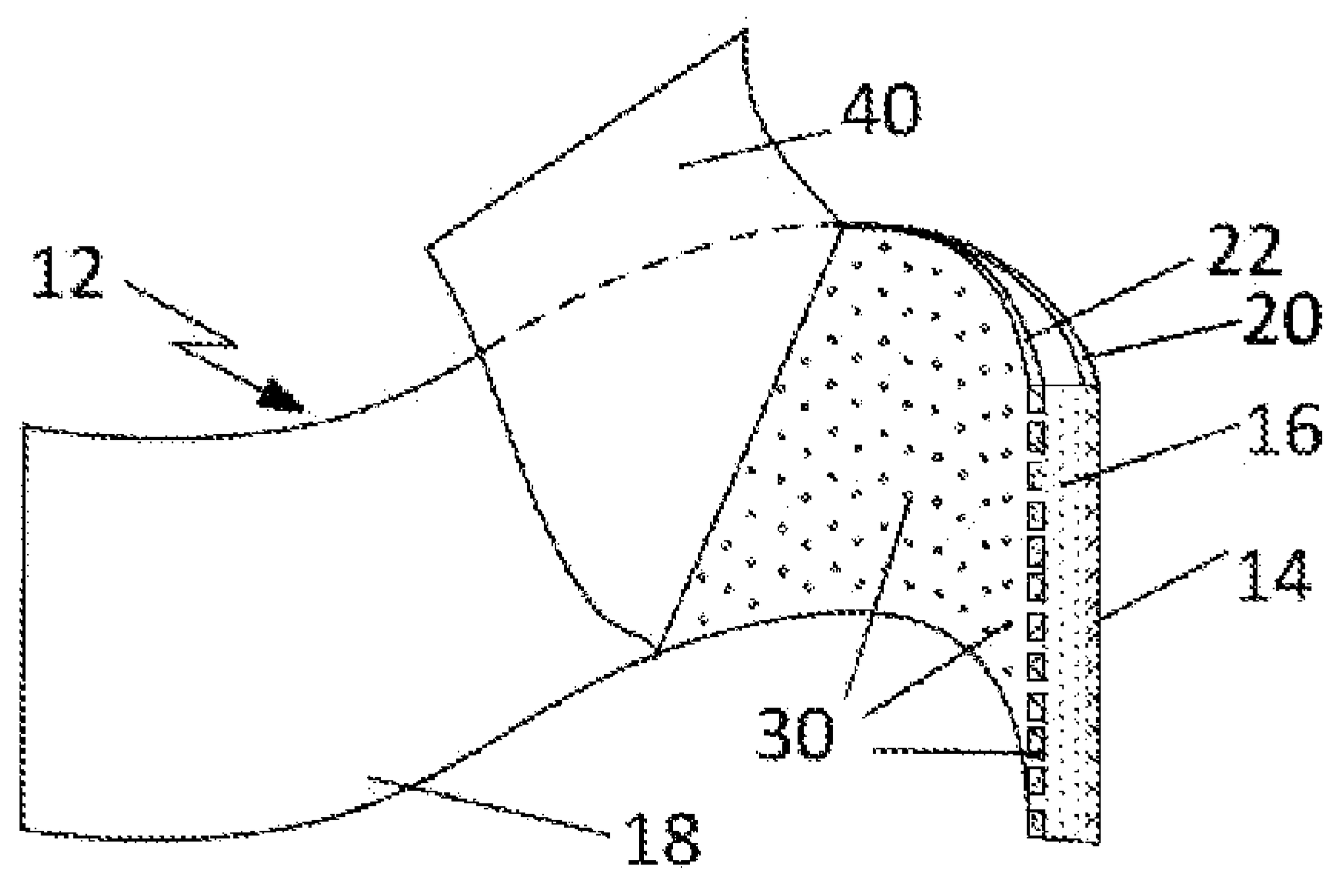


FIG. 5

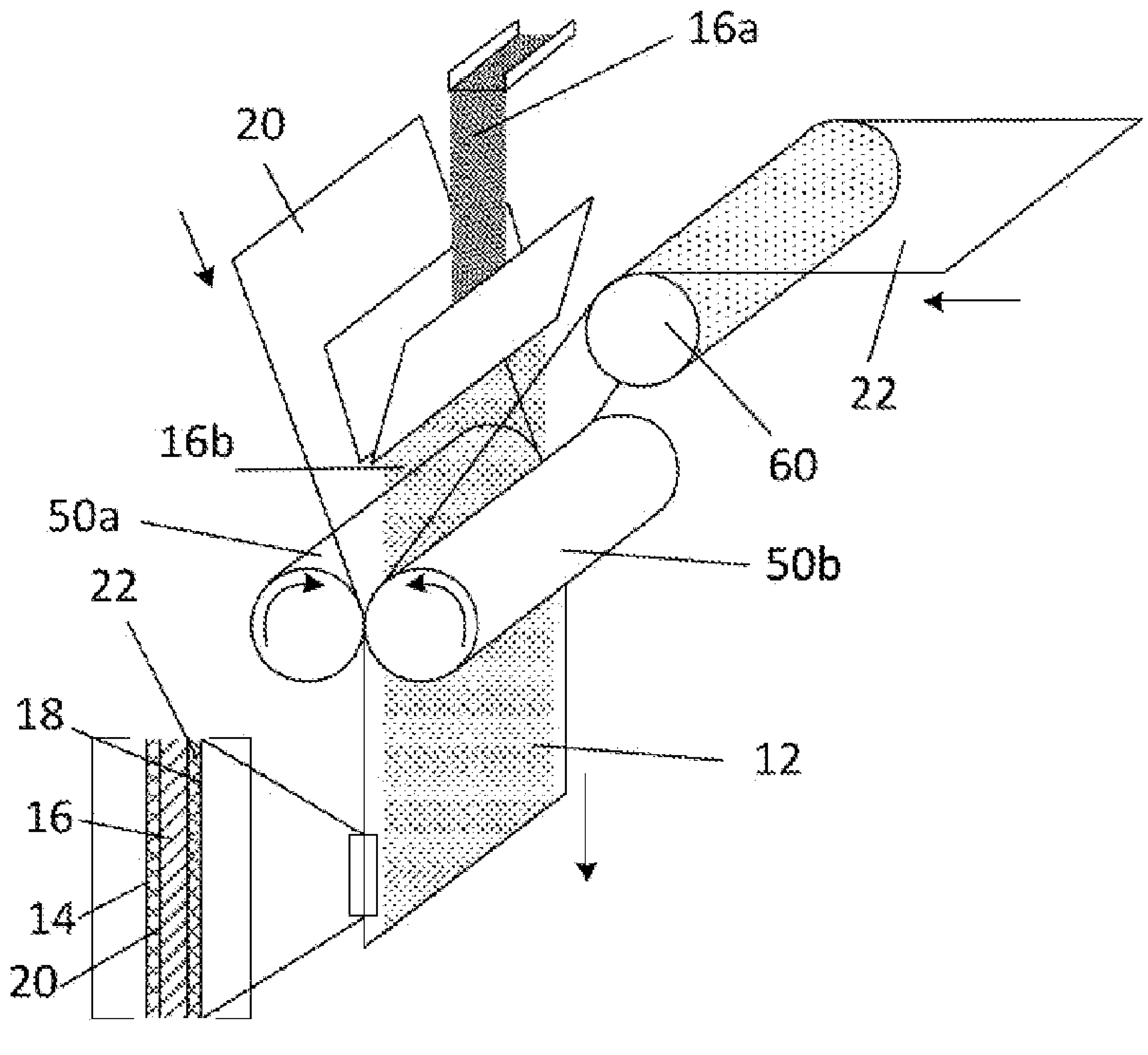


FIG. 6

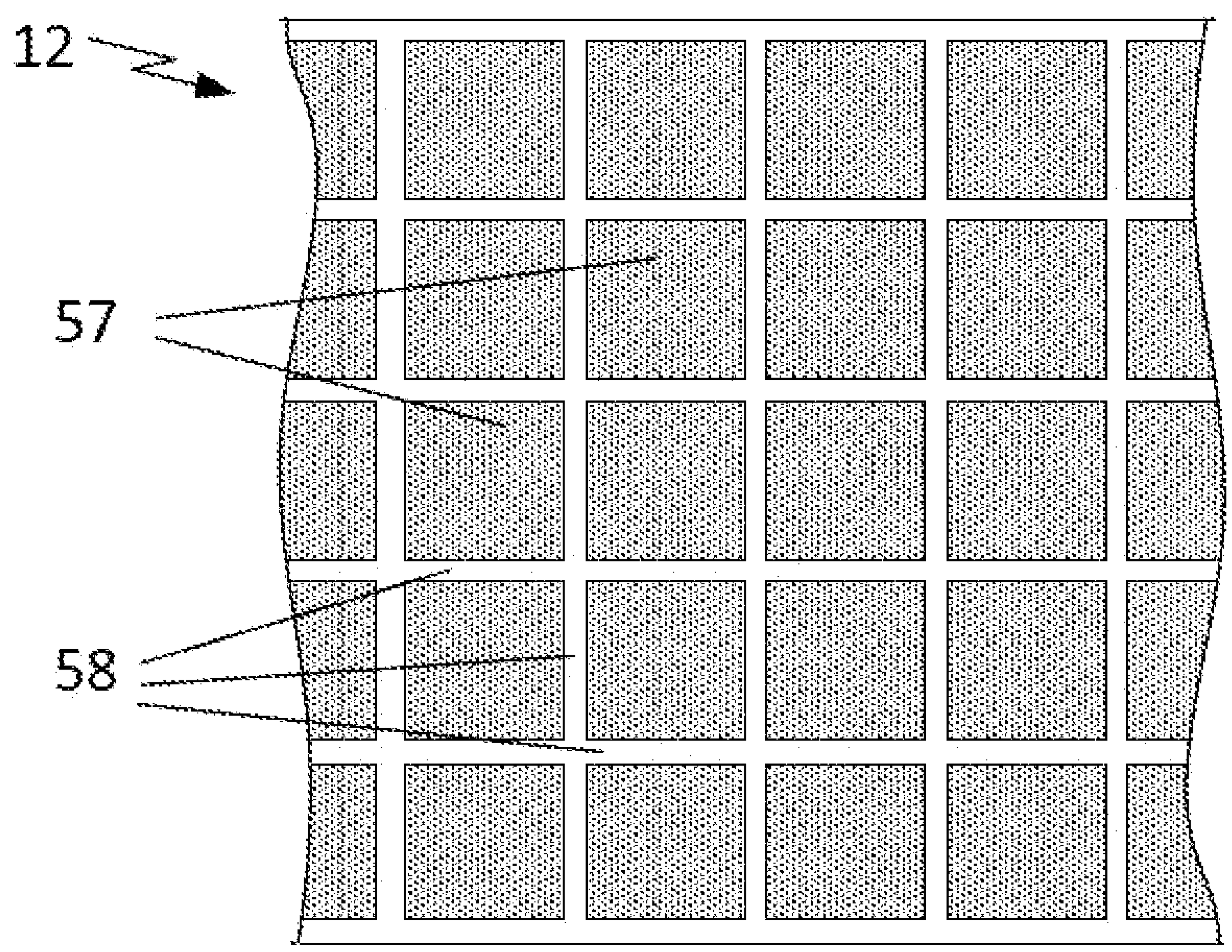


FIG. 7

SELF-COOLING CONTAINERS AND WRAPS

BACKGROUND

[0001] Proper handling of items that need to be kept cold can be difficult during transport of the items. For example, ice cream can begin to melt while being taken home from the store and re-freezing can give the ice cream a different texture. In addition, proper handling of food is important to minimize spoiling of the food and prevent foodborne illnesses, both of which may be associated with growth of bacteria, or other germs. Bacteria, or other germs, need time, food and moisture to grow, and typically grow best at temperatures of about 5° C. to about 57° C. Bacteria are present in many types of foods, such as meats, seafood, dairy products, fruits, and cooked vegetables. When these types of potentially hazardous foods are left for a sufficient period of time at temperatures of about 5° C. to about 57° C., bacteria can grow quickly or make poisons that can make people sick, spoil the food, or both.

[0002] Bacteria will not grow when the temperature of the food is colder than about 5° C. For this reason, certain foods are stored at temperatures below about 5° C. Proper handling of these foods can be very important in and between the production/preparation facilities, warehouses, and supermarkets. Therefore, such foods are kept in cold storage and transported in refrigerated vehicles. Transportation by the end consumer may often be the most challenging step in the transportation chain.

[0003] Once a product exits the cold chain, such as when a consumer/purchaser removes the product from cold storage to take home, mishandling and poor storage by the consumer may lead to a reduction in perceived quality of the product, spoiling of the food, or in extreme cases, food poisoning. Therefore, ensuring that product quality is maintained once the product exits the cold chain is highly desirable to the consumer's overall perception of the product and health.

[0004] Carrying bulky coolers and bags of ice for temporary transport of food items is often inconvenient. There remains a need for convenient cooling devices that are ideally inexpensive and simple to use.

SUMMARY

[0005] Self-cooling devices or packagings that begin cooling upon exposure to ambient moisture in the air may provide convenient cooling for many uses, such as the transport of food. The device or packaging may contain reactants that are able to produce an endothermic reaction upon hydration to thereby enable the devices or packaging to be placed around an item and cool the item in the presence of ambient atmospheric moisture. Since ambient water vapor provides one of the reactants, a water portion does not necessarily need to be stored with or within the device, significantly reducing the weight of the cooling device.

[0006] In an embodiment, a self-cooling container includes at least one panel defining an interior space for containing a product therein, the panel having an internal surface defining the interior space and an external surface disposed outwardly of the internal surface, and at least a portion of the at least one panel comprises a reactant adapted to produce an endothermic reaction upon hydration of the reactant by ambient water vapor.

[0007] In an embodiment, a cooling wrap configured to be disposed about and cool an item includes a reactant adapted to produce an endothermic reaction upon hydration of the reactant with ambient moisture.

[0008] In an embodiment, a method of maintaining a temperature of a food item includes disposing a cooling material adjacent to at least a portion of the food item, the cooling material including a reactant adapted to produce an endothermic reaction upon hydration of the reactant with ambient water vapor, storing the food item in a cold, dry environment, removing the food item from the cold, dry environment, and exposing the cooling material to ambient water vapor to hydrate the reactant, initiate the endothermic reaction and maintain a temperature of the food item.

[0009] In an embodiment, a method of using a cooling wrap is provided. The cooling wrap includes a reactant adapted to produce an endothermic reaction upon hydration of the reactant. In one embodiment, the method includes cooling an item, disposing the cooling wrap around at least a portion of the item to be cooled, exposing the cooling wrap to ambient moisture to hydrate the reactant, and initiating the endothermic reaction. In another embodiment, the method includes exposing the cooling wrap to ambient moisture to hydrate the reactant, initiating the endothermic reaction, and disposing the cooling wrap around at least a portion of the item to be cooled.

[0010] In an embodiment, a method of producing a material for cooling an object includes selecting a reactant capable of an endothermic reaction upon hydration of the reactant with ambient water vapor, and enveloping the reactant in at least one polymer film, wherein at least a portion of the polymer film is permeable to water vapor.

BRIEF DESCRIPTION OF THE FIGURES

[0011] FIG. **1** depicts illustrative cross-sectional and isometric views of a cooling container according to an embodiment.

[0012] FIGS. **2**-**4** depict cross-sectional views of cooling panels according to embodiments.

[0013] FIG. **5** depicts a flexible cooling wrap according to an embodiment.

[0014] FIG. **6** depicts an illustrative system for producing a cooling sheet according to an embodiment.

[0015] FIG. **7** depicts a view of a surface of a cooling sheet according to an embodiment.

DETAILED DESCRIPTION

[0016] A cooling material, such as a wrap or a container, may include reactants that undergo a strongly endothermic reaction upon exposure to atmospheric water vapor. In an embodiment, an endothermic process absorbs heat from the environment during the dissolution of the reactants in water, and therefore, when applied adjacent an object, may draw heat from the object to cool the object. Such a cooling material may provide a convenient method for keeping foods cool upon removal of the foods from cold storage. Such cooling materials may be used for transport of pharmaceuticals, vaccines, blood, plasma, organs, and temperature sensitive medical products, as well as other types of products that should remain thermostatic to remain effective.

[0017] In an embodiment, a cooling material, such as a wrap, may be exposed to atmospheric humidity to initiate an endothermic reaction, and the material may be placed or wrapped around an object to cool the object. In alternative embodiments, an object, such as a food product may be provided in packaging formed from the cooling material, or alternatively, a food product may be wrapped with the cooling material. Once provided with the cooling material, the food product may be placed into cold storage. Since refrigerated air in cold storage generally has low humidity levels, minimal reaction may occur while in cold storage. However, upon removal of the product from cold storage into ambient air, water vapor in the air may activate the reactants and produce an endothermic reaction to thereby provide a cooling environment for the product. In addition, since water vapor condenses on cold surfaces, the cold temperature of the product and cooling material may enhance condensation of water vapor on the cooling material. The condensed water may penetrate into the reactants to enhance hydration of the reactants and enhance cooling.

[0018] In an embodiment, a cooling material may include at least two dehydrated chemical reactants that are able to provide an endothermic reaction in the presence of moisture, and a covering or support material to retain the reactants. The composition of the chemical reactants, in addition to the precise arrangement of the components, and the rate at which moisture penetrates to the reactants are factors that can modify the reaction rate and the amount of cooling that is able to be provided. In situations where it may be determined that a faster hydration may be required, additional water may be applied to the packaging, for example, by misting with water.

[0019] In an embodiment, the reactants may include at least one chemical composition that is capable of undergoing an endothermic reaction caused by dissolution of water-soluble salts during hydration. The reactants may include at least one water-soluble salt that contains at least one of potassium, sodium, ammonium, and nitrogen.

[0020] In an embodiment, the water-soluble salt may be a non-toxic salt, or a salt which is generally regarded as safe for use in food applications. The water-soluble salt (shown with associated heat of solution) may be potassium bromide (KBr-19.87 kj/mol), potassium chloride (KCl-17.22 kj/mol), potassium iodide (KI-20.33 kj/mol), potassium nitrate (KNO_3-34.89 kj/mol), potassium sulfate (K_2SO_4-23.8 kj/mol), sodium bromide dihydrate ($NaBr2H_2O$-18.64 kj/mol), sodium chloride (NaCl-3.88 kj/mol), sodium chlorate ($NaClO_3$-21.72 kj/mol), sodium iodide dihydrate ($NaI.2H_2O$-16.13 kj/mol), sodium perchlorate ($NaClO_4$-13.88 kj/mol), sodium acetate trihydrate ($NaC_2H_3O_2.3H_2O$-19.66 kj/mol), sodium thiosulfate pentahydrate ($Na_2S_2O_3.5H_2O$-47.4 kj/mol), ammonium bromide (NH_4Br-16.78 kj/mol), ammonium nitrate (NH_4NO_3-25.69 kj/mol), ammonium chloride (NH_4Cl-14.78 kj/mol), urea ($CO(NH_2)_2$-15 kj/mol), ammonium phosphate ($(NH_4)_3PO_4$-14.45 kj/mol), or any combination thereof.

[0021] In some cooling applications, the toxicity of the reagents may not be critical. In such applications the soluble salt (some shown with associated heat of solution) may be potassium fluoride dihydrate ($KF.2H_2O$-6.97 kj/mol), potassium nitrite (KNO_2-13.35 kj/mol), potassium thiosulfate pentahydrate ($K_2S_2O_3.5H_2O$-47 kj/mol), potassium cyanide (KCN-11.72 kj/mol), potassium cyanate (KCNO-20.25 kj/mol), potassium thiocyanide (KCNS-24.23 kj/mol), sodium chlorite monohydrate ($NaClO_2.H_2O$-22.51 kj/mol), sodium chlorite dihydrate ($NaClO_2.2H_2O$ sodium chlorite trihydrate ($NaClO_2.3H_2O$-28.58 kj/mol), sodium bromide dihydrate ($NaBr.2H_2O$-18.64 kj/mol), sodium thiocyanide (NaCNS-6.83 kj/mol), sodium nitrite ($NaNO_2$-13.89 kj/mol), sodium nitrate ($NaNO_3$-20.5 kj/mol), sodium cyanide dihydrate ($NaCN.2H_2O$-18.58 kj/mol), sodium cyanate (NaCNO-19.2 kj/mol), ammonium perchlorate (NH_4ClO_4-33.47 kj/mol), ammonium iodide (NH_4I-13.72 kj/mol), ammonium iodate (NH_4IO_3-31.8 kj/mol), ammonium nitrite (NH_4NO_2-19.25 kj/mol), ammonium cyanide (NH_4CN-17.57 kj/mol), ammonium thiocyanide (NH_4CNS-22.58 kj/mol), ammonium phosphate ($(NH_4)_3PO_4$-14.45 kj/mol), diammonium phosphate ($(NH_4)_2HPO_4$), ammonium polyphosphate ($[NH_4PO_3]_n$), ammonium pyrophosphate, ammonium metaphosphate (NH_4PO_3), silver nitrate ($AgNO_3$-22.59 kj/mol), rubidium nitrate ($RbNO_3$-36.48 kj/mol), or any combination thereof.

[0022] Salts having a larger heat of solution (enthalpy of solution) may result in a more endothermic reaction upon hydration. Thus, of the listed salts, sodium thiosulfate pentahydrate ($Na_2S_2O_3.5H_2O$) with a heat of solution of about 47.4 kj/mol, may produce the greatest cooling effect. For lower cost, non-toxic materials, potassium nitrate, with a heat of solution of about 34.89 kj/mol, may produce a high cooling effect. For example, a liter of water at about ambient room temperature in an insulated vessel may be cooled by about 17° C. with about 50 grams of potassium nitrate.

[0023] In an additional embodiment, an endothermic reaction may be produced by a reaction between at least two dry components, wherein the reaction is initiated upon solvation of at least one of the dry components. Such endothermic reaction schemes may require a larger volume of atmospheric moisture to initiate the reaction that is required for cooling by solvation of salts as discussed above. This may be advantageous for items that are briefly exposed to atmospheric humidity during their preparation and/or handling, and for which complete cooling activation is not yet desired.

[0024] By using a two (or more)-component reaction system, greater control over the reaction may be afforded as the reactants may be chosen and the reaction system configured so that small concentrations of atmospheric moisture may not initiate the reactions. The reactants may be chosen so that solvation of one or both of the reactants may be necessary for the reaction to occur. Consequently, a greater amount of condensation may be needed to initiate the reaction. However, once sufficient moisture is present to solvate the reagents, the reaction may occur relatively rapidly and may reach completion within about 30 minutes to about 60 minutes. The slower initiation and more rapid completion, as compared to the dehydrated salts, may make this type of system more suitable for frozen goods. In situations where a faster initiation of a two-component system may be desired, additional water may be applied to the packaging, for example, by misting with water.

[0025] One type of system which is able to produce such a reaction is an acid/carbonate system, where at least one of the components includes an organic acid and at least one other of the components includes a carbonate. An acid/carbonate reaction produces carbon dioxide during the reaction, and the carbon dioxide may be vented through perforations in the material, for example, the same perforations that may allow entry of water into the material.

[0026] In an acid/carbonate system, the organic acid may be citric acid, acetic acid, propanoic acid, tartaric acid, succinic acid, formic acid, fumaric acid, or lactic acid, or any combination thereof. The carbonate may be calcium carbonate, sodium carbonate, potassium carbonate, magnesium carbonate, lithium carbonate, or any combination thereof.

[0027] For any of the reactants as discussed above, a dehydrated hydrogel may be included with the reactants to ensure that as the reactants do not leech from the packaging and/or crystallize on the outer surface of the package. For example, as a salt is hydrated, the salt may dissolve in the water liquid and leach from the package. With an included hydrogel, the hydrogel may also become hydrated and provide a gel matrix for holding the salt solution in the packaging. Some example of dehydrated hydrogels include sol gels, silicone gels, polyacrylamide gels, polyvinyl alcohol gels, polyacrylate gels, acrylate polymers, agarose, alginate, methylcellulose, hyaluronan (hyaluronic acid), or any combination thereof.

[0028] In an embodiment, the reactants may also include a thermal buffer material so that, when disposed about an object to be cooled, may provide an insulation for enhancing the longevity of the cooling by slowing transfer of heat from the surroundings back into the object being cooled. The thermal buffer material may be a phase-change material that is included with the reactants. Upon hydration and activation of the reactants and cooling of the phase-change material, the phase-change material may transition from a liquid to a solid. After the reactants are exhausted, the phase-change material may become solidified, and as the materials warm, the phase change of the materials from solid back to liquid may absorb thermal energy from the surroundings, preventing the thermal energy from being transferred to the product itself, thereby providing a thermal buffer.

[0029] Some examples of phase-change materials that may act as a thermal buffer include salt hydrates, paraffin, fatty acids, or any combination thereof. Some examples of fatty acids that may act as a thermal buffer include capric acid, lauric acid, palmitic acid, a stearic fatty acid, or any combination thereof. Some examples of salt hydrates that may act as a thermal buffer include hydrated sodium acetate, calcium chloride hexahydrate, potassium fluoride tetrahydrate, a eutectic salt mixture, or any combination thereof.

[0030] The reactants and any additional components as discussed above may be incorporated into a layer of material such as a sheet or panel that may be rigid or flexible. For example, as shown in FIG. **1**, a container **10** may be formed by a panel **12**. The container **10** may be substantially bowl-shaped, cubic, or any other shape. As shown in FIG. **1**, the panel **12** may define an interior surface **14** and an exterior surface **18**, and at least some of the panel may include reactant materials **16**. The container **10** may also include a lid **13** that may be constructed in a manner similar to the panel **12**. The container **10** may be disposed around and enclose, for example, a food item. When the container is exposed to ambient atmospheric moisture, the reactant materials **16** may become hydrated and an endothermic reaction may be initiated to provide cooling of the contents.

[0031] FIG. **2** depicts a cross-sectional view of a cooling panel according to a first embodiment. As shown in FIG. **2**, the panel **12** may include reactant materials **16** disposed between a first polymer film **20** and a second polymer film **22**. The first polymer film **20** may define the interior surface **14** and the second polymer film **22** may define the exterior surface **18**. At least the second polymer film **22** may be permeable to moisture so that upon exposure to atmospheric moisture, the water may penetrate through the film and hydrate the reactant materials **16**. The moisture permeable film may be a porous film, a perforated film (see FIG. **5**), or a combination of the two.

[0032] Each of the first polymer film **20** and the second polymer film **22** may individually be polylactic acid (PLA), co-poly lactic acid/glycolic acid (PLGA), cellulose, starch, polyethylene, polypropylene, polyvinyl chloride (PVC), polyethlene terephthalate. (PET), nylon, polyolefin, ethylene-vinyl acetate, ethylene-vinyl alcohol, ethylene-acrylic acid, polystyrene, polyvinyl alcohol, polyethylene terephthalate, polyethylene naphthalate, polycarbonates, cellulose polymers, polyamide, polyacrylonitrile, acrylonitrile/styrene, or any combination thereof.

[0033] Cost and environmental impact may make some of the above materials more suitable than others. In an embodiment, it may be desirable that the materials have simple processing requirements, suitable mechanical properties, be low cost and ideally be recyclable or biodegradable. In this regard, some suitable sustainable materials may include PLA, PLGA, cellulose, and starch polymers, while some suitable conventional polymers may include polyethylene, polypropylene, PVC, and PET. Additional polymers may also be included, either for one or both of the film materials, or in smaller quantities in the material to provide specific process properties. For example, heat shrink polymers, such as nylon and polyolefin may be used to produce a material that may be applied to an object and then heat-shrunk to tightly wrap the object.

[0034] The structure of the final cooling material may be dictated by the material selection of the supporting polymer film. The thickness and material selection of the supporting material may enable the bulk film to be made with a range of mechanical properties including control over rigidity, flexibility and thickness. The process requirements of the structural layer and the perforated layer dictate the methods by which the overall material may be processed. For example, selection of appropriate thermoplastic materials may enable the film to be molded directly into containers, whereas selection of thin and flexible materials having a thickness of about 10 μm to about 250 μm may enable the film to be applied as a label or used as a direct food covering, for example in meat packaging.

[0035] At least one of the first polymer film **20** and the second polymer film **22** may be a thermoplastic polymer or a thermoset polymer that when heated to a softening temperature is deformable to form different shapes. The container **10** may then be molded from a panel **12** to provide a desired shape. For example, a panel **12** may be formed as a substantially continuous sheet, and upon heating to an appropriate temperature, may be press molded into bowl-shaped containers, such as that represented in FIG. **1**. Alternatively, a panel **12** may be formed, cut and folded to form a container **10**. For example, a single panel **12** may be cut and folded into a cubic box having **6** contiguous panel portions, a bottom, four sides and a top, that may be folded together to form the container **10**.

[0036] FIG. **3** depicts a cross-sectional view of a cooling panel according to a second embodiment. As shown in FIG. **3**, a panel **12** may be formed from a material layer **24** having a first surface defining the internal surface **14** of the panel, and a second surface **26** external to the first surface. The reactant material **16** may be a coating material disposed on at least a portion of the second surface **26**.

[0037] FIG. **4** depicts a cross-sectional view of a cooling panel according to a third embodiment. As shown in FIG. **4**, a panel **12** may be formed from a material layer **24** having a first surface defining the internal surface **14** of the panel, and a second surface **26** external to the first surface. An additional cooling layer of reactant material **16** may be disposed on at least a portion of the surface **26**. The cooling layer may have a structure similar to the cooling layer disclosed with respect to FIG. **2**, wherein the reactant material **16** is disposed between a first polymer film **20** and a second polymer film **22**. The cooling layer may be fixed, for example, by adhesive, to the surface **26**.

[0038] FIG. **5** shows an embodiment of a flexible panel **12** of a construction similar to that represented in FIG. **2**. Several representative perforations **30** are depicted in the polymer film **22** to depict an example of a porous film. The perforations **30** have a size and a density, and the size and density may be configured to provide a rate of moisture passage through the film. Perforations **30** may have a size of about 0.5 μm to about 500 μm, and the density of the perforations in the film may be about 5000 holes/cm^2 to about 20 holes/cm^2. In this regard, larger sized perforations and a greater density of perforations may enable passage of a larger amount of water for a faster reaction, while smaller sized perforations and a lesser density of perforations may enable passage of less water for a slower reaction. Panels **12** may therefore be configured to have different rates of hydration to provide different reaction rates and varied degrees or durations of cooling. If the amount of reactant **16** is the same, a panel **12** having a greater rate of water passage will have a higher degree of cooling that may last for a shorter period of time than a panel **12** having a slower rate of passage of water to provide a lesser degree of cooling that may last for a longer period of time.

[0039] A flexible panel **12**, such as that of FIG. **5**, may be used to form a flexible cooling wrap material that may be wrapped externally around a product to be cooled, or may be used to form a bag into which an item may be inserted. Thus, instead of placing an item, such as a food product inside a container, such as container **10** of FIG. **1**, the cooling wrap may be wrapped around the item with the permeable film **22** disposed outwardly toward the ambient air, or an item may be inserted into a pre-formed bag. In this manner, irregularly shaped items, or prepackaged items not including a cooling material may be wrapped or bagged at a time when the wrapping or bag is needed. For example, a consumer may remove a food item from cold storage for purchase, and immediately place the food item in a cooling bag made from the flexible material as shown in FIG. **5**.

[0040] As shown in FIG. **5**, cooling wraps or bags may have a removable moisture-impermeable covering **40** that prohibits moisture from entering through the perforations **30** prior to removal of the covering. At the time of use, the covering **40** may be removed to expose the perforations **30**, and the wrap may be disposed about the item to be cooled. Alternatively, the covering **40** may be configured as a sealable moisture-impermeable package or bag that completely surrounds the wrap. In such an embodiment, the wrap may be removed from the bag before use to expose the wrap to moisture.

[0041] In embodiments of cooling materials wherein salts provide the reactant, the cooling materials may be regenerated by removing moisture from the material. This may be done, for example, by vaporizing the water to dry the salts. The vaporization may be done with heating, under vacuum, or both. Once dry, the cooling material may be stored in a water-impermeable pouch or water-impermeable bag for additional use.

[0042] In an embodiment, a cooling material may be produced by enveloping the reactant in at least one polymer film that is permeable to water vapor. For example, the reactant may be disposed on a portion of the film, and another portion of the film may be folded over the reactant, sealing the reactant between the films.

[0043] In an alternative embodiment, a cooling material may be produced by dispensing the reactant between a first polymer film and a second polymer film, and sealing the first polymer film to the second polymer film to envelop the reactant between the films. At least one of the two films may be a moisture permeable film.

[0044] FIG. **6** depicts a schematic representation of a system which may be used to seal a reactant between two polymer films. A first polymer film **20** may be provided from a first supply roll (not shown) and a second polymer film **22** may be provided from a second supply roll (not shown). Each of the first and second polymer films **20**, **22** may be fed downwardly and into a face-to-face orientation. The films may be fed to a sealing system to seal the films to one another. The sealing system may include two adjacent rollers **50***a*, **50***b* that may be pressure and/or sealing rollers. The films may be fed between the rollers and sealed to one another. A dry reactant **16***a* may be fed into a gravity distribution trough **55** that disperses the reactant into a reactant stream **16***b* and distributes the reactant between the films **20**, **22** prior to the sealing rollers **50***a*, **50***b*. Additional components, such as a hydrogel or thermal buffer material may be mixed into the reactant stream **16***b*. The two films **20**, **22** may be adhered together thermally or with an adhesive.

[0045] In an embodiment, to avoid pooling of reactant material within the sheet **12**, the films may be sealed together at intervals to establish pockets **57** separated by sealing seams **58** as shown in FIG. **7**. Dry granular reactant may then be free flowing within the individual pockets **57**, while still substantially covering the entire area of the sheet **12**.

[0046] In embodiments wherein the outer film material **22** is moisture impermeable, a perforator **60**, as represented in FIG. **6**, may be used along the feed path of the material. In an embodiment, the perforator **60** may be a drum with projecting pins on the surface to punch holes in the film material as it passes over the drum. Alternatively, porous polymer films may be used. Porous polymer films may be produced by lithography and/or templating with water droplets.

[0047] The two films **20**, **22** may be adhered together thermally or with an adhesive. Rollers **50***a*, **50***b* may apply heat and/or pressure to the films **20**, **22** to seal the films to one another and envelop the reactant **16** between the films. The finished sheet product, or panel **12**, may be transported to further processing equipment for forming into wraps, containers, bags, or the like. Alternatively, the finished sheet panel **12** may be wrapped on a roll for transport to a further site for additional processing. To inhibit reaction, the finished product may be stored in a dry, water-proof enclosure. Depending on the material used for the outer surface **18**, printing may be directly applied to the outer surface, allowing the sheet material to be used in place of additional labels and thereby allowing for a reduction in costs.

EXAMPLES

Example 1

Preparation of a Cooling Material

[0048] An elongated sheet of cooling material will have inner and outer films of polyvinyl chloride having a thickness of about 12.5 μm and a width of about 10 cm enveloping a reactant of potassium nitrate at a density of about 0.25 g/cm^2 between the films. The outer film will be perforated with holes of a diameter of about 100 μm at a density of about 80 holes/cm^2, and the films will be sealed together at intervals of about 2 cm along both the width and length dimensions in a manner as represented in FIG. **7** thereby having reactant pockets of approximately a 2 cm by 2 cm area.

Example 2

Production of a Cooling Material

[0049] Continuous sheets of the cooling material of Example 1 having a width of about 10 cm will be formed using a system as illustrated in FIG. **6** by using two polyvinyl chloride (PVC) films of about 12.5 μm thickness and potassium nitrate as the reactant. The films will be unrolled and fed to the sealing rollers, and the film intended to provide the external surface will be perforated to have holes with diameters of about 100 μm at a density of about 100 holes/cm^2.

[0050] Powdered anhydrous potassium nitrate will be deposited by gravity flow between the films at a density of about 0.2 g/cm^2, and the films will be thermally bonded together to form pockets of potassium nitrate across the width and length of the sheet. The completed cooling material sheet will be rolled with the external surface inwardly to inhibit moisture entry into the material. In other words, the non-perforated (non-moisture permeable) film will be radially outwardly disposed on the roll. For long term storage, the roll will be placed in a non-moisture permeable and sealable bag.

Example 3

Use of a Cooling Wrap

[0051] A flexible wrap, such as that of Examples 1 and 2, will be used for keeping a patient's medicine cold for transport from a pharmacy to the patient's home. A length of the cooling wrap of Example 1 will be cut off of the roll and removed from the bag, exposing the wrap to ambient moisture. The medicine will be removed from refrigeration and wrapped in the cooling wrap for transport. The endothermic reaction initiated by exposure to atmospheric humidity will cool the wrap, causing condensation on the wrap, thereby drawing additional moisture into the reactants to produce a cooling temperature sufficient for transport of the medicine to the patient's home without a rise in temperature of the medicine.

Example 4

A Self-Cooling Food Container

[0052] An environmentally-friendly food container having a self-cooling surface will be formed from poly lactic acid (PLA). A first cooling component will be formed as an elongated sheet of cooling material with inner and outer films of PLA having a width of about 20 cm enveloping a reactant of potassium nitrate at a density of about 0.3 g/cm^2 between the films. The outer film will be perforated with holes of a diameter of about 100 um at a density of about 100 holes/cm^2, and the films will be sealed together at intervals of about 1 cm along both the width and length dimensions in a manner as represented in FIG. **7**, thereby having reactant pockets of approximately a 1 cm by 1 cm area.

[0053] A second structural component will be a sheet of PLA having a thickness of about 2 mm The cooling sheet will be attached to the structural sheet with an adhesive with the perforated layer facing outwardly. To form the final container, the joined layers will be heated to a temperature of about**60**° C. to soften the PLA, and the material will be molded to form rectangular bowls similar to the representation of FIG. **1**. The containers will be stored in a dry environment to prevent activation of the reactants.

Example 5

Use of a Self-Cooling Container

[0054] A container produced in accordance with Example 4 will be used to maintain the temperature of ice cream during transport of the ice cream by a consumer from a store to the consumer's home. Containers having a 2 liter internal capacity will be formed as in Example 4, and will be filled with ice cream. Lids will be attached, and the containers will be placed in cold, dry storage for complete freezing of the ice cream. The containers will be transported to the grocery in refrigerated trucks and will be placed immediately into cold storage upon arrival at the grocery. Because of the dry, cool environments, the reactants will remain substantially unaffected.

[0055] A consumer will remove the container from cold storage to take home, and upon removal, expose the container to ambient air and the moisture in the air, thereby initiating the endothermic reaction. Moisture will condense on the container and provide additional water for the reactants, thereby cooling the material automatically upon removal from cold storage, and providing a cold environment for maintaining the temperature of the ice cream at a temperature below the freezing temperature.

[0056] This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

[0057] In the above 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 used, 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.

[0058] 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.

[0059] As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

[0060] While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups.

[0061] 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.

[0062] 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."

[0063] 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.

[0064] 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.

[0065] Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

1. A self-cooling container comprising at least one panel defining an interior space for containing a product therein, the panel having an internal surface defining the interior space and an external surface disposed outwardly of the internal surface, and at least a portion of the at least one panel comprises a reactant adapted to produce an endothermic reaction upon hydration of the reactant by ambient water vapor.

2. The container of claim **1**, wherein the at least one panel comprises:

- a first polymer film forming the internal surface;
- a second polymer film forming the external surface, the second polymer film being moisture permeable; and
- the reactant is disposed between the first polymer film and the second polymer film.

3. (canceled)

4. The container of claim **1**, wherein the at least one panel comprises:

a material layer having a first surface defining the internal surface of the at least one panel, and a second surface external to the first surface; and

the reactant is disposed on at least a portion of the second surface of the material layer.

5. The container of claim **1**, wherein the at least one panel comprises:

a first material layer having a first surface defining the internal surface of the at least one panel, and a second surface external to the first surface; and

a cooling layer disposed adjacent the second surface of the first material layer, wherein the cooling layer comprises the reactant.

6. The container of claim **5**, wherein:

the cooling layer comprises a layer of the reactant disposed between a first polymer film and a second polymer film;

at least one of the first polymer film and the second polymer film comprises a moisture-permeable film; and

the moisture-permeable film is disposed outwardly away from the first material layer and defines the external surface of the at least one panel.

7. The container of claim **6**, wherein each of the first polymer film and the second polymer film individually comprises: poly lactic acid (PLA), co-poly lactic acid/glycolic acid (PLGA), cellulose, starch, polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, nylon, polyolefin, ethylene-vinyl acetate, ethylene-vinyl alcohol, ethylene-acrylic acid, polystyrene, polyvinyl alcohol, polyethylene terephthalate, polyethylene naphthalate, polycarbonates, cellulose polymers, polyamide, polyacrylonitrile, acrylonitrile/styrene, or any combination thereof.

8. The container of claim **6**, wherein the moisture-permeable film comprises a porous film.

9.-**12**. (canceled)

13. The container of claim **1**, wherein the reactant comprises at least one water-soluble salt that contains at least one of potassium, sodium, ammonium, and nitrogen.

14. The container of claim **13**, wherein the at least one water-soluble salt is a non-toxic salt selected from a group comprising: potassium bromide (KBr), potassium chloride (KCl), potassium iodide (KI), potassium nitrate (KNO_3), potassium sulfate (K_2SO_4), sodium bromide dihydrate ($NaBr.2H_2O$), sodium chloride (NaCl), sodium chlorate ($NaClO_3$), sodium iodide diydrate ($NaI.2H_2O$), sodium perchlorate ($NaClO_4$), sodium acetate trihydrate ($NaC_2H_3O_2.3H_2O$), sodium thiosulfate pentahydrate ($Na_2S_2O_3.5H_2O$), ammonium bromide (NH_4Br), ammonium nitrate (NH_4NO_3), ammonium chloride (NH_4Cl), urea ($CO(NH_2)_2$), and ammonium phosphate ($(NH_4)_3PO_4$).

15. (canceled)

16. The container of claim **1**, wherein the reactant comprises at least one dehydrated hydrogel.

17. The container of claim **16**, wherein the dehydrated hydrogel comprises a sol gel, a silicone gel, a polyacrylamide gel, a polyvinyl alcohol gel, a polyacrylate gel, an acrylate polymer, agarose, alginate, methylcellulose, hyaluronan, or any combination thereof.

18. The container of claim **1**, wherein the reactant comprises a thermal buffer material.

19. The container of claim **18**, wherein the thermal buffer material comprises a phase-change material selected from the group consisting of salt hydrates, paraffin and fatty acids.

20.-**22**. (canceled)

23. The container of claim **1**, wherein the reactant comprises a plurality of components capable of undergoing an endothermic reaction upon solvation of at least one of the plurality of components.

24. The container of claim **23**, wherein a first component of the plurality of components comprises an organic acid and a second component of the plurality of components comprises a carbonate.

25. The container of claim **24**, wherein the organic acid comprises citric acid, acetic acid, propanoic acid, tartaric acid, succinic acid, formic acid, fumaric acid, lactic acid, or any combination thereof.

26. The container of claim **24**, wherein the carbonate comprises calcium carbonate, sodium carbonate, potassium carbonate, magnesium carbonate, lithium carbonate, or any combination thereof.

27.-**53**. (canceled)

54. A method for maintaining a temperature of a food item, the method comprising:

disposing a cooling material adjacent at least a portion of the food item, the cooling material comprising a reactant adapted to produce an endothermic reaction upon hydration of the reactant with ambient water vapor;

storing the food item in a cold, dry environment;

removing the food item from the cold, dry environment; and

exposing the cooling material to the ambient water vapor to hydrate the reactant, initiate the endothermic reaction and maintain the temperature of the food item.

55. (canceled)

56. The method of claim **54**, wherein the disposing comprises disposing a cooling material covered by a removable, moisture impermeable wrap, and the exposing comprises removing the moisture impermeable wrap to expose the cooling material to the ambient water vapor to hydrate the reactant and initiate the endothermic reaction.

57. (canceled)

58. The method of claim **54**, wherein the reactant comprises at least one soluble salt capable of undergoing an endothermic reaction caused by dissolution of the at least one soluble salt during hydration, and the exposing comprises exposing the at least one soluble salt to the ambient water vapor to at least begin to dissolve the at least one soluble salt and initiate the endothermic reaction.

59. The method of claim **58**, wherein the at least one soluble salt is a non-toxic salt selected from a group comprising: potassium bromide (KBr), potassium chloride (KCl), potassium iodide (KI), potassium nitrate (KNO_3), potassium sulfate (K_2SO_4), sodium bromide dihydrate ($NaBr.2H_2O$), sodium chloride (NaCl), sodium chlorate ($NaClO_3$), sodium iodide diydrate ($NaI.2H_2O$), sodium perchlorate ($NaClO_4$), sodium acetate trihydrate ($NaC_2H_3O_2.3H_2O$), sodium thiosulfate pentahydrate ($Na_2S_2O_3.5H_2O$), ammonium bromide (NH_4Br), ammonium nitrate (NH_4NO_3), ammonium chloride (NH_4Cl), urea ($CO(NH_2)_2$), and ammonium phosphate ($(NH_4)_3PO_4$).

60. The method of claim **58**, wherein the at least one soluble salt is mixed with at least one dehydrated hydrogel, and the exposing further comprises exposing the hydrogel to the ambient water vapor to hydrate the hydrogel to form a gel with the at least one dissolved soluble salt to retain the at least one dissolved salt in the cooling material.

61. The method of claim **60**, wherein dehydrated hydrogel comprises a sol gel, a silicone gel, a polyacrylamide gel, a polyvinyl alcohol gel, a polyacrylate gel, an acrylate polymer, agarose, alginate, methylcellulose, hyaluronan, or any combination thereof.

62. The method of claim **54**, wherein the reactant comprises a plurality of components capable of undergoing an endothermic reaction upon solvation of at least one of the plurality of components, and the exposing comprises solvating the at least one of the plurality of components to initiate the endothermic reaction between the plurality of components.

63. The method of claim **62**, wherein a first component of the plurality of components comprises an organic acid selected from the group consisting of citric acid, acetic acid, propanoic acid, tartaric acid, succinic acid, formic acid, fumaric acid and lactic acid and a second component of the plurality of components comprises a carbonate selected from the group consisting of calcium carbonate, sodium carbonate potassium carbonate, magnesium carbonate and lithium carbonate.

64. (canceled)

65. (canceled)

66. The method of claim **54**, wherein:

The disposing comprises disposing a cooling material further comprising a phase-change material configured to provide an at least partially solid thermal barrier upon hydration and cooling of the phase-change material; and

the method further comprises, upon exposure to the ambient water vapor, hydrating the phase-change material to produce an at least partial phase change the phase-change material to form a thermal barrier to retain cooling of the food item.

67. The method of claim **66**, wherein the phase-change material comprises paraffin, capric acid, lauric acid, palmitic acid, a stearic fatty acid, hydrated sodium acetate, calcium chloride hexahydrate, potassium fluoride tetrahydrate, a eutectic salt mixture, or any combination thereof.

68.-**108**. (canceled)

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