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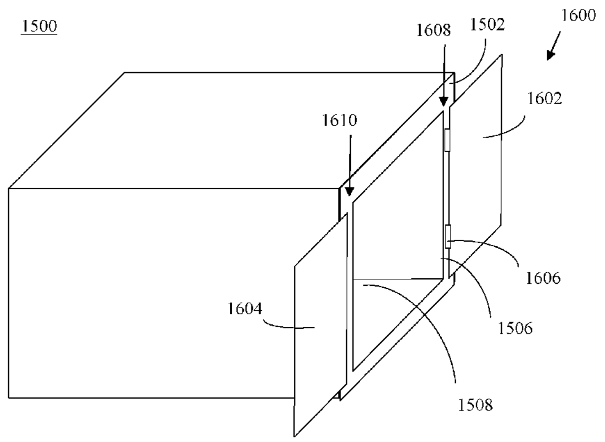

FIG. 16

(57) Abstract: Methods, systems, and apparatuses are provided herein for a container that can include one or more functions, and is modular in construction. In embodiments, the container is assembled to be relatively lightweight, while being stiff, strong, flexible, and/or durable. The container may include one or more functional elements configured to perform functions, such as power generation, power storage, wireless communications capability, data storage, sensor functions, display functionality, and/or further functions. The container may be formed from one or more multilayered panels. Materials forming layers of the panels may be enhanced with micro-scale and/or nano-scale technologies/components.

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NANO-ENHANCED MODULARLY CONSTRUCTED CONTAINER

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to the construction of composite containers/enclosures, and more particularly to modularly constructed composite containers/enclosures.

Background Art

[0002] A need exists for lightweight durable materials, as well as more efficient processes for assembling structures, in many applications. Such durable materials may be needed for various reasons, such as a need to provide resistance to mechanical, thermal, chemical, and/or other environmental phenomena, and/or to address further requirements for durability. A wide variety of applications may benefit from materials that have such durability. Examples of such applications include vehicles (e.g., delivery trucks, trains, trailers, boats, aircraft, etc.), shipping and storage containers, homes, and further structures. Applications that require movement of materials would benefit from materials having a decreased weight. For instance, items such as vehicles, shipping and storage containers, etc., require the expenditure of energy for the purpose of movement, and therefore would benefit from lighter weight materials. Thus, what is desired are materials that are lightweight and durable, and that may be used in a variety of applications.

[0003] Thus, what is desired are durable and easy to assemble materials, and a manufacturing process that incorporates such materials for construction of enclosures such as vehicles (e.g., delivery trucks, trailers, trains, trailers, boats, aircraft, etc.), shipping containers, homes, and other enclosure structures.

[0004] Furthermore, many applications, including vehicles, shipping and storage containers, homes, and further structures would benefit from additional functionality. Such functionality may include greater intelligence, sensors, and further types of functionality. However, such additional functionality may result in a higher cost to an application. Thus, what is desired are ways of providing additional functionality to applications in a manner that does not significantly increase costs and that is spatially efficient.

BRIEF SUMMARY OF THE INVENTION

[0005] Methods, systems, and apparatuses are provided herein for containers and for assembling the same. Such containers may be used in/as structures such as delivery trucks, shipping containers, aircraft, modular homes, and further structures.

[0006] In one implementation, a container includes a plurality of panels, a nanomaterial, and an attachment mechanism. The plurality of panels forms an enclosure having an internal cavity. Each panel is formed of a plurality of layers arranged in a stack. The nanomaterial is dispersed in a material of at least one layer of one or more of the panels. The attachment mechanism attaches together a first panel and a second panel of the plurality of panels.

[0007] The attachment mechanism may be any suitable type of attachment mechanism. For instance, the first panel may include a first flange and the second panel may include a second flange. The attachment mechanism may include a clip that couples the first flange to the second flange to attach the first panel to the second panel.

[0008] Each panel may include one or more layers. Layers can be formed from and/or may include a variety of materials, including a neat material, a woven material, a ribbon, a cured foam material, a plurality of solid rods, or a plurality of hollow tubes. Layers in a panel may be attached together by an adhesive material between one or more layers of the panel, by compression, or by any other suitable attachment technique. For example, a foam layer may be formed as an adhesive layer between other layers to attach together multiple layers.

[0009] A container may further include one or more functional elements included in one or more layers of one or more panels. Examples of functional elements include a power generator, a storage device, a communication module, a heat generator, a display, a microcontroller, and a sensor.

[0010] A panel may include an outer layer that is configured to provide protection for the container. A container may include an opening through a panel that opens to the internal cavity, and a door coupled to the panel that is configured to enable access and disable access to the internal cavity through the opening.

[0011] In another implementation, a method of fabricating a container is provided. A plurality of panels are attached together to form an enclosure having an internal cavity, with each panel being formed of a plurality of layers arranged in a stack. In one example, a plurality of layers may be joined (e.g., foamed) together during a monolithic panel forming process to form a container. At least one of the panels may be formed to include one or more nanomaterials and/or functional elements included in a material of a layer of the panel.

[0012] These and other objects, advantages and features will become readily apparent in view of the following detailed description of the invention. Note that the Summary and Abstract sections may set forth one or more, but not all exemplary embodiments of the present invention as contemplated by the inventor(s).

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0013] The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention.

[0014] FIG. 1 shows a perspective exploded view of a panel, according to an example embodiment of the present invention.

[0015] FIG. 2 shows a perspective side view of the panel of FIG. 1, in assembled (non-exploded) form, according to an example embodiment of the present invention.

[0016] FIG. 3 shows a perspective exploded view of a multi-layer panel that includes rods, according to an example embodiment of the present invention.

[0017] FIG. 4 shows a perspective side view of the panel of FIG. 5, in non-exploded form, according to an example embodiment of the present invention.

[0018] FIG. 5 shows a perspective side view of a panel that includes rods, according to an example embodiment of the present invention.

[0019] FIG. 6 shows a cross-sectional view of a panel that includes rods, according to an example embodiment of the present invention.

[0020] FIG. 7 shows a perspective exploded view of a panel having layers formed from multiple co-planar layer sections, according to an embodiment of the present invention.

[0021] FIG. 8 shows a perspective side view of the panel of FIG. 9, in non-exploded form, according to an example embodiment of the present invention.

[0022] FIGS. 9 and 10 show example first and second container portions, respectively, which can be combined to form a container/enclosure, according to an example embodiment of the present invention.

[0023] FIG. 11 shows a container/enclosure formed by joining the first and second container portions shown in FIGS. 9 and 10, according to an example embodiment of the present invention.

[0024] FIGS. 12 and 13 show perspective views of clip-type fasteners that may optionally be used with an adhesive to join the first and second panels shown in FIGS. 9 and 10, according to example embodiments of the present invention.

[0025] FIG. 14 shows a container/enclosure formed by clipping together the first and second container portions shown in FIGS. 9 and 10, according to an example embodiment of the present invention.

[0026] FIG. 15 shows a perspective view of a container, according to an example embodiment of the present invention.

[0027] FIGS. 16 and 17 show the container of FIG. 15 with the addition of a door mechanism, according to an example embodiment of the present invention.

[0028] FIG. 18 shows a block diagram of a panel that includes functional elements, according to an example embodiment of the present invention.

[0029] FIGS. 19A-19C show cross-sectional views of example container walls/panels, according to embodiments of the present invention.

[0030] FIG. 20 shows a flowchart for fabricating a container, according to an example embodiment of the present invention.

[0031] FIG. 21 shows a container fabrication system, according to an example embodiment of the present invention.

[0032] FIG. 22 shows example layer fabricating processes that may be performed in the flowchart of FIG. 20, according to embodiments of the present invention.

[0033] FIG. 23 shows a block diagram of a layer fabricator, according to an example embodiment of the present invention.

[0034] FIG. 24 shows examples of panel processing that may be performed in the flowchart of FIG. 20, according to embodiments of the present invention.

[0035] FIG. 25 shows a block diagram of a panel processor, according to an example embodiment of the present invention.

[0036] The present invention will now be described with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION OF THE INVENTION

Introduction

[0037] The present specification discloses one or more embodiments that incorporate the features of the invention. The disclosed embodiment(s) merely exemplify the invention. The scope of the invention is not limited to the disclosed embodiment(s). The invention is defined by the claims appended hereto.

[0038] References in the specification to "one embodiment," "an embodiment," "an example embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0039] Furthermore, it should be understood that spatial descriptions (e.g., "above," "below," "up," "left," "right," "down," "top," "bottom," "vertical," "horizontal," etc.) used herein are for purposes of illustration only, and that practical implementations of the structures described herein can be spatially arranged in any orientation or manner.

Example Embodiments

[0040] The example embodiments described herein are provided for illustrative purposes, and are not limiting. Further structural and operational embodiments, including modifications/alterations, will become apparent to persons skilled in the relevant art(s) from the teachings herein.

[0041] Methods, systems, and apparatuses are provided herein for a box or container, also referred to as a "unibox." The container may be formed from two or more parts, portions, or pieces, such as being formed of two halves. The pieces may be formed in a variety of ways. For instance, in an example two-piece embodiment, a pair of molds may be constructed. A first half of a container may be manufactured within a first mold of the pair, deriving a shape from the first mold. A second half of the container may be manufactured using the second mold. Alternatively, a single mold may be used to form both halves of the pair. For example, in an embodiment, the container may be a monolithically molded container that forms an enclosure.

[0042] The separate pieces may be joined together using adhesives, rivets, nails, screws, bolts, clamping mechanisms, and/or by other attachment mechanisms. For instance, in a two-piece embodiment, the two halves may each include an interior flange that can be used to connect the two halves together. Through the use of interior flanges, an outside surface of the container can remain smooth and have a monolithic appearance.

[0043] In embodiments, the container is assembled to be lightweight, strong, and tough/durable. Furthermore, the container may be assembled to have any size, including being relatively large, such as having a size to be used as a container car, shipping container, semi-trailer, aircraft body, home/building, or other structure.

[0044] In further embodiments, the container may include one or more functions, such as computing/decision-making, power generation, power storage, wireless communications capability, memory, one or more sensors, a display for graphics/video, being enabled to programmatically change colors, and/or further functions.

[0045] In embodiments, the container may be single or multilayered, manufactured with one or more materials, and may be enhanced with one or more micro-scale and/or nano-scale technologies/components/particles. Structures, such as trucks, trailers, boats, airplanes, homes, container cars, shipping containers, and further "containers," currently are manufactured using multiple panels that are joined together. Embodiments of the present invention enable such container structures to be manufactured more efficiently, such as by using fewer parts and having lower labor costs, and by using parts that are stronger and/or lighter than conventional panels used to assemble structures. Furthermore, such structures may be manufactured more safely, as laborers are not required to construct the container while enclosed within the container.

[0046] In embodiments, containers can be assembled/manufactured into any geometric shape or contour, including rectangular, cylindrical, round, etc. In an embodiment, a container is a formed as a shaped, multilayered panel, assembled from one or more materials. The materials may be optionally enhanced with micro-scale and/or nano-scale technologies/components.

[0047] For example, the structure of a container may be modularly formed by combining multiple layers of one or more materials. A layer of a container may be formed completely of a single material (i.e., a homogeneous layer), such as a polymer material. For example, a layer may be formed of a thermoplastic or thermosetting plastic material. Alternatively, a layer may be formed of a first material combined with one or more further materials (e.g., a heterogeneous layer).

[0048] Examples of such further materials are micro-scale and/or nano-scale technologies, component, and/or materials. As used herein, a nanoscale material or "nanomaterial" is a structure having at least one region or characteristic dimension with a dimension of less than 1000 nm. Examples of nanomaterials, including NEMS (nanoelectromechanical systems) devices and NST (nanosystems technology) devices, are described throughout this document. As used herein, a microscale material or device is a structure having at least one region or characteristic dimension with a dimension in the range of 1 micrometer (μm) to 1000 μm. Examples of microscale materials and devices, including MEMS (microelectromechanical systems) devices and MST (microsystems technology) devices, are described throughout this document.

[0049] For example, in an embodiment, the material of a layer may be enhanced with one or more nanomaterials. Nanomaterials/components such as nanowires, nanotubes, nanorods, nanoparticles, nanosensors, etc., may be used to enhance the first material of a layer, such as to strengthen the material, harden the material, or otherwise modify properties of the layer. For instance, any type of nanotube may be used, including single-walled nanotubes and multi-walled nanotubes. Example types of nanoparticles include organic nanoparticles, such as fullerenes (e.g., buckyballs), graphite, other carbon nanoparticles, nano-platelets, and inorganic nanoparticles, such as particles formed by titanium (Ti), titanium oxide (TiO), or nano-clay. Further types of nanomaterials not mentioned herein may also be used, as would be known to persons skilled in the relevant art(s). Micro-scale materials/components may additionally or alternatively be used in layers. The micro-scale and/or nano-scale components can vary in size, concentration, orientation, make-up (type), and mixture (multiple types of components in one system), depending on the particular application. Further, these functional elements may be either distributed through the material and impregnated in the matrix, or may be discrete elements embedded in the material.

[0050] The introduction of nanomaterials into panel embodiments can provide numerous benefits. Many nanomaterials have beneficial properties, including strength, stiffness, and hardness. Carbon nanotubes are one of the strongest and stiffest materials known in terms of tensile strength and elastic modulus. A single-wall carbon nanotube is a sheet of graphite (graphene) that is one atom thick, and is rolled in a cylinder with diameter of the order of a nanometer. A carbon nanotube may have a length-to-diameter ratio that exceeds 10,000. Multi-walled carbon nanotubes have been tested to have a tensile strength in the order of 63 GPa, which is much greater than that for high-carbon steel, having a tensile strength of approximately 1.2 GPa. Because carbon nanotubes have a low density for a solid (1.3-1.4 g/cm^3), the specific strength of carbon nanotubes (e.g., 48,462 kN·m/kg) is extremely high, compared to that for high-carbon steel (e.g., 154 kN·m/kg). Furthermore, polymerized single walled nanotubes are comparable to diamond in terms of hardness, but are less brittle. Thus, in applications requiring durable materials such as delivery vehicles, incorporating nanomaterials in layers of panels can provide benefits in strength, stiffness, and hardness, among other benefits. The concentration and types of nanomaterials formed in a layer can be selected as desired for a particular application.

[0051] In an embodiment, a layer may be formed as a planar sheet of a material. In another embodiment, a layer may be formed from, or may include fibers, woven fibers and/or ribbons of material. In an embodiment, a layer may be a "foam" layer or may include a foam-based material. For example, a foam layer may be formed by applying a suitable material (e.g., a liquid or gel resin, including a polymer such as a polyurethane) between two solid layers of material (e.g., a polymer, metal, or ceramic material), or into a mold, and causing the material to foam and harden/cure. For example, the material may be a combination of two or more materials that cure when mixed together. The material of the foam layer may have further materials (e.g., nanomaterials, fibers, ribbons, woven fibers, woven ribbons, functional materials, etc.) dispersed within the foam layer prior to hardening, to provide the benefits of the further materials to the foam layer.

[0052] Layers of a container may be modularly configured in any way, by combining layers, as desirable for a particular application. For instance, layers may be stacked to form the structure of a container. Any combination of one or more woven, one or more non-woven layers, and one or more foam layers may be stacked and/or shaped to form a container. The layers that form a container may be rigid or flexible. When the layers are flexible, the formed container may have flexiblity. Such flexibility may be desirable for damping a velocity of received projectiles, vehicle collisions, or other impacts. Likewise, containers formed to be stiffer may be desirable for providing structural integrity in a variety of applications. Any number of layers (and type) can be stacked to provide a desired level of durability, resistance to projectiles, hardness, etc.

[0053] Containers can be formed to have flat, curved, or contoured surfaces, and can be formed in any geometric shape having an enclosure. In an embodiment, the layers of the container may be shaped prior to being attached together to form the container. In another embodiment, the container may be shaped during the process of forming the layers. For instance, the layers may be formed in a mold that provides a shape of a portion of a container, or an entirety of a container. For example, a container may be formed by a plurality of layers joined together during a monolithic process, where a foam material is formed between layers to join them together. Such a process may be performed in a mold chamber to form a container into the shape predetermined by the mold chamber. In this manner, a monolithically molded container may be formed. In another embodiment, the container may be shaped after the layers are attached together. For instance, a formed panel may be bent into a desired shape, may be cut into multiple pieces that may be reassembled (e.g., using any of nails, screws, bolts, an adhesive material, etc.) into the container.

[0054] Example embodiments for layer materials, layers, containers, and processes and systems for assembling the same, are described in the following subsections.

Example Layers and Layer Material Embodiments

[0055] Example embodiments for layers and for layer materials used to assemble panels and containers are described in this section. Such example embodiments are provided for purposes of illustrations, and are not intended to be limiting. Further structural and operational embodiments, including modifications/alterations, will become apparent to persons skilled in the relevant art(s) from the teachings herein.

[0056] For example, FIG. 1 shows a perspective exploded view of a panel 100, according to an embodiment of the present invention. Panel 100 is a portion of a container piece. Panel 100 is shown in FIG. 1 as planar, for illustrative purposes. In embodiments, panel 100 may be shaped, molded, or otherwise formed into a piece of a container. FIG. 2 shows a perspective side view of panel 100, in non-exploded form. As shown in FIGS. 1 and 2, panel 100 includes a first layer 102, a second layer 104, a third layer 106, a fourth layer 108, a fifth layer 110, and a sixth layer 112. In FIG. 2, first layer 102 is attached to second layer 104, second layer 104 is attached to third layer 106, third layer 106 is attached to fourth layer 108, fourth layer 108 is attached to fifth layer 110, and fifth layer 110 is attached to sixth layer 112 to form panel 100 as a stack of layers.

[0057] As shown in FIG. 1, second and third layers 104 and 106 are woven layers of material. Layers 104 and 106 may have any thickness and area, as desired for a particular application. As shown in FIG. 1, layers 104 and 106 may include a mesh material (e.g., two or more sets of fibers having distinct directions that are woven together). For example, as shown in FIG. 1, layers 104 and 106 include a first set of fibers aligned in a first direction that are woven with a second set of fibers aligned perpendicularly (e.g., 90 degrees) to the first direction. In embodiments, the first and second sets of fibers may have any relative alignment in a layer, including being aligned 90 degrees, 45 degrees, or other angle relative to each other. Layers that include a mesh may also include further orientations of fibers, random or otherwise, which may have different lengths relative to each other (e.g., substantially continuous, chopped, etc.). An example of such a layer is a fiberglass matte. Layers 104 and 106 may be weaves of fibers, weaves of woven fibers (a "yarn"), weaves of ribbons, or weaves of further configurations of material.

[0058] For example, in an embodiment, layers 104 and 106 may be weaves of polypropylene ribbons, and each of layers 104 and 106 may have a thickness in the range of 0.005-0.006 inches (e.g., 0.132 mm) and a weight of approximately 0.02 lbs/sq-ft (0.11 Kg/sq-meter). Polypropylene may be formed into ribbons using an extrusion process, and the ribbons may be weaved together to form the fabric of each of layers 104 and 106. In an embodiment, nanomaterials (e.g., multi-walled carbon nanotubes) may be introduced into the polymer (e.g., polypropylene) resin before performing the extrusion. For example, layer 104 and/or layer 106 may include a plurality of fiberglass infused polyester tubes having a 0.25 inch inner diameter and a 0.5 inch outer diameter. Persons skilled in the relevant arts would be able to implement tubes having various sizes, including various cross-sectional dimensions, various materials, and various orientations and positions within a stack.

[0059] In an alternative embodiment, layers 104 and 106 (and/or one or more other layers in panel 100) may include fibers or rods arranged in a single substantially uniform direction (e.g., being parallel/unidirectional). The fibers/rods may alternatively be oriented in a plurality of directions to accommodate loadings to panel 100 from multiple directions.The fibers may be individual fibers or woven fibers. In embodiments, the rods may be solid or hollow. Example embodiments for layers that include rods are described in further detail below. In a still further embodiment, layers 104 and 106 (and/or one or more other layers in panel 100) may include fibers having random orientations.

[0060] First, fourth, and sixth layers 102, 108, and 112 are homogeneous planar layers of material. Layers 102, 108, and 112 may be formed in a variety of ways, including by a molding process, an extruding process, being cut from a larger sheet of material, or by other process of forming, as would be known to persons skilled in the relevant art(s). Layers 102, 108, and 112 may be made of a variety of materials, such as a thin film, monolithic material. For example, layers 102, 108, and 112 may be made of a polymer, such as polyurethane, polyester, acrylic, phenolic, epoxy, elastomerics, polyolefins, polypropylene, polyethylene, vinyl ester, etc. In one embodiment, layers 102, 108, and

112 may be made of a homogeneous material. For example, in an embodiment, each of layers 102, 108, and 112 may be a polyurethane (PU) thin film, having a thickness in the range of 0.010-0.015 inches. In another embodiment, layers 102, 108, and 112 may include a first material (e.g., a polymer) that has one or more further materials included therein, such as one or more microscale materials and/or nanomaterials. A layer that does not include such microscale materials and nanomaterials may be referred to as a "neat" layer.

[0061] Fifth layer 110 is a foam layer. Fifth layer 110 may be formed in various ways, such as by applying a suitable material (e.g., liquid or gel such as an epoxy) between two solid layers of material (e.g., fourth and sixth layers 108 and 112 in FIGS. 1 and 2), and causing the material to cure (e.g., into a stiff or flexible form). Alternatively, fifth layer 110 may be formed (e.g., in a mold) and subsequently positioned between fourth and sixth layers 108 and 112. For example, the material of fifth layer 110 may be a combination of two or more materials that cure when mixed together. The material of layer 110 may have further materials (e.g., nano-materials, functional components, etc.) dispersed within prior to curing, to provide the benefits of the further materials to fifth layer 110.

[0062] Note that the particular arrangement of layers, the number of layers, and combination of different types of layers for panel 100 in FIGS. 1 and 2 are provided for purposes of illustration, and are not intended to be limiting. In embodiments, the number of each type of layer in the structure of a container, and a ratio of layer types (e.g., solid, woven, foam, etc.) can have any value. Layers may be attached (e.g., laminated, glued, etc.) to each other in panel 100 in a variety of ways. For example, an adhesive material, such as a glue, a resin, a foam material, a thin film adhesive, etc., may be applied to surfaces of layers to attach adjacent layers together. The adhesive material may be applied in any form, including as a gel, liquid, or solid, an in any manner, including by pouring, flowing, spraying, rolling on, etc. In an example, pressure thermoforming techniques, such as autoclave or a compression molding process, may be used to compress/heat layers into panel 100. For instance, one or more thin sheets of thermoplastic adhesive may be interspersed between adjacent layers of a stack. The thin sheets of thermoplastic adhesive themselves may be homogeneous materials or heterogeneous materials (e.g., have one or more nanomaterials and/or functional materials included therein). The stack may be heated, thereby activating the thermoplastic adhesive to adhere the layers of the stack together. In another embodiment, a foam layer, as described above, may be formed between two other layers. The foam layer may operate as an adhesive material to attach together the two layers (in addition to providing any further features that may be provided by the foam layer).

[0063] Note that in a further embodiment, panel 100 may include one or more layers of further materials. For example, panel 100 may include one or more layers of fabric made from another synthetic fiber such as Kevlar, additional types of nanoparticles, etc., that are interspersed throughout panel 100. In another embodiment, panel 100 may include one or more layers of recyclable materials. For example, the properties of an extruded polypropylene (or other material) ribbon may be enhanced by recycling and then re-extruding the polypropylene into ribbon form a second time or even further times.

[0064] Each layer may be selected/tuned to a degree of precision based on the requirements of a particular application, such as impact resistance, stiffness, melt-point, flammability, chemical resistance, electrical conductivity, aerial density, and/or other requirements. Such tuning can be performed in a number of ways. For example, tuning can be performed by selecting the material for the layer, selecting dimensions of the layer (e.g., thickness, length, width), selecting whether the layer is woven, non-woven, or foam, if the layer is woven, selecting whether fibers, matte, yarn, and/or ribbon is woven to form the layer, selecting whether to add nanomaterials to the layer, selecting the type of and concentration of nanomaterials added to the layer (if added), and/or by performing other selection criteria described elsewhere herein or otherwise known.

[0065] In an embodiment, a panel may be manufactured to be any weight, including lightweight, medium weight, or heavyweight, depending on factors such as materials used in layers of the panel, thicknesses of the layers, a number of layers, etc. A panel may be manufactured of any thickness, including thick, medium thickness, and/or thin. For example, in one embodiment, a panel can be 0.5 pounds per square foot at ¼” thick. In an embodiment, a panel may be stiff or flexible.

[0066] Embodiments enable a modularly-constructed container to be constructed from modular/interchangeable components. Embodiments provide building blocks that may be fully integrated to create a self-contained system. Panels may be modularly combined as building blocks to create a variety of container form factors. Furthermore, containers may be manufactured that are fully integrated and self-contained. For example, the structure of a container may include power generation and storage capability. Micro- and/or nanotechnology based technologies can be integrated with traditional manufacturing techniques as desired based on the particular application. MNT encompasses any technologies where the performance criterion is met by engineering on and having knowledge of the same size scale as the phenomena of interest.

[0067] One example container configuration includes multiple materials and components in a layered system. A polymer "skin" layer is provided on both outer sides of the pieces of the container. Such polymer skin layers may be the same or differ from the outside to the inside of a given container. A secondary material layer of each piece may be a foam core layer, reinforced with a weave of fibers, random fibers, rods, and/or further materials distributed throughout the layer. Multiple layers of each can be used to enable a desired strength/thickness. The container layers can include one or more sensors and/or other functional elements distributed throughout the container (e.g., in the skin layers and/or the core layer(s)). In an embodiment, the sensors may also be built into the matte/weave/fibers/skins. Each layer/material may be enhanced with nanomaterials.

[0068] For instance, in embodiments, one or more layers of a panel may include rods that provide structural reinforcement to the panel. FIG. 3 shows a perspective exploded view of a panel 300 that includes rods, according to an example embodiment of the present invention. FIG. 4 shows a perspective side view of panel 300, in non-exploded form. As shown in FIGS. 3 and 4, panel 300 includes a first layer 302, a second layer 304, and a third layer 306. First and second layers 302 may each be any layer type described elsewhere herein, including a layer of a homogeneous material, a layer of material that includes micro- and/or nanomaterials, a layer that includes functional elements, a layer that includes a layer that includes fibers, ribbons, and/or woven materials, etc. Third layer 306 is a layer of rods 308, and may also be referred to as a "rod layer." Any number of rods 308 may be present in layer 306. For instance, in the example of FIGS. 3 and 4, third layer 306 includes first-third rods 308a-308c. Rods 308 have a generally cylindrical shape, having a circular cross-section, although rods 308 may have other shapes, including having rectangular cross-sections. Furthermore, rods 308 may have any length, as desired for a particular application. Third layer 306 is positioned between first and second layers 302 and 304 to form panel 300 as a stack of layers.

[0069] Rods 308 can be solid (e.g., as shown in FIGS. 3 and 4) or can be hollow (e.g., can be tubes). Rods 308 can be made of any suitable material, including any polymer mentioned elsewhere herein or otherwise known, a metal (e.g., aluminum, titanium, etc.) or combination of metals/alloy (e.g., steel), a ceramic material, a composite material, fiberglass infused polyester tubes, etc. Rods 308 can be made of layer materials described elsewhere herein, including having fibers, weaves, nanomaterials, and/or functional elements included therein. In the example of FIGS. 3 and 4, rods 308a-308c are shown having a substantially parallel/unidirectional arrangement. However, in alternative embodiments, rods 308 in third layer 306 may have other arrangements, including a non-parallel arrangement (e.g., a random arrangement). Rods 308 can have any suitable size, including having diameters in the order of an inch, having nano-scale diameters, or having diameters greater than or between these ranges.

[0070] A panel that includes rods 308 may be manufactured in a variety of ways. For instance, as shown in FIGS. 3 and 4, first and second layers 302 and 304 may be formed separately from each other. As shown in FIG. 3, a first set of cylindrical recesses 310 (e.g., recesses 310a-310c) may be formed in a surface of first layer 302, and a second set of cylindrical recesses 312 (e.g., recesses 312a-312c) may be formed in a surface of second layer 304. Recesses 310 and 312 may be formed in any manner, such as by a molding process (e.g., by molds used to form layers 302 and 304), by machining recesses 310 and 312 into layers 302 and 304, by impressing recesses 310 and 312 into layers 302 and 304 (e.g., by heating layers 302 and 304 and subsequently applying pressure), etc. To form panel 300, rods 308 may be positioned between layers 302 and 304, and layers 302 and 304 may be moved into contact with each other, with rods 308 fitting into recesses 310 and 312.

[0071] In another embodiment, recesses 310 and 312 may not be pre-formed in first and second layers 302 and 304. To form panel 300, rods 308 may be positioned between layers 302 and 304, and layers 302 and 304 may be moved into contact with each other.

By compressing layers 302 and 304 together, rods 308 may form recesses 310 and 312 in layers 302 and 304, respectively.

[0072] In another embodiment, layers 302 and 304 may instead be formed as a single layer in which rods 308 are positioned. FIG. 5 shows an example of a panel 500 which is formed of a single layer 502 of material that encapsulates rods 308 (e.g., rods 308a-308c). For instance, layer 502 may be formed in any manner described elsewhere herein or otherwise known, and holes may be drilled through layer 502 in which rods 308 may be inserted. Alternatively, rods 308 may be positioned in a mold, and a material may be inserted into the mold to form layer 502 around rods 308. Panels 300 and 500 may be formed in alternative ways, as would be known to persons skilled in the relevant art(s).

[0073] Referring back to FIGS. 3 and 4, layers 302, 304, and 306 may be attached together in any manner, including in other ways for attaching layers described elsewhere herein. For instance, FIG. 6 shows a cross-sectional view of a panel 600, formed according to an example embodiment of the present invention. Panel 600 is an example of panel 300 shown in FIGS. 3 and 4. As shown in FIG. 6, panel 600 includes first, second, and third layers 302, 304, and 306. Furthermore, panel 600 includes a first coating layer 602, a second coating layer 604, a first adhesive layer 606, and a second adhesive layer 608. First coating layer 602 is positioned on a first surface of first layer 302 that is opposite a second surface of first layer 302 that is adjacent to third layer 306. Second coating layer 604 is positioned on a first surface of second layer 304 that is opposite a second surface of second layer 304 that is adjacent to third layer 306. First and second coating layers 602 and 604 may each be any type of coating layer described elsewhere herein, including a layer of material (e.g., a polymer) that includes nanomaterials, etc. First and second coating layers 602 and 604 may be applied to first and second layers 302 and 304, respectively, in any manner described herein, including by laminating, molding, spraying, etc.

[0074] First and second adhesive layers 606 and 608 bond together first, second, and third layers 302, 304, and 306. First adhesive layer 606 may be applied to the second surface of first layer 302, and second adhesive layer 608 may be applied to the second surface of second layer 304. First and second adhesive layers 606 may each be any type of adhesive material described elsewhere herein, including a resin, a foam layer, a glue, an epoxy, etc., and may optionally include micro- and/or nanomaterials. First and second coating layers 602 and 604 may be applied to first and second layers 302 and 304, respectively, in any manner described herein, including by laminating, molding, spraying, etc. When first and second layers 302 and 304 are moved into contact with each other (e.g., by a compression mechanism), first and second adhesive layers 606 and 608 come into contact with each other and bond together first, second, and third layers 302, 304, and 306. Furthermore, first and second adhesive layers 606 and 608 may combine to form a single layer in panel 600.

[0075] Rods 308 provide additional strength to panels 300, 500, and 600, including strength in tension, compression, and/or torsion with respect to panels 300, 500, and 600. Rods 308 may be textured (e.g., provided with grooves, ridges, etc.) to enhance adhesion with layers 302, 304, and/or 502. Panels 300, 500, and 600, may be combined in any manner to form larger panels. For example, FIG. 7 shows a perspective exploded view of a panel 700, according to an embodiment of the present invention. FIG. 8 shows a perspective side view of panel 700, in non-exploded form. As shown in FIGS. 7 and 8, panel 300 includes a first layer 702, a second layer 704, and third layer 306. First layer 702 includes a plurality of first layers 302 (shown in FIG. 3). Second layer 704 includes a plurality of second layers 304 (shown in FIG. 3). For example, in the embodiment of FIGS. 7 and 8, first layer 702 includes layers 302a and 302b, and second layer includes layers 304a and 304b. In other embodiments, first and second layers 702 and 704 may include further numbers of layers 302 and 304, respectively, to generate panel 700 to have any desired length.

[0076] As shown in FIG. 7, layers 302a and 302b are positioned in series to form first layer 702, such that recesses 310 in layers 302a and 302b are aligned with each other. Furthermore, layers 304a and 304b are positioned in series to form second layer 704, such that recesses 312 in layers 304a and 304b are aligned with each other. To form panel 700, rods 308 (e.g., rods 308a-308c) of third layer 306 are positioned between layers 702 and 704, and layers 702 and 704 are moved into contact with each other, with rods 308 fitting into recesses 310 and 312 in layers 302a and 302b and layers 304a and 304b, respectively. Note that in embodiments, layers 302 in first layer 702 may be aligned in any manner relative to layers 304 in second layer 704. For example, as shown in FIGS. 7

and 8, layers 302 in first layer 702 may be staggered relative to layers 304 in second layer 704. For instance, when panel 700 is formed, layer 302b of first layer 702 may have a first portion in contact with layer 304a and a second portion in contact with layer 304b of layer 704, as shown in FIG. 8. Furthermore, layer 304a of second layer 704 may have a first portion in contact with layer 302a and a second portion in contact with layer 302b of layer 702, as shown in FIG. 8. Such a staggered arrangement of layers 302 and 304 may enable greater adhesion and strength in panel 700. In an alternative embodiment, each layer 302 in first layer 702 may be aligned with a corresponding layer 304 in second layer 704, in a non-staggered arrangement. Furthermore, note that in embodiments, layers 302 in first layer 702 may have different lengths from layers 304 in second layer 704. Furthermore, in embodiments, layers 302 in first layer 702 may have different lengths from each other, and layers 304 in second layer 704 may have different lengths from each other.

[0077] Further description and examples of layer materials (e.g., polymers, fibers, ribbons, yarns, rods, etc.), layers (e.g., homogeneous, heterogeneous, fiber layers, yarn layers, woven layers, rod layers, etc.), panels, and adhesive materials that may be incorporated in panels are described in U.S. Application No. [to be assigned], titled "Nano-Enhanced Modularly Constructed Container," which is incorporated by reference in its entirety herein.

Example Container Embodiments

[0078] Containers formed using panels may have a variety of configuration. In embodiments, a container may be formed from a single panel, a pair of panels, three panels, and/or any further numbers of panels. Furthermore, a container may be formed by panels having various shapes. For instance, FIGS. 9 and 10 show perspective views of first and second container portions 900 and 1000, respectively, according to an embodiment of the present invention. First and second container portions 300 and 1000 may be combined to form a container. First and second container portions 900 and 1000 are shown for purposes of illustration, and are not intended to be limiting. Container portions may have shapes alternative to those shown for container portions 900 and 1000, as would be known to persons skilled in the relevant art(s) from the teachings herein.

Such container portions may be combined to form containers of shapes other than rectangular, as desired for a particular application.

[0079] First and second container portions 900 and 1000 may each be formed from one or more panels (e.g., panel 100 shown in FIGS. 1 and 2) having any number and combination of layers, as described elsewhere herein. For example, first and second container portions 900 and 1000 may each be single-piece, monolithic container portions formed according to a molding process, as described elsewhere herein. As shown in FIGS. 9 and 10, first and second container portions 900 and 1000 both have a three-dimensional rectangular shape. As shown in FIG. 9, first container portion 900 has a rectangular opening 906 in a surface 902, and second container portion 1000 has a rectangular opening 1006 in a surface 1002. Opening 906 opens to a rectangular cavity 908 that is interior to first container portion 900, and opening 1006 opens to a rectangular cavity 1008 that is interior to second container portion 1000.

[0080] Container portions 900 and 1000 may be joined together to form a rectangular enclosure. FIG. 11 shows a cross-sectional view of an enclosure or container 1100 formed by a combination of first and second container portions 900 and 1000, according to an example embodiment of the present invention. In the embodiment of FIG. 11, surfaces 902 and 1002 of first and second container portions 900 and 1000 are attached together to form container 1100. As shown in FIG. 11, an enclosed cavity/space 1102 is formed (by cavities 908 and 1008 shown in FIGS. 9 and 10) inside container 1100 when first and second container portions 900 and 1000 are attached together.

[0081] First and second container portions 900 and 1000 may be attached together in various ways. For instance, as shown in FIGS. 9 and 10, first and second container portions 900 and 1000 may each have a flange 904 and 1004, respectively. First and second container portions 900 and 1000 can be attached to each other by flanges 904 and 1004 using a variety of attaching mechanisms, including rivets, bolts, screws, nails, an adhesive material, etc., to provide a strong bond and a smooth outer surface of container 1100, without the attachment mechanism being externally visible. An attachment mechanism used to attach together first and second container portions 900 and 1000 may be applied at flanges 904 and 1004. For instance, flanges 904 and 1004 may be glued/epoxied, nailed, riveted, screwed, bolted, clipped, etc., together, to attach first and second container portions 900 and 1000.

[0082] FIGS. 12 and 13 show perspective views of example clips 1200 and 1300, respectively, according to example embodiments of the present invention. Clips 1200 and 1300 may be used to join together first and second container portions 900 and 1000. Clip 1200 shown in FIG. 12 is a generally rectangular clip fastener having first and second opposing surfaces 1204 and 1206. Clip 1200 has a slot 1202 centrally located on first surface 1204 of clip 1200 along a length of clip 1200. Second surface 1206 of clip 1200 is generally planar. Clip 1200 can be positioned over flanges 904 and 1004, such that an edge of each of flanges 904 and 1004 is positioned in slot 1202, to hold together flanges 904 and 1004, and to thereby couple first container portion 900 to second container portion 1000. Clip 1300 shown in FIG. 13 is a generally rectangular clip fastener having first and second opposing surfaces 1304 and 1306. Clip 1300 has a slot 1302 centrally located on surface 1304 of clip 1300 along a length of clip 1300. Slot 1302 has a rounded inner surface. Second surface 1304 of clip is rounded. Clip 1300 can be positioned over flanges 904 and 1004, such that an edge of each of flanges 904 and 1004 are positioned in slot 1302, to hold together flanges 904 and 1004, and to thereby couple first container portion 900 to second container portion 1000. Clips 1200 and 1300 may optionally be used with an adhesive and/or other attaching mechanism, to join first and second container portions 900 and 1000.

[0083] For instance, FIG. 14 shows container 1100 of FIG. 11, according to an example embodiment of the present invention. As shown in FIG. 14, a plurality of clips 1200 is used to hold together flanges 904 and 1004 of first and second container portions 900 and 1000. For instance, a first clip 1200a holds together flanges 904 and 1004 at a first surface of enclosed space 1102 in container 1100, and a second clip 1200b holds together flanges 904 and 1004 at a second surface of enclosed space 1102 in container 1100.

[0084] Clips 1200 and 1300 may include various materials, such as a metal or a combination of polymers/fibers, and may be formed according to any suitable manufacturing process, including being machined, cast, molded, extruded, or otherwise formed. Furthermore, clips 1200 and 1300 may have any size and any slot depth, as desired for a particular application.

[0085] Flanges 904 and 1004 may be made of a similar material to the rest of first and second container portions 900 and 1000, or of a different material, such as a metal or other material. Furthermore, although shown in FIGS. 9 and 10, respectively, as being present surrounding all four sides of openings 906 and 1006 in surfaces 902 and 1002 of container portions 900 and 1000, each flange 904 and 1004 may be present at any number of one or more sides of the respective opening, and may be present along a portion or along an entire length of a side of the respective opening. Alternatively, flanges 904 and 1004 may not be present, and first and second container portions 900 and 1000 may be attached together at the peripheries of surfaces 902 and 1002, and/or at other location(s).

[0086] In alternative embodiments, first and second container portions 900 and 1000 can have other shapes (e.g., hemispherical, triangular, etc.) than shown in FIGS. 9 and 10 to form alternative shapes, including more complex shapes, for container 1100. First and second container portions 900 and 1000 can be formed to have their shapes using various fabrication processes described herein or otherwise known, such as being formed in separate molds or in a same mold (in the current example, portions 900 and 1000 may be identical, and thus can be formed by the same mold), by being formed by one or more panels that are bent or otherwise altered, by being formed from one or more panels that are cut into multiple pieces and reassembled (e.g., using any of nails, screws, bolts, an adhesive material, etc.) into the shapes shown in FIGS. 9 and 10, or by other fabrication process.

[0087] In an embodiment, container 1100 may be manufactured to be any weight, including being relatively lightweight, medium weight, or heavyweight. A container may be manufactured to have walls of any thickness, including walls that are relatively thick, of medium thickness, and/or are thin. For example, in one embodiment, the material of a wall of container 1100 can be 0.5 pounds per square foot at ¼" thick. In an embodiment, a container may be stiff or flexible.

[0088] Furthermore, in an embodiment, a container may be formed in include one or more openings to enable access to the interior cavity of the container. For instance, in embodiments, one or more surfaces of a container may include a port, a window, or other type of continuous opening. In another embodiment, one or more surfaces of a container may include a door, a hatch, or other type of opening having a covering that may be opened or closed as needed.

[0089] For instance, FIG. 15 shows a perspective view of a container 1500, according to an embodiment of the present invention. Container 1500 may be any type of enclosure structure mentioned herein, including a truck trailer (e.g., carried by a semi-tractor trailer). Container 1500 may be a single-piece panel (e.g., monolithically molded) or may be formed from multiple panels. The panel(s) forming container 1500 may include any number and combination of layers, as described elsewhere herein. As shown in FIG. 15, container 1500 has a three-dimensional rectangular shape. Container 1500 has a rectangular opening 1506 in a side surface 1502. Opening 1506 opens to a rectangular cavity 1508 that is interior to container 1500.

[0090] Container 1500 may include a covering for opening 1506 that may be opened or closed as needed. For example, FIG. 16 shows container 1500 with the addition of a door mechanism 1600, according to an example embodiment of the present invention. In embodiments, door mechanism 1600 may include any number and combination of doors that may be closed to disable access to cavity 1508, or opened to enable access to cavity 1508, including a single door, a pair of doors, etc. In the example of FIG. 16, door mechanism 1600 includes a pair of doors 1602 and 1604. Door 1602 is coupled to container 1500 at a first edge 1608 of opening 1506, and door 1604 is coupled to container 1500 at a second edge 1610 of opening 1506 (that is opposed to first edge 1608). A variety of mechanisms may be used to couple doors 1602 and 1604 to container 1500, and to enable movement of doors 1602 and 1604, including hinges or springs for swing doors, tracks for sliding doors or folding doors, etc. For example, as shown in FIG. 15, doors 1602 and 1604 are coupled to container 1500 by a plurality of hinges 1606.

[0091] In FIG. 16, doors 1602 and 1604 are shown in an open position, such that access to cavity 1508 in container 1500 is enabled. FIG. 17 shows container 1500 with doors 1602 and 1604 in a closed position, such that access to cavity 1508 in container is disabled. Doors 1602 and 1604 may include a locking and/or latching mechanism to enable a user to lock, latch, open, and/or close doors 1602 and 1604. A cargo may be moved into cavity 1508 when doors 1602 and 1604 are opened, and stored in cavity 1508 when doors 1602 and 1604 are closed. Container 1500 may be delivered from a starting location to a destination location (e.g., driven, flown, shipped by boat, moved by train, etc.), where the cargo may be removed from cavity 1508 when doors 1602 and 1604 are opened. The panel structure of container 1500 may be configured to provide protection for the stored cargo, including environmental protection, such as protection from impacts, heat, cold, moisture, etc. Doors 1602 and 1604 may be made from one or more panels as described herein, having any number and combination of types of layers, or may not be panels. Doors 1602 and 1604 may be made from a same material as container 1500 or from a different material.

[0092] Note that in a further embodiment, a door mechanism, such as doors 1602 and 1604, may be attached to container 1500 to close cavity 1508 (cover opening 1506) in a permanent or semi-permanent configuration. For example, an attachment mechanism, such as one or more bolts, screws, nails, rivets, or other attachment mechanism may be used to attach the door mechanism to cover opening 1506 in a manner that requires the attachment mechanism to be removed prior to a user being enabled to open or remove the door mechanism.

[0093] In embodiments, containers may be formed to have any shape, including a rectangular shape (e.g., as shown in FIGS. 11 and 15), which may be used as a cargo container, truck trailer, etc., being shaped as a house or other dwelling, or being shaped as a portion of a vehicle. For instance, a container may be formed as a boat hull, a car body, a truck body, a train body, an aircraft fuselage, etc., to enable a durable and relatively lightweight vehicle.

Example Functional Element Embodiments

[0094] In embodiments, a container of the present invention, such as container 1100 of FIG. 11 or container 1500 of FIG. 15, may include one or more functional elements. For example, FIG. 18 shows a block diagram of a container 1800, according to an example embodiment of the present invention. In an embodiment, a container may include one or more of the functional elements shown in FIG. 18 for container 1800. FIG. 18 shows a container 1800 that includes a power generator 1802, power storage 1804, a communication module 1806, a data storage 1808, a sensor 1810, a display 1812, a microcontroller 1814, an environmental control module 1816, and a coating 1818.

Embodiments for each of these elements, which may be present in container embodiments, are described as follows. The elements of FIG. 18 may be incorporated into one or more layers of the structural walls of container 1800. For example, walls of container 1800 may be formed of multi-layer material similar to panel 100 of FIGS. 1 and 2, having any number of layers and combination of layer types. The elements of FIG. 18 may be incorporated into one or more of the layers of panel 100 forming the walls of container 1800. For example, arrays of any of these elements may be present in one or more layers of a panel or container. Embodiments for each of these elements, which may be present in container embodiments, are described as follows. Note that the elements shown in FIG. 15 may be distributed or discrete. The elements are shown in FIG. 15 as discrete for purposes of illustration.

[0095] In embodiments, container 1800 may include a communication medium, wired and/or wireless, for elements of container 1800 to communicate with each other and/or for communication within elements (e.g., for elements that include an array of sub-elements). For example, communication module 1806, as further described below, may be used for communications within container 1800, as well as communications with entities external to container 1800. In another example, a layer of container 1800 may be a flexible (or non-flexible) trace layer providing a network of electrical connections for container 1800. Wires, wire ribbons, nanowires, and/or further types of electrically conducting (including semi-conducting), materials may be used for physical electrical connections within container 1800. For example, in an embodiment, a particular layer of container 1800 may be configured as an interconnection layer for container 1800. The interconnection layer may include electrical wiring or other electrical connections of any form, to distribute power to elements of container 1800 and/or to enable elements of container 1800 to communicate with each other.

[0100] In an embodiment, a container may be configured to generate power. For example, power generator 1802 may include one or more power generation mechanisms, such as a solar power generator (e.g., solar cells), mechanical motion power generators (e.g., piezoelectric membranes, piezoelectric nanorods that generate power due to vibration, nanowires that generate electricity due to motion/vibration, etc.), resistive power generators, and/or further power generation/energy harvesting mechanisms to generator power for container 1800. For example, an outer layer of container 1800 may be an active photovoltaic layer. A single power generation mechanism may be present in container 1800, or multiple power generation mechanisms may be present in container 1800. For example, an array of power generation elements may be distributed throughout container 1800 (e.g., within a material of one or more layers of container 1800, and/or on a surface of one or more layers of container 1800), or otherwise positioned in container 1800. For example, in an embodiment, power generator 1802 may be a MEMS power harvesting integrated circuit die or chip. An array of such dies/chips may be present in container 1800. In an embodiment, a material of one or more layers of container 1800 may be configured to generate power. In another embodiment, one or more discrete power generator elements may be included in one or more layers of container 1800.

[0101] In an embodiment, a container may be configured to store power/energy, such as through the incorporation of one or more batteries, and/or other form of distributed power storage mechanism or element. For example, power storage 1804 may include one or more batteries and/or other types of power storage mechanisms/elements. For instance, in an embodiment, a container may include a pair of electrically conductive (e.g., metal) layers that sandwich a dielectric layer to form a capacitor for storing power. Example types of batteries include thin film lithium ion batteries, distributed chip scale capacitors, conventional batteries, etc. A single power storage mechanism/element may be present in container 1800, or multiple power storage mechanisms/elements may be present in container 1800. For example, an array of power storage elements may be distributed throughout container 1800, or otherwise positioned in container 1800.

[0102] In an embodiment, a container may be configured to communicate wirelessly with other devices that are external or internal to the container, including receiving information from, and transmitting information to such external and/or internal devices. For example, container 1800 may include communication module 1806. Communication module 1806 may include a transmitter and a receiver (or transceiver), and one or more antennas. Communications module 1806 is configured to enable container 1800 to communicate with other communication modules of container 1800 and/or with one or more remote entities. For example, communications module 1806 may be configured to communicate with a structure with which container 1800 is associated, such as a controller, GPS system, or other component of a vehicle with which container 1800 is associated. Container 1800 may be configured to communicate with a remote computer system, including a mobile device (e.g., Palm Pilot, personal digital assistant (PDA, notebook computer, etc.), a centralized entity, etc.

[0103] For example, communications module 1800 may be configured to communicate with a communications network in a wired or wireless fashion, including a personal area network (PAN) (e.g., a BLUETOOTH network), a local area network (e.g., a wireless LAN, such as an IEEE 802.11 network), and/or a wide area network (WAN) such as the Internet. Thus, communication module 1806 may include a BLUETOOTH chip, WLAN chip, etc., conventionally used in devices, and/or other communication enabling hardware/software/firmware. Communication module 1806 may communicate according to radio frequencies (RF), infrared (IR) frequencies, etc. Communication module 1806 may be configured to transmit data from container 1800, such as data captured by sensor 1810, information from microcontroller 1814, and/or further data. Furthermore, communication module 1806 may be configured to receive data for container 1800, such as instructions for container 1800 (e.g., for microcontroller 1814), data for storage in data storage 1808, image data for display by display 1812, and/or further data.

[0104] A single power communication module 1806 may be present in container 1800, or multiple communication modules 1806 may be present in container 1800. For example, an array of communication modules 1806 may be distributed throughout container 1800, or otherwise positioned in container 1800.

[0105] In an embodiment, a container may be configured to store information. For example, container 1800 may include data storage 1808. Data storage 1808 is used to store information/data for container 1800. For example, captured sensor data, manifest data, etc., may be stored in data storage 1808. Images may be stored in data storage 1808, such as advertisement images, etc., that may be displayed by display 1812, as further described below.

[0106] Data storage 1808 can be any type of storage medium, including memory circuits (e.g., a RAM, ROM, EEPROM, or FLASH memory chip), a hard disk/drive, optical disk/drive (e.g., CDROM, DVD, etc), etc., and any combination thereof. Data storage 1808 can be built-in storage of container 1800, and/or can be additional storage installed (removable or non-removable) in container 1800. A single storage element may be present in container 1800, or multiple storage elements may be present in container 1800. For example, an array of storage elements may be distributed throughout container 1800, or otherwise positioned in container 1800.

[0107] In an embodiment, a container may incorporate one or more sensors. For example, container 1800 may include sensor 1810. Sensor 1810 can be any type of sensor, including a microscale sensor (e.g., a microelectromechanical sensor (MEMS)) or a nanoscale sensor. For example, sensor 1810 can be an environmental sensor that detects an environmental attribute such as a gas (e.g., carbon dioxide, carbon monoxide, methane, etc.), a chemical, weather, temperature, pressure, light, wind, vibration, etc. Sensor 1810 can be a sensor desired to be used in homeland security applications. For instance, sensor 1810 may be configured to sense bomb making materials, toxic substances, nuclear materials/radiation, chemical warfare agents, etc. Sensor 1810 can be configured to sense motion, such as being an accelerometer, a gyro, or other motion sensor. For example, sensor 1810 may be configured to detect a tilt, such as the tilt of a payload carried by a truck or other structure associated with container 1800. Sensor 1810 can be a light sensor, a sound sensor (e.g., a microphone), or any other sensor type. A single sensor 1810 may be present in container 1800, or multiple sensors 1810 may be present in container 1800. For example, an array of sensors 1810 may be distributed throughout container 1800, or otherwise positioned in container 1800. Sensor(s) 1810 may be positioned anywhere in container 1800, including in a coating 1818 of container 1800 and/or in a layer of container 1800 (e.g., embedded in a foam layer, etc.). In an embodiment, one or more of sensor(s) 1810 may be upgradable and/or changeable (e.g., may be changed if a sensor ceases to function correctly).

[0108] In an embodiment, a container may include one or more displays to display text and/or graphics, such as video, and/or to enable container 1800 to change colors programmatically. For instance, container 1800 may include display 1812. Display 1812 may be any type of display, including an LCD (liquid crystal display) container or other display mechanism. In another embodiment, display 1812 is a micro- or nano-enabled display. For example, display 1812 may include an array of mirrors, similar in scale and operation to a digital light processing (DLP) display. Alternatively, display 1812 may include an array of nanomaterials in a layer (or multiple layers) of container 1800 configured to function as a display. Such a display may be present over any portion, including all, of a surface of container 1800, including an entire surface of the structure with which container 1800 is associated. Such a display 1812 (or combination of displays 1812) may be configured to display a color as the color of the structure (e.g., a blue truck, a red car, etc.), one or more static images (e.g., advertising or marketing images), one or more motion images (e.g., video, such as an advertising video), etc. A single display 1812 may be present in container 1800, or multiple displays 1812 may be present in container 1800. For example, an array of displays 1812 may be distributed throughout container 1800, or otherwise positioned in container 1800. For instance, display 1812 may be a device or a layer (e.g., a complete or partial layer) in container 1800. In one example embodiment, display 1812 may be configured to display one or more pre-programmed images and/or videos. In another embodiment, display 1812 may display images and/or video according to instructions received from microcontroller 1814. In an embodiment, particular images and/or video may be displayed by display 1812 depending upon stimuli received/detected by sensor 1810.

[0109] In an embodiment, a container may include temperature/environmental control functionality. For example, in one embodiment, container 1800 may include environmental control module 1816. Environmental control module 1816 may include a heat generator (e.g., including one or more heating elements) and/or a cooling device (e.g., one or more heat removing/transferring or cooling elements) and/or may include one or more temperature sensors (and/or may receive temperature information from sensor 1810). For example, environmental control module 1816 may include a thermoelectric cooler for cooling purposes. Container 1800 may include materials (e.g., metals, etc.) configured to transfer/spread heat.

[0110] Environmental control module 1816 may be used to regulate the temperature of container 1800. For example, environmental control module 1816 may regulate a temperature of container 1800 to regulate a temperature of a structure that container 1800 is incorporated into and/or to regulate a temperature of a cargo contained in container 1800. Environmental control module 1816 may regulate a temperature of container 1800 to minimize variability in operation of sensor 1810. Environmental control module 1816 may regulate a temperature of container 1800 for additional reasons. A single environmental control module 1816 may be present in container 1800, or multiple environmental control modules 1816 may be present in container 1800. For example, an array of environmental control modules 1816 may be distributed throughout container 1800, or otherwise positioned in container 1800.

[0111] In an embodiment, a container may be controlled by a user and/or be centrally controlled. For example, in one embodiment, container 1800 may include a user interface, such as a keypad, touch pad, a roller ball, a stick, a click wheel, and/or voice recognition technology for a user to control and/or otherwise interact with container 1800. In an embodiment, container 1800 may include microcontroller 1814. Microcontroller 1814 may be any type of microcontroller/processor, including hardware, software, and/or firmware, including in silicon, nanowires, and/or any other form. Microcontroller 1814 may be present to perform a control function for container 1800, including coordinating/instructing operation of display 1812, accessing communication module 1806 to receive and/or transmit communications, to access data storage 1808, communicating with sensor 1810, controlling/monitoring environmental control module 1818, etc. A single microcontroller 1814 may be present in container 1800, or multiple microcontrollers 1814 may be present in container 1800. For example, an array of microcontrollers 1814 may be distributed throughout container 1800, or otherwise positioned in container 1800.

[0112] Container 1800 may include one or more layers, such as one or more outer layers (e.g., top and bottom layers) configured to provide environmental protection for container 1800. For example, the one or more protective layers may be made from a harder and/or more durable material (e.g., a dense polymer, a metal, etc.) and/or may incorporate nanomaterials and/or other particles (e.g., metal particles) that increase a durability and/or hardness of the one or more layers. The one or more protective layers may provide protection against weather (e.g., rain, sleet, snow, extreme cold, extreme heat), against impacts (e.g., from vehicles, from projectiles such as bullets, etc.), against explosions, and/or against further external threats and/or internal threats or sources of damage. For example, container 1800 may be a container configured to contain an explosive material. Container 1800 may be configured to damp an explosive force if the explosive material inside explodes. Furthermore, the protective layers may include one or more functional elements, as desired for a particular application. For example, a protection layer may include solar energy collection elements (e.g., power generators 1802).

[0113] In embodiments, a container may include one or more of a variety of types of coatings 1818, such as polymers, paints, ceramics, metals, etc. For example, in an embodiment, coating 1818 of container 1800 is a skin gel coat, which may be clear or opaque, and may be applied in any manner, such as by spraying, painting, depositing, etc. Coating 1818 may be a color-changing paint, for example. For example, a color of coating 1818 may be configured to change according to environmental attributes (e.g., temperature), or according to a control signal provided by microcontroller 1814

[0114] The elements of container 1800 shown in FIG. 18 may be distributed homogeneously through the material of the layer(s) of container 1800, or may be formed by discrete elements impregnated within in the material. In further embodiments, container 1800 may include additional and/or alternative elements to those shown in FIG. 18, such as signal conditioning elements, radio frequency identification (RFID) reader and/or tag functionality, etc. Further description and examples of functional elements that may be incorporated in one or more layers of a container are described in U.S. Application No. [to be assigned], titled "Nano-Enhanced Smart Panel," which is incorporated by reference in its entirety herein.

[0115] FIG. 19A shows a cross-sectional view of a wall 1900 of an example container, according to another embodiment of the present invention. Container wall 1900 includes a first coating layer 1902a, a second coating layer 1902b, an active layer 1904, a first conductive layer 1906a, a second conductive layer 1906b, and an energy storage layer 1908. Active layer 1904, first conductive layer 1906a, second conductive layer 1906b, and energy storage layer 1908 are included in a core portion 1910 of container wall 1900. First coating layer 1902a is formed on a first surface of a core portion 1912 of container wall 1900. Second coating layer 1902b is formed on a second surface of core portion 1912 of container wall 1900. Layers 1902a, 1902b, 1904, 1906a, 1906b, and 1908 may include any of the materials and layer types (e.g., homogeneous, heterogeneous, solid, woven, foam, etc.) described elsewhere herein, and may be attached together in any manner described elsewhere herein or otherwise known.

[0116] Core portion 1912 of container wall 1900 has a first portion 1914 and a second portion 1916. First portion 1914 of core portion 1912 includes a stack of first conductive layer 1906a, energy storage layer 1908, and second conductive layer 1906b. Second portion 1916 of core portion 1912 includes active layer 1904.

[0117] First and second coating layers 1902a and 1902b provide environmental protection for container wall 1900. First and second conductive layers 1906a and 1906b provide power and signal pathways from energy storage layer 1908 to active layer 1904. Energy storage layer 1908 provides a repository power for the container. Active layer 1904 provides functionality of the container. For example, FIGS. 19B and 19C show cross-sectional views of second portion 1916 in container wall 1900, according to example embodiments of the present invention. As shown in FIG. 19B, active layer 1904 includes a plurality of functional/active elements 1908 (e.g., first and second active elements 1908a and 1908b) embedded in active layer 1904. For example, active elements 1908 may be any of the elements/components described elsewhere herein, discrete, distributed, or a combination thereof, such as those shown in container 600 in FIG. 6. In the embodiment of FIG. 19C, active layer 1904 includes a plurality of functional/active elements 1910 distributed throughout a material of active layer 1904 to form a homogeneous layer.

[0118] In embodiments, multiple layers of materials may be used to form a single functional layer. Functional/active elements 1908/1910 can include processing elements, sensing elements, communication elements, and/or any other elements described elsewhere herein. More than one type of active element can be used in any single layer. Layers of panels, such as container wall 1900, may be manufactured/assembled according to a particular application. The embodiment of FIG. 19 is provided for illustrative purposes, and is not intended to be limiting. Any number of layers, layer types, and embedded materials/components may be used in a particular container structure. Any layer may include more than one function. For example, a protection layer (e.g., coating layers 1902a and/or 1902b shown in FIG. 19) may include solar energy collection elements.

Example Assembly Embodiments for Containers

[0119] Containers may be assembled in a variety of ways, according to embodiments. For instance, FIG. 20 shows a flowchart 2000 for fabricating a container, according to an example embodiment of the present invention. Flowchart 2000 may be performed by a variety of assembly systems, which may incorporate any suitable manual, mechanical, electrical, chemical, and/or other fabrication techniques. For example, FIG. 21 shows a container fabrication system 2100, according to an embodiment of the present invention. For illustrative purposes, flowchart 2000 is described with respect to container fabrication system 2100 shown in FIG. 21. As shown in FIG. 21, system 2100 includes a layer fabricator 2102, a layer attacher 2104, and a panel processor 2106. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the discussion regarding flowchart 2000. Flowchart 2000 is described as follows.

[0120] Flowchart 2000 begins with step 2002. In step 2002, a plurality of layers is formed. For instance, referring to FIG. 21, layer fabricator 2102 may perform step 2002. Layer fabricator 2102 is configured to form one or more layers that may be combined to form a panel. As shown in FIG. 21, layer fabricator 2102 receives layer material 2112. Layer material 2112 may include one or more materials used to form layers of a panel. For example, layer material 2112 may include one or more polymers, such as polyurethane, polyester, acrylic, phenolic, epoxy, elastomerics, polyolefins, polypropylene, polyethylene, and/or vinyl ester, a ceramic material, a metal, and/or other layer materials.

[0121] In an embodiment, step 2002 of flowchart 2000 may include one or both of the steps shown in a flowchart 2200 in FIG. 22. In step 2202 of flowchart 2200, a layer is formed that includes at least one functional element. For instance, as shown in FIG. 21, layer fabricator 2102 may optionally receive functional elements 2110, and may incorporate functional elements 2110 in one or more layers. Functional elements 2110 may include one or more (e.g., in an array, distributed, etc.) of the functional elements described elsewhere herein, including power generator 1802, power storage 1804, communication module 1806, data storage 1808, sensor 1810, display 1812, microcontroller 1814, and environmental control module 1816 shown in FIG. 18. The particular functional elements included in a layer may be selected based on a particular application for the layer/panel, as would be known to persons skilled in the relevant art(s) from the teachings herein.

[0122] In an embodiment where functional elements 2110 is/are received by layer fabricator 2102, one or more of functional elements 2110 may be incorporated into a material of layer material 2112 by layer fabricator 2102 (prior to forming a layer), may be incorporated into a formed layer by layer fabricator 2102, and/or may be applied to a surface of a formed layer by layer fabricator 2102. In embodiments, the one or more functional elements 2110 may be incorporated into a material of layer material 2112 by layer fabricator 2102 in any manner described elsewhere herein or otherwise known, including incorporating the one or more functional elements 2110 into a solid (e.g., powder) or liquid material of layer material 2112 prior to formation of a layer. The one or more functional elements 2110 may be incorporated into a formed layer by layer fabricator 2102 in any manner described elsewhere herein or otherwise known, including by machining, drilling, or otherwise forming an opening in the formed layer and inserting the one or more functional elements into the opening. The one or more functional elements 2110 may be applied to a surface of a formed layer by layer fabricator 2102 in any manner described elsewhere herein or otherwise known, including, including by spraying on, by using an attachment mechanism (e.g., an adhesive material, solder, one or more nails, screws, bolts, rivets, etc.), or by other technique.

[0123] Referring back to FIG. 22, in step 2204, at least one layer is formed that includes a nanomaterial. For instance, as shown in FIG. 21, layer fabricator 2102 may optionally receive nanomaterial 2108, and may incorporate nanomaterial 2108 in one or more layers. Nanomaterial 2108 may include one or more of the nanomaterials described elsewhere herein, including nanowires, nanorods, nanotubes (e.g., carbon nanotubes), glass fibres, carbon fibres, nanoparticles (e.g., silver nanoparticles), nano silica, nano clay, nano aluminum, nano silver, nano carbon, black oxides, graphene, nano platelets, organic and inorganic nano elements, etc. It is noted that persons skilled in the relevant art(s) would be capable of selecting from a wide variety of nanomaterials, whether or not such materials include the “nano” prefix. The particular nanomaterials included in a layer may be selected based on a particular application for the layer/panel, as would be known to persons skilled in the relevant art(s) from the teachings herein. For example, silver nanoparticles may be included in a layer for bacteria resistance in a medical application. It is also recognized that the nanomaterials may be treated in such as way as to provide additional functionality. Such additional functionality may be stand alone (e.g., nano chemical sensors) or the nanomaterials may interact with other components in a panel to enable a desired functionality (e.g., as in the case of reinforcing fibers, electrical conductivity, or thermal conductivity).

[0124] In an embodiment where nanomaterial 2108 is received by layer fabricator 2102, nanomaterial 2108 may be incorporated into a material of layer material 2112 by layer fabricator 2102 in any manner described elsewhere herein or otherwise known. For example, in an embodiment, nanomaterial 2108 may be added to a foam material to be incorporated into a layer.

[0125] For instance, FIG. 23 shows a block diagram of a layer fabricator 2300, according to an example embodiment of the present invention. Layer fabricator 2300 is an example of layer fabricator 2102 of FIG. 21. As shown in FIG. 23, layer fabricator 2300 includes a mixture container 2302 and a mold 2304. Mixture container 2302 is a container that receives a first material 2308 of layer material 2112, such as a resin or other layer material. Nanomaterial 2108 and/or functional elements 2110 may optionally be added to mixture container 2302. Mixture container 2302 is configured to mix the combination of first material 2308, functional elements 2110, and nanomaterial 2108. Mixture container 2302 may be configured to perform the mixing in any manner, including by paddle mixing, ultrasonic mixing, milling, shear mixing, agitation, boiling, and/or any other suitable mixing technique, which may be selected based on the particular application. A second material 2310 of layer material 2112 may optionally be received by mixture container 2302. Second material 2310 may be a second resin or other layer material to function as a catalyst to a foaming and/or curing process. Second material 2310 may be mixed with first material 2308, functional elements 2110, and nanomaterial 2108 in mixture container 2302 as described above. Note that the order in which these materials/elements are mixed may be modified/selected to enable particular desired functionalities in the resulting layer(s).

[0126] As shown in FIG. 23, mixture container 2302 outputs a mixed layer material 2306, which is received by mold 2304. Mold 2304 is an enclosure having a predefined shape that is a desired shape for a layer being formed by layer fabricator 2300 (e.g., planar shaped, curved, enclosure shaped, etc.). Further layer materials may be optionally input to mold 2304, including one or more rods (e.g., rods 308 shown in FIG. 3), fibers, ribbons, woven materials (e.g., woven layers 104 and/or 106 shown in FIG. 1) and/or other layer materials described elsewhere herein. The foaming process proceeds in mold 2304, such that mixed layer material 2306 is allowed to foam/expand to fill mold 2304, and to cure/harden into the predetermined shape of the enclosure of mold 2304. If rods, fibers, ribbons, woven materials, and/or further layer materials are present in mold 2404, the foam spreads and hardens around the rods, fibers, ribbons, woven materials, and/or further layer materials. As described above, second material 2310 may cause mixed layer material 2306 to foam. Alternatively, second material 2310 may not be added to mixture container 2302, and mold 2304 may apply heat, pressure, water vapor, or other foaming/curing agent to mixed layer material 2306 to induce the foaming. As shown in FIG. 23, mold 2304 outputs layer 2114, which is formed of the cured material of mixed layer material 2306. Layer 2114 has a shape based on the enclosure of mold 2304. Mold 2304 may have a shape of a portion of a container, or may have a shape of a complete container, and thus may be used to monolithically mold a single-piece container.

[0127] Note that the example of FIG. 23 is provided for purposes of illustration. Layer fabricator 2102 shown in FIG. 21 may be configured to form layers using a mold (as shown in FIG. 23), such as an injection molding process or a compression molding process, and/or according to other techniques, including an extrusion process, a roll process, a casting process, and/or any other technique used to process polymers and/or other materials into shapes and configurations.

[0128] In step 2004, the plurality of layers is attached together in a stack to form at least one panel. For instance, referring to FIG. 21, layer attacher 2104 may perform step 2004. Layer attacher 2104 receives a plurality of layers 2114 from layer fabricator 2102. Furthermore, layer attacher 2104 may optionally receive one or more functional elements 2110 and/or nanomaterial 2108. Layer attacher 2104 is configured to stack the received plurality of layers 2114 in a predetermined order, and to attach together the plurality of layers 2114 in the stack to form a panel 2118. In an embodiment, layer attacher 2104 may receive an adhesive material 2116. Adhesive material 2116 may be any adhesive material mentioned elsewhere herein or otherwise known, including an epoxy, laminate, a glue, a foam material (e.g., a combination of a first material and a catalyst material, as described above), a thin film adhesive, and/or other adhesive material. Layer attacher 2104 may be configured to apply adhesive material 2116 to one or more layers and/or between one or more adjacent pairs of layers in the stack. Layer attacher 2104 may apply a compressive force, heat, and/or other curing agent/technique to the stack to cause the plurality of layers 2114 to become attached together to form panel 2118.

[0129] Note that in embodiments, a formed panel (e.g., any of panels 100, 300, 500, 600, 700, a panel having a construction similar to wall 1900, etc.) may be received by layer attacher 2104 to be stacked and attached to one or more other formed panels and/or layers. Layer attacher 2104 may be configured to form one panel 2118 that is used to form a container, or a plurality of panels 2118 that can be combined to form panel 2118.

[0130] In step 2006, the at least one panel is processed to form a container. For instance, referring to FIG. 21, panel processor 2106 may perform step 2006. Panel processor 2106 receives one or more panels 2118, and processes the one or more panels 2118 to form a container 2120. Panel processor 2106 may optionally perform additional post-processing on container 2120.

[0131] For instance, in an embodiment, step 2006 of flowchart 2000 may include one or more of the steps shown in a flowchart 2400 shown in FIG. 24. Flowchart 2400 is a flowchart for example processing of one or more panels to form a container, according to an example embodiment of the present invention. For instance, flowchart 2400 may be performed by panel processor 2106. FIG. 26 shows a block diagram of a panel processor 2500, according to an example embodiment of the present invention. Panel processor 2500 is an example of panel processor 2106 of FIG. 21. As shown in FIG. 25, panel processor 2500 includes a panel shaper 2502, a panel combiner 2504, a coating applicator 2506, and a door attacher 2508. Any one or more of these elements of panel processor 2500 may be present, in embodiments. Flowchart 2400 is described as follows with reference to panel processor 2500 shown in FIG. 25, for purposes of illustration.

[0132] In step 2402 of flowchart 2400, a shape of a panel is modified. Step 2402 is optional. For instance, as shown in FIG. 25, panel shaper 2502 may optionally receive one or more panels 2118, and may shape one or more of the received panel(s) 2118. In an embodiment, a single panel 2118 may be shaped by panel shaper 2502 into the shape of a container. In another embodiment, panel shaper 2502 may shape multiple panels 2118 into various shapes that that may be combined to form a container. Panel shaper 2502 may shape a panel 2118 in various ways including by bending a panel with pressure and/or heat, by removing portions of a panel 2118, by separating (e.g., cutting, sawing, etc.) a panel 2118 into multiple pieces and assembling at least a portion of the pieces into a new shape, and/or in further ways, as would be known to persons skilled in the relevant art(s). Any type of attachment mechanism described herein or otherwise known may be used to assemble portions of a panel 2118. In embodiments, panel shaper 2502 may include one or more saws, hydraulic presses or other types of presses, clamps, heating mechanisms, nail guns, adhesive applicators, etc.

[0133] Panel shaper 2502 may not be required if panels 2118 received from layer attacher 2104 are previously shaped (e.g., by a molding process performed by layer fabricator 2102 and/or by layer attacher 2104 shown in FIG. 21). In an embodiment, panel shaper 2502 is not present in panel processor 2500, and panels 2118 are provided to panel combiner 2504 as panels 2510.

[0134] In step 2404, a plurality of panels is attached together to form the container. Step 2404 is optional. For instance, as shown in FIG. 25, panel combiner 2504 may optionally receive and attached together a plurality of panels 2510 to form a container 2512. For instance, panel combiner 2504 may be used to attach container portions 900 and 1000 shown in FIGS. 9 and 10 to form container 1100 shown in FIG. 11. Panel combiner 2504 may combine panels 2510 in various ways including by any type of attachment mechanism described herein or otherwise known, including by using adhesive material 2116. In embodiments, panel combiner 2504 may include one or more clamps, nail guns, adhesive applicators, etc., for attaching together panels 2510.

[0135] Panel combiner 2504 may not be required if a single piece (i.e., single panel) container is being formed by system 2100. In an embodiment, panel combiner 2504 is not present in panel processor 2500, and panel 2510 is provided to coating applicator 2506 as container 2512.

[0136] In step 2406, a coating is applied to the container. Step 2406 is optional. For instance, as shown in FIG. 25, coating applicator 2506 may optionally receive and apply a coating to container 2512, to output a container 2514. A material of the coating, and techniques for applying the coating, may be any of those described elsewhere herein, or otherwise known. For example, as shown in FIG. 25, coating applicator 2506 may receive nanomaterial 2108 and/or functional elements 2110, and include nanomaterial 2108 and/or functional elements 2110 in a coating applied to container 2512. For example, coating applicator 2406 may be used to apply first and second coating layers 1902a and 1902b shown in FIGS. 19A-19C. Coating applicator 2406 may include any mechanism for applying a coating, including a sprayer, one or more rollers, and/or other mechanism, as would be known to persons skilled in the relevant art(s). In an embodiment, coating applicator 2506 is not present in panel processor 2500, and container 2512 is provided to door attacher 2508 as container 2514.

[0137] In step 2408, a door is attached to the container. Step 2408 is optional. For instance, as shown in FIG. 25, door attacher 2508 may optionally receive container 2514, and attach one or more doors to container 2514 to form container 2120. For example, door attacher 2508 may be used to attach doors 1602 and 1604 shown in FIG. 16 to container 1500. Door attacher 2508 may include any mechanism for attaching doors, including clamps, door mounts, hinge applicators, track applicators, adhesive applicators, etc., as would be known to persons skilled in the relevant art(s).

[0138] Door attacher 2508 may not be required if a container formed by system 2100 does not require a door. In an embodiment, door attacher 2508 is not present in panel processor 2500, and container 2514 is output from panel processor 2500 as container 2120.

[0139] Referring back to FIG. 21, in embodiments, container 2120 formed by system 2100 may include any number and combination of layers and panels, including being a monolithically molded container.

[0140] Referring back to flowchart 2000 (FIG. 20), in step 2008, the container is applied to an application. In embodiments, container 2120 generated by system 2100 may be configured, delivered, and/or applied to be used in any suitable application described elsewhere herein or otherwise known to persons skilled in the relevant art(s) from the teachings herein.

Example Container Applications

[0141] The container material embodiments of FIGS. 1-8, the container embodiments of FIGS. 9-19C, the fabrication processes of FIGS. 20, 22, and 24, and fabrication systems of FIGS. 21, 23, and 25 are provided for illustrative purposes, and are not intended to be limiting. Containers may be manufactured/assembled as desired for a particular application. Any number of layers, layer types, layer sizes (e.g., lengths, widths, and thicknesses), and embedded materials/components may be used in a particular container. Any layer may include any number of one or more functions (e.g., functional elements). A container may be fabricated having any desired hardness, strength, durability, and functionality, as desired by combining the appropriate layer materials, micro- and/or nanomaterials, functional materials. For instance, one or more foam layers may be provided that include microscale materials, nanomaterials, and/or functional materials to provide functional characteristics desired for a particular container. One or more woven layers may be provided that provide strength and flexibility for a particular container. One or more bar layers may be provided that provide greater strength and rigidity for a particular container. One or more coating layers may be provided that provide environmental protection for a particular container. These layer types, and further layer types, may be provided to provide any characteristics and functionality described elsewhere herein.

[0142] In an embodiment, a container may form a large structure, such as an automobile, a truck such as a delivery truck, a trailer, a shipping container, a boat, an aircraft skin, a home/building or further structure. Such structures may be newly built with a container of the present invention, and/or existing structures may be retrofitted with a container of the present invention. In an embodiment, a container may be built or wrapped around a structure. For example, a container may be formed/attached around an outer surface of an automobile, truck, shipping container, aircraft, etc. Alternatively, a container may form a portion or all of the structure. For example, a container of the present invention may replace a container of an automobile, truck, shipping container, aircraft, home, other building, boat, or other structure. A container may be a canister that stores a flammable and/or explosive material, such as a fuel, fireworks, ammunition, or other explosive material.

[0143] Containers formed according to embodiments of the present invention have many applications. For example, containers may be used in applications of homeland security, environmental monitoring, defense, displays, recreational vehicles, inventory management, shipping, infrastructure, construction, transportation, energy generation, storage, distribution, weather monitoring, transportation of freight, travel, etc.

Conclusion

[0144] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

WHAT IS CLAIMED IS:

1. A container, comprising:

a plurality of panels that form an enclosure having an internal cavity, each panel comprising a plurality of layers arranged in a stack;

a nanomaterial dispersed in a material of at least one layer of at least one panel of the plurality of panels; and

an attachment mechanism that attaches together a first panel and a second panel of the plurality of panels.

2. The container of claim 1, wherein the first panel includes a first flange and the second panel includes a second flange.

3. The container of claim 2, wherein the attachment mechanism includes a clip that couples the first flange to the second flange to attach the first panel to the second panel.

4. The container of claim 1, wherein the nanomaterial is one or more of a nanowire, a nanotube, a nanorod, or a nanoparticle.

5. The container of claim 1, wherein a layer of at least one panel includes at least one of a woven material, a ribbon, a cured foam material, a plurality of solid rods, or a plurality of hollow tubes.

6. The container of claim 1, further comprising:

an adhesive material between one or more layers in the stack of at least one panel.

7. The container of claim 1, further comprising:

at least one functional element included in a layer of at least one panel.

8. The container of claim 7, wherein the at least one functional element includes at least one of a power generator, a storage device, a communication module, a heat generator, a display, a microcontroller, or a sensor.

9. The container of claim 1, wherein at least one panel includes an outer layer that is configured to provide protection for the container.

10. The container of claim 1, further comprising:

an opening through a panel that opens to the internal cavity; and

a door coupled to the panel that is configured to enable access and disable access to the internal cavity through the opening.

11. A method of forming a container, comprising:

attaching together a plurality of panels to form an enclosure having an internal cavity, each panel comprising a plurality of layers arranged in a stack, and at least one panel of the plurality of panels including a nanomaterial.

12. The method of claim 11, further comprising:

forming a layer of a panel of the plurality of panels, said forming including

dispersing the nanomaterial in a material used to form the layer.

13. The method of claim 11, wherein a first panel of the plurality of panels includes a first flange and a second panel of the plurality of panels includes a second flange, wherein said attaching comprises:

clipping the first flange to the second flange to attach the first panel to the second panel.

14. The method of claim 11, further comprising:

forming a layer of a panel of the plurality of panels that includes at least one of a woven material, a ribbon, a plurality of parallel solid rods, or a plurality of parallel hollow tubes.

15. The method of claim 11, further comprising:

inserting a resin material into a mold; and

adding a catalyst material to the resin material to cause a foam material to be produced that conforms to the shape of the mold to form a layer of a panel of the plurality of panels.

16. The method of claim 11, further comprising:

forming a layer of a panel of the plurality of layers that includes at least one functional element.

17. The method of claim 11, further comprising:

forming a coating on a surface of the container configured to provide protection from an external stimulus.

18. The method of claim 11, further comprising:

forming an opening through a panel of the plurality of panels that opens to the internal cavity; and

coupling a door to the panel that is configured to enable access and disable access to the internal cavity through the opening.

19. A container, comprising:

a monolithically molded container that forms an enclosure having an internal cavity, wherein at least one wall of the container includes a plurality of layers arranged in a stack; and

a nanomaterial dispersed in a material of at least one layer of the plurality of layers.

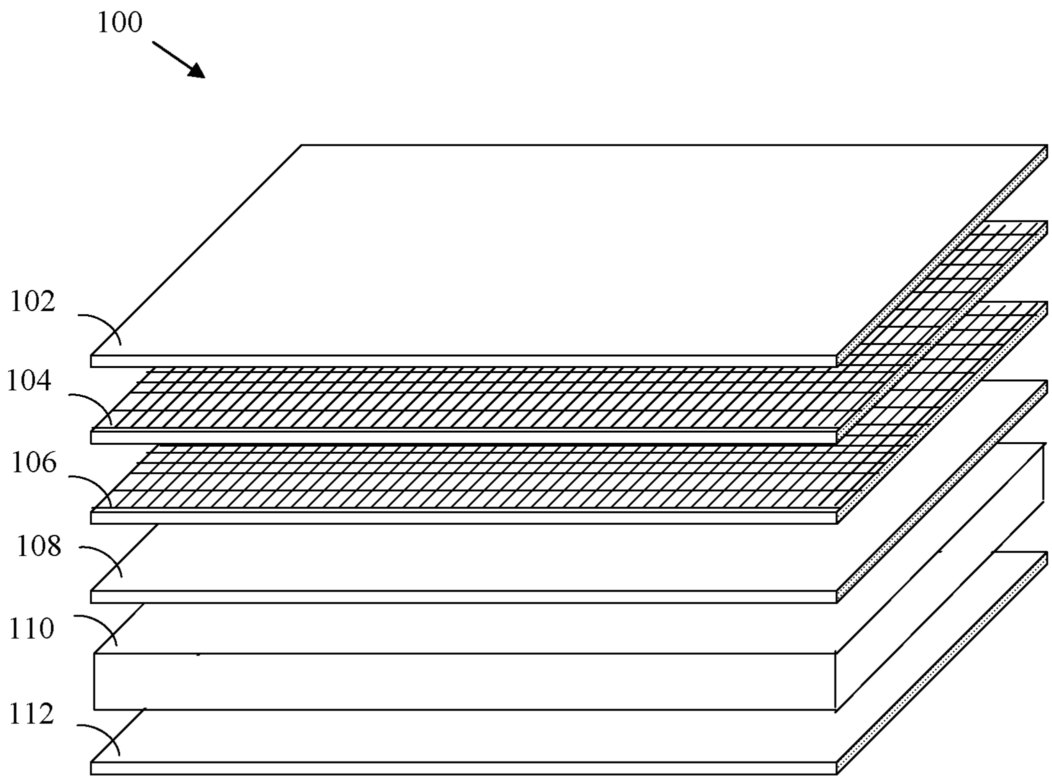

FIG. 1

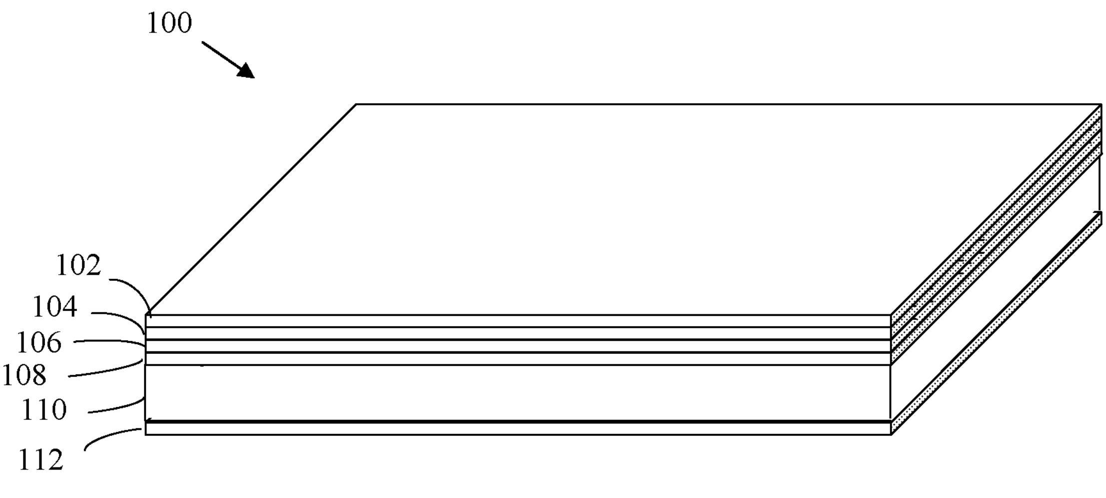

FIG. 2

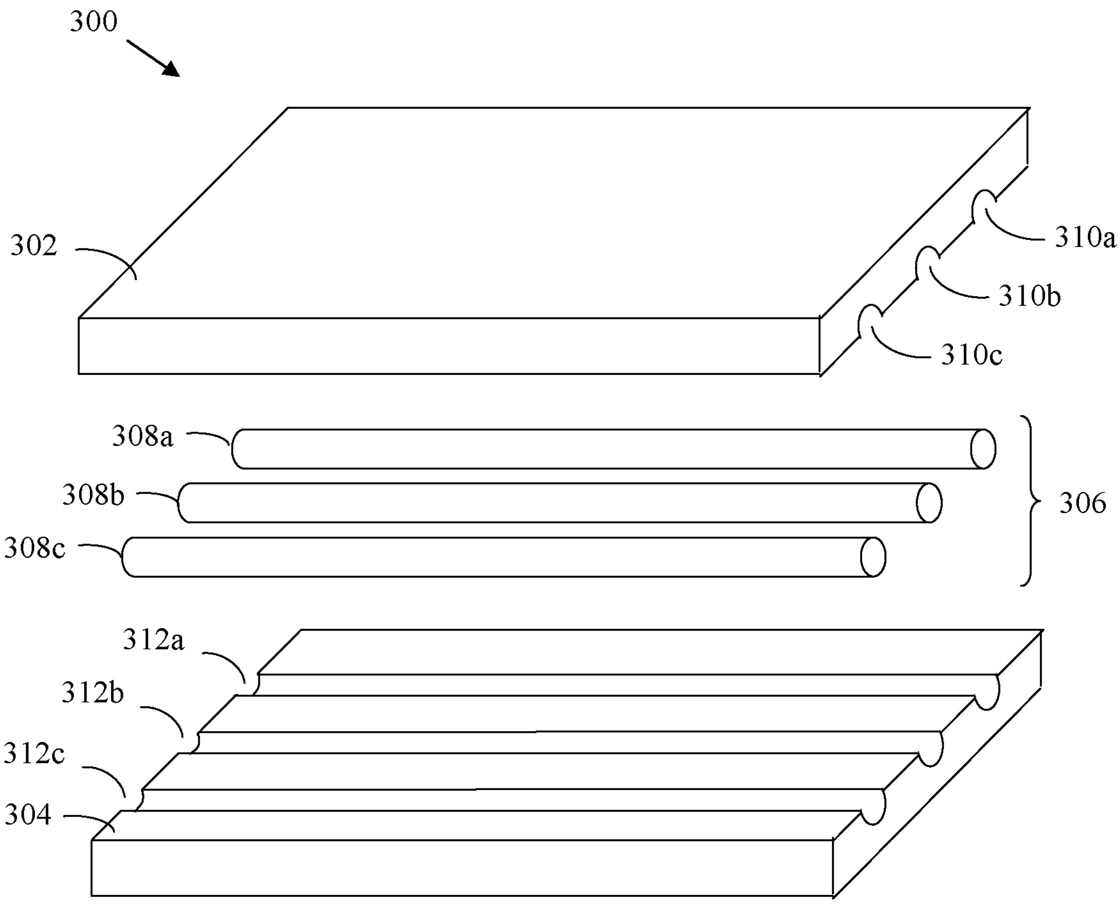
300
302
310a
310b
310c
308a
308b
308c
306
312a
312b
312c
304

FIG. 3

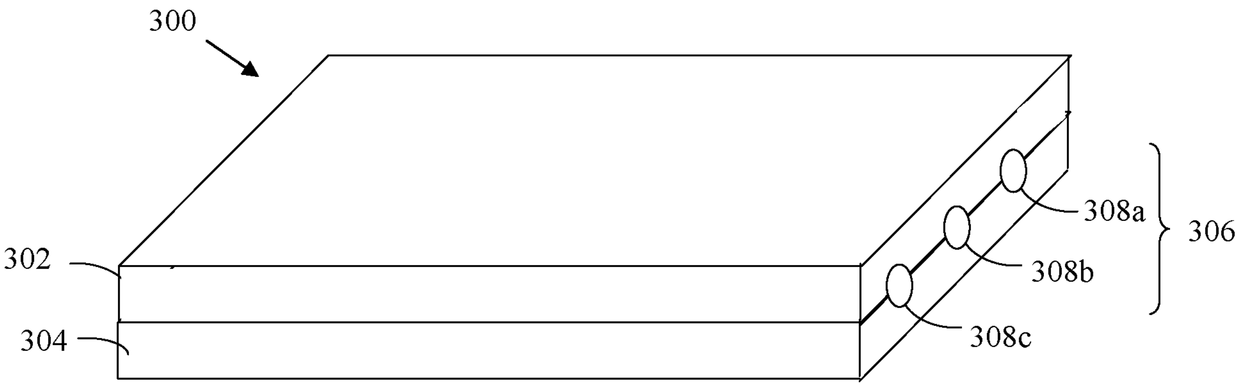
300
302
304
308a
308b
308c
306

FIG. 4

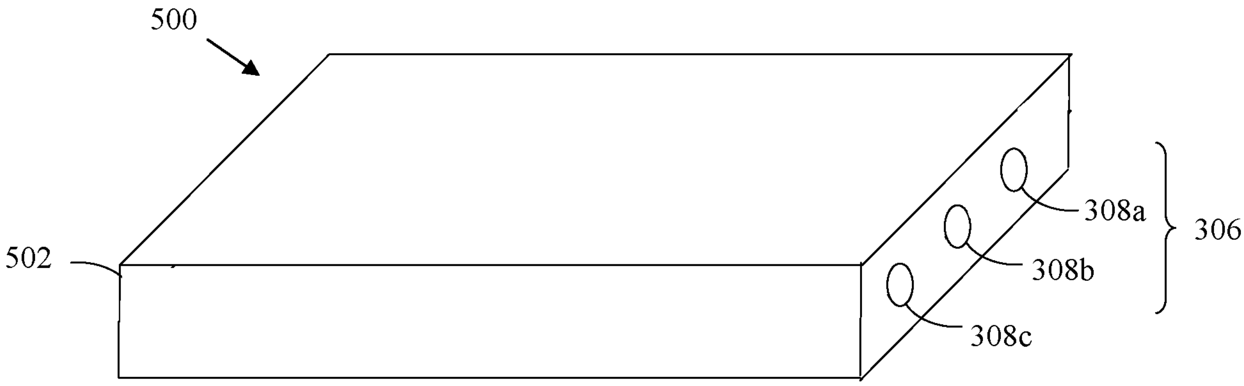
500
502
308a
308b
308c
306

FIG. 5

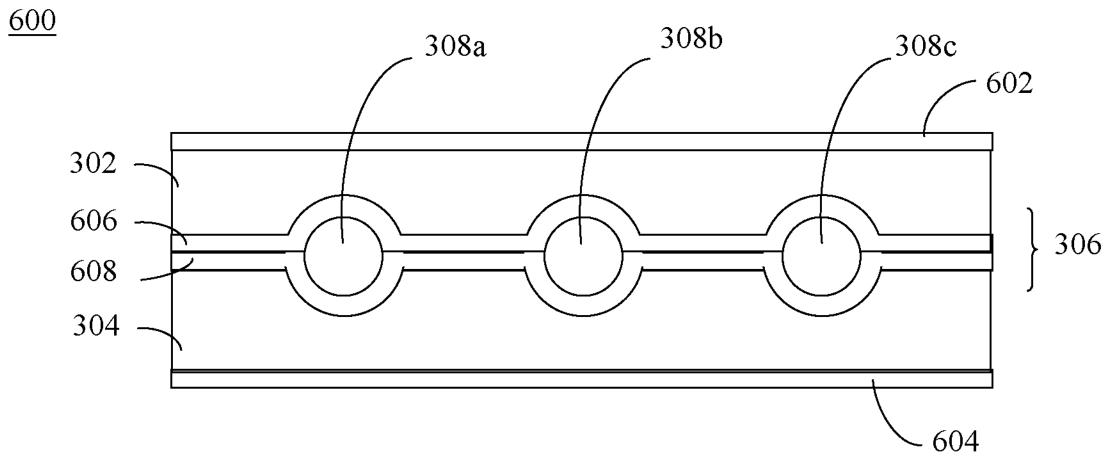
600
308a
308b
308c
602
302
606
608
304
306
604

FIG. 6

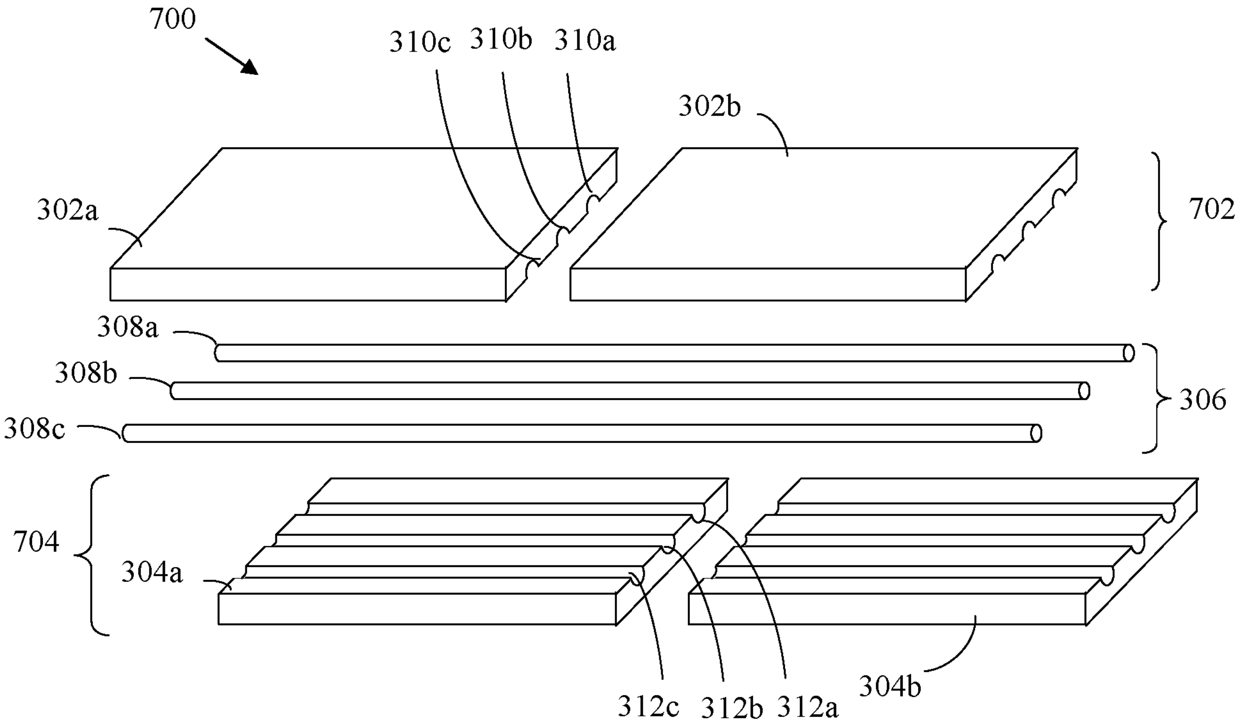
700
310c
310b
310a
302b
302a
702
308a
308b
308c
306
704
304a
312c
312b
312a
304b

FIG. 7

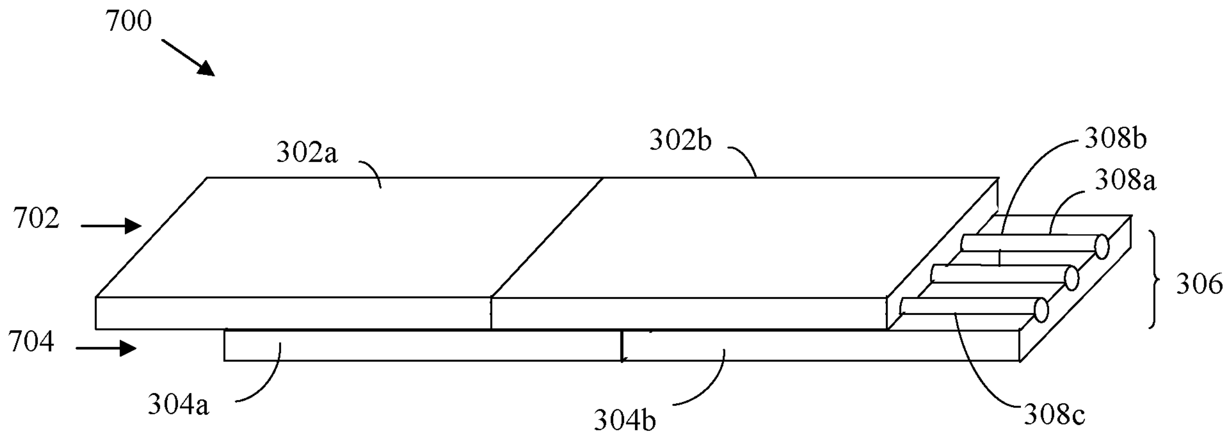
700
302a
302b
308b
308a
702
306
704
304a
304b
308c

FIG. 8

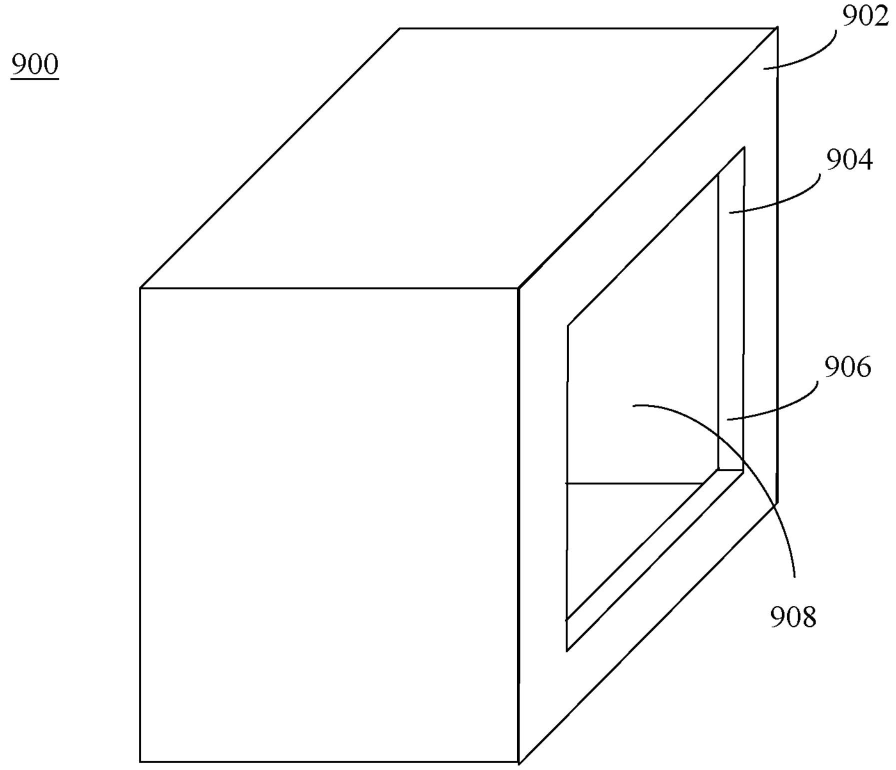

FIG. 9

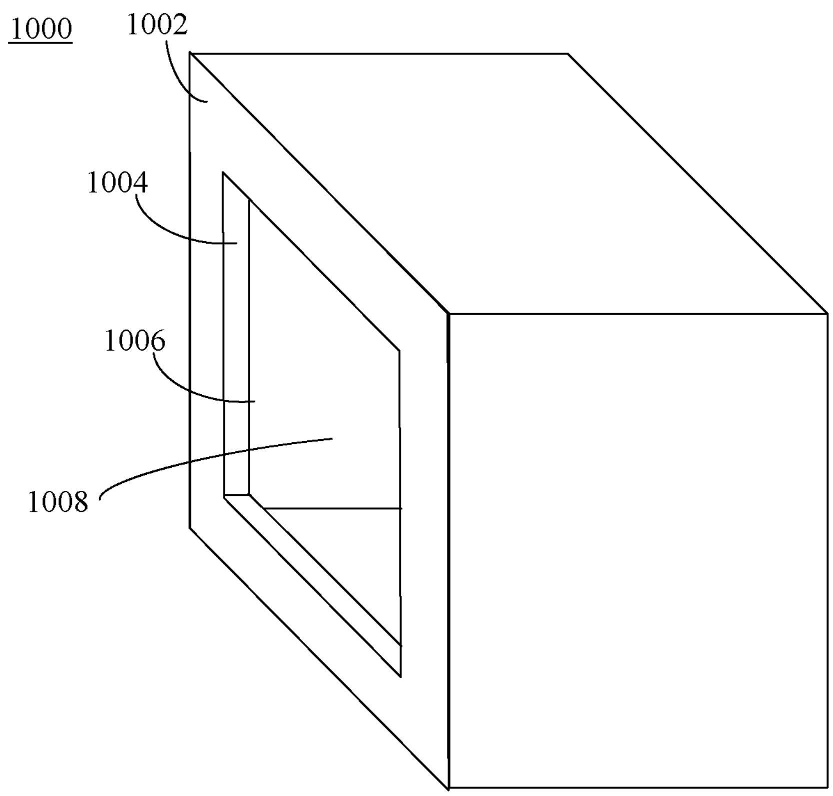

FIG. 10

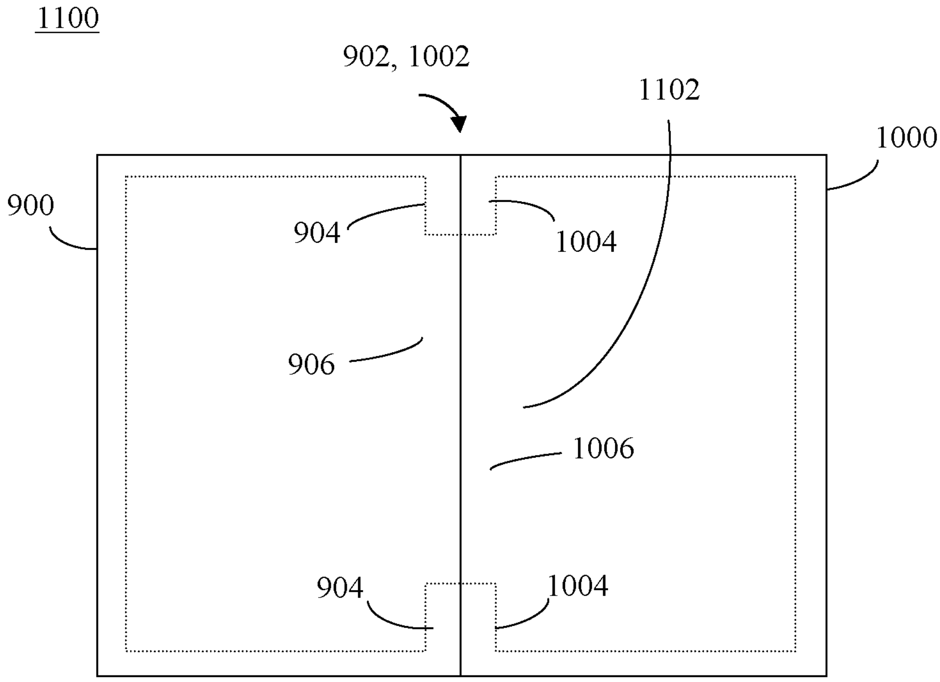
1100
902, 1002
1102
1000
900
904
1004
906
1006
904
1004

FIG. 11

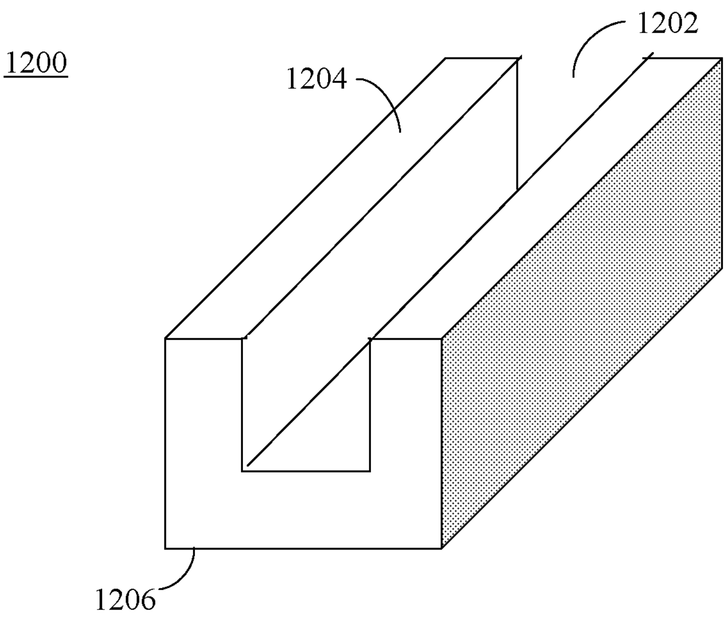
1200
1204
1202
1206

FIG. 12

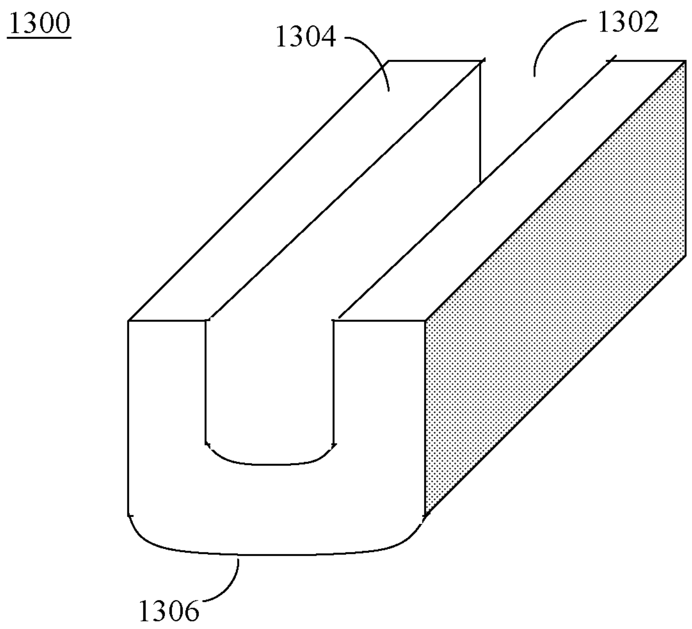
1300
1304
1302
1306

FIG. 13

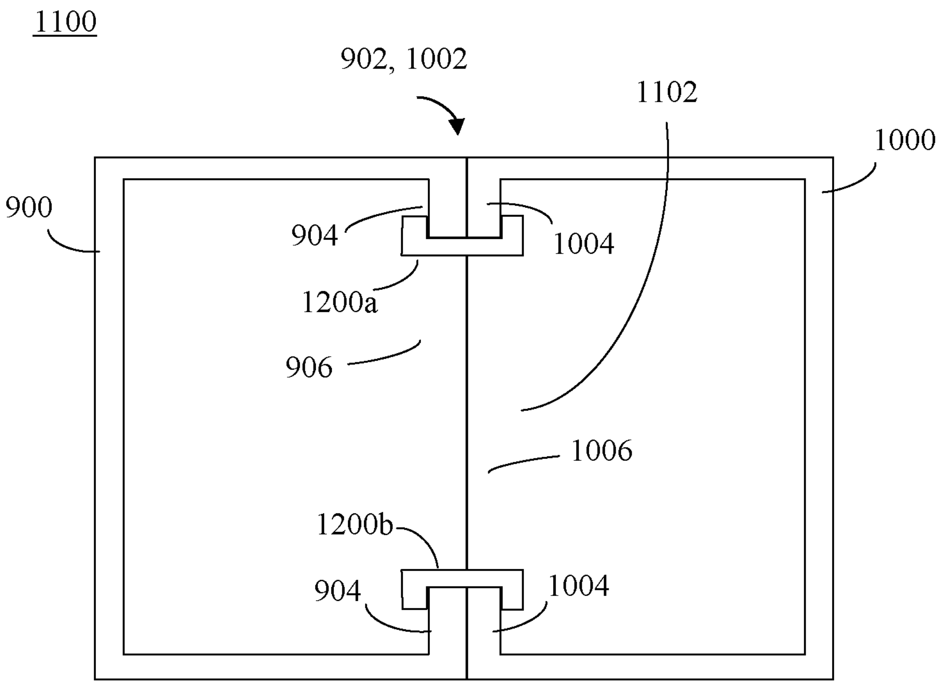
1100
902, 1002
1102
1000
900
904
1004
1200a
906
1006
1200b
904
1004

FIG. 14

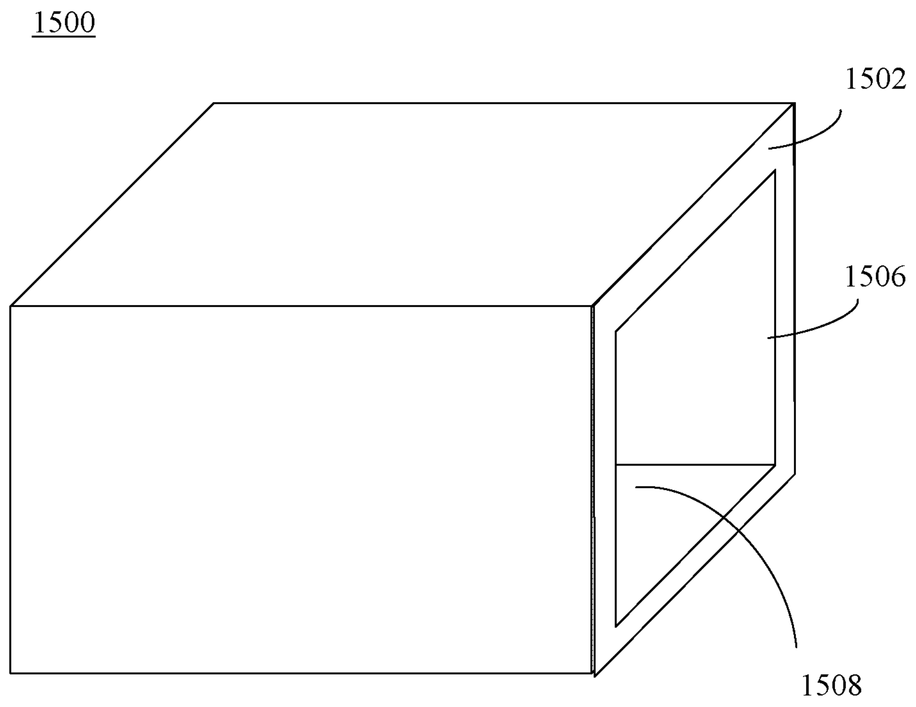
1500
1502
1506
1508

FIG. 15

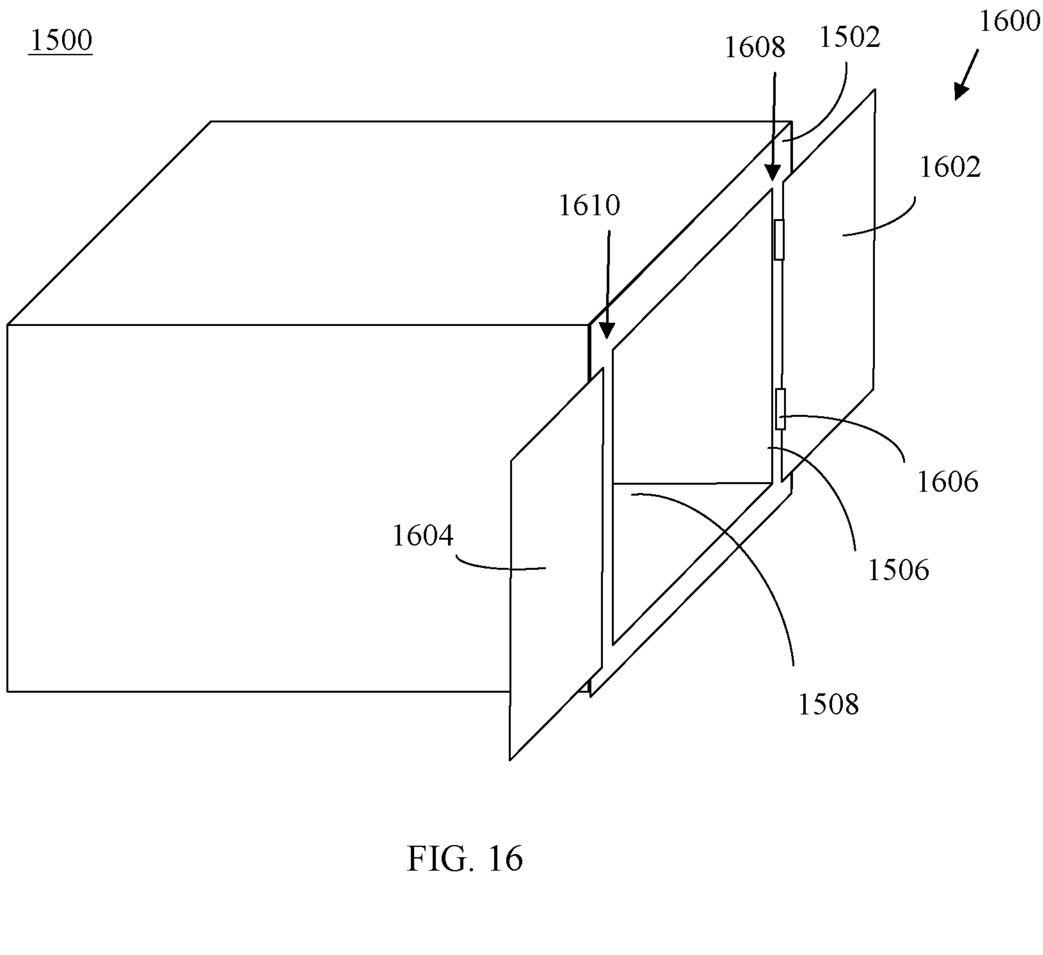
1500
1608
1502
1600
1602
1610
1606
1604
1506
1508

FIG. 16

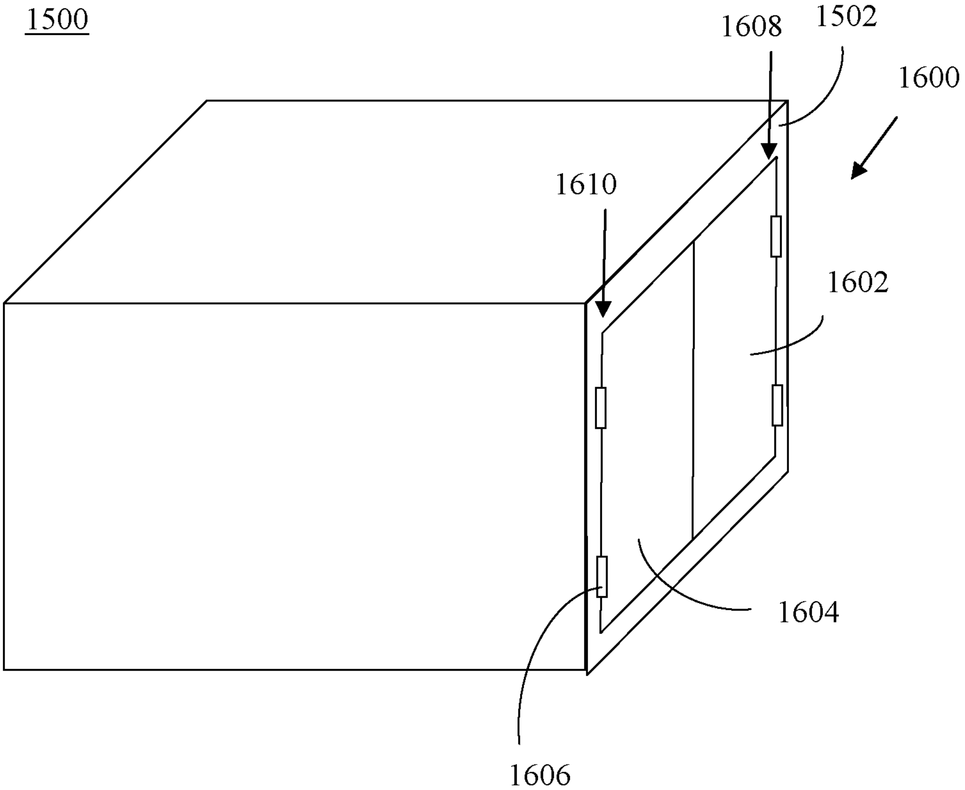

FIG. 17

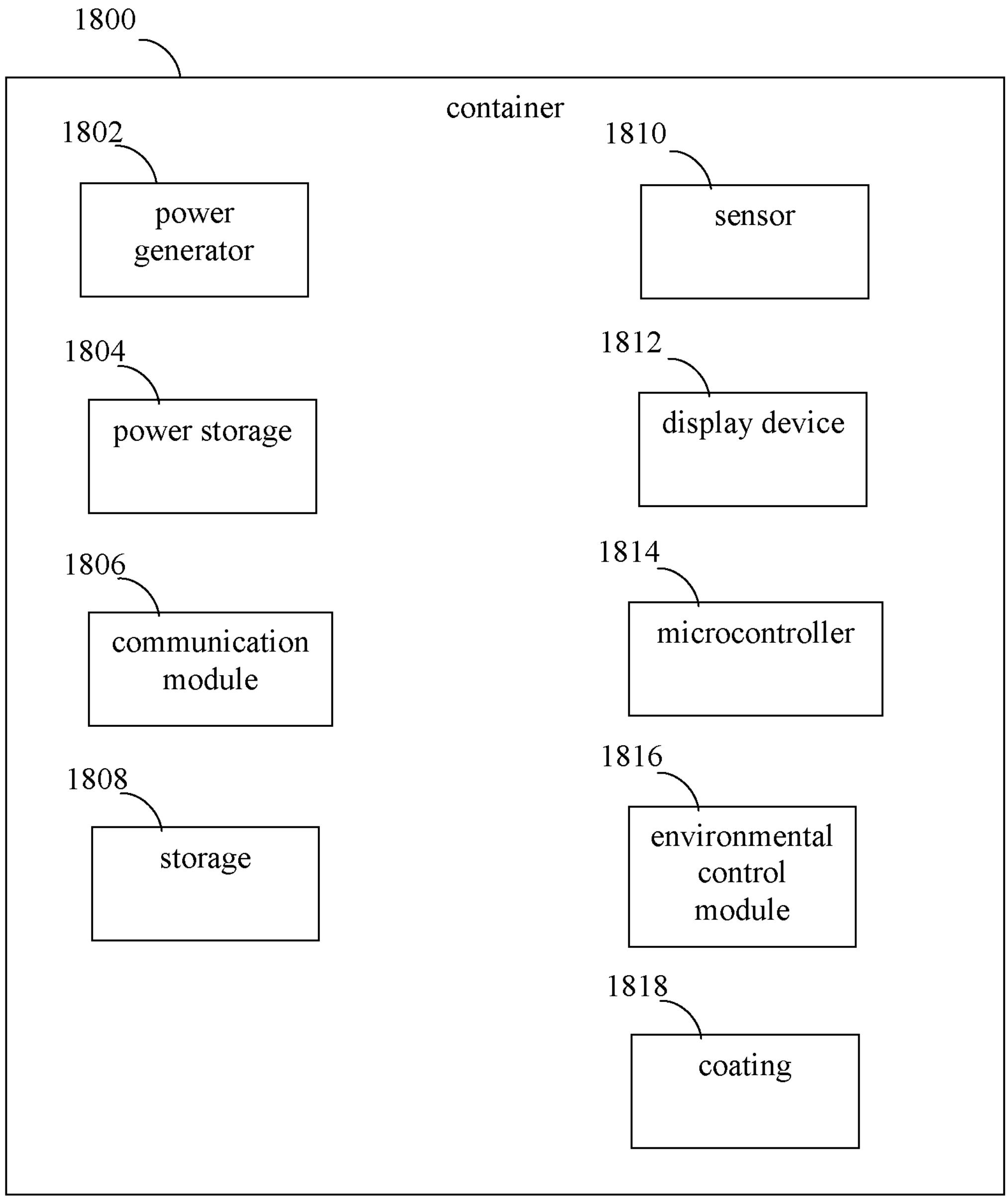
1800
container
1802
power generator
1804
power storage
1806
communication module
1808
storage
1810
sensor
1812
display device
1814
microcontroller
1816
environmental control module
1818
coating

FIG. 18

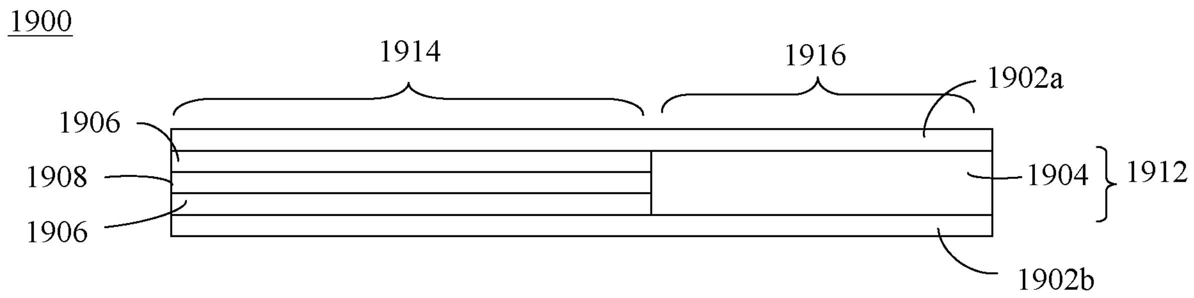

FIG. 19A

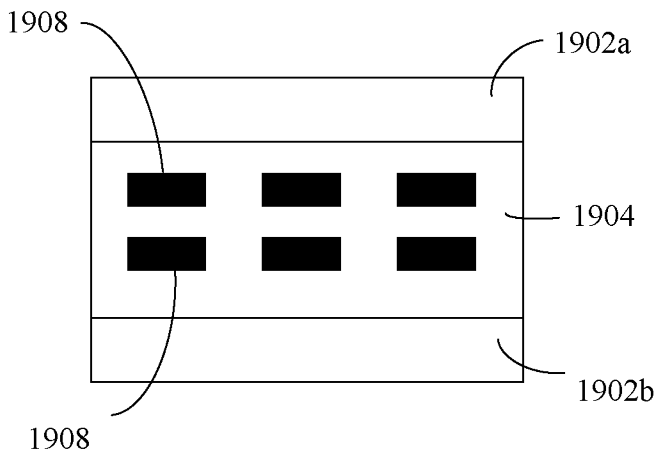

FIG. 19B

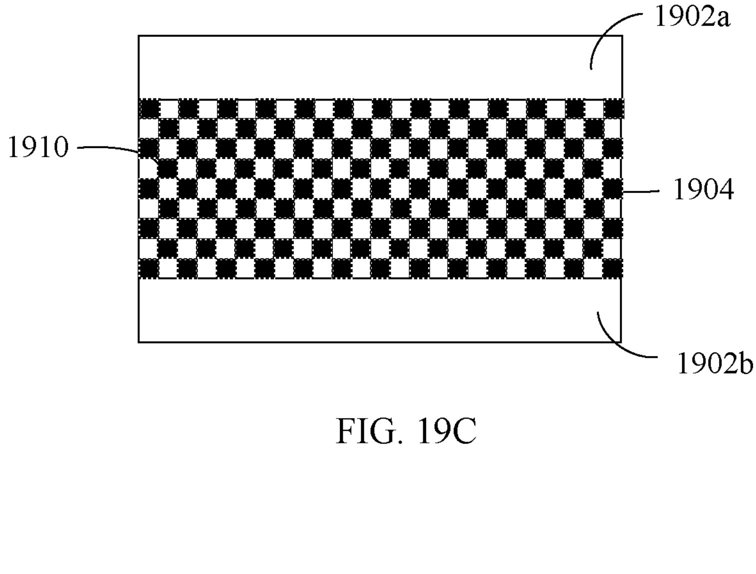

FIG. 19C

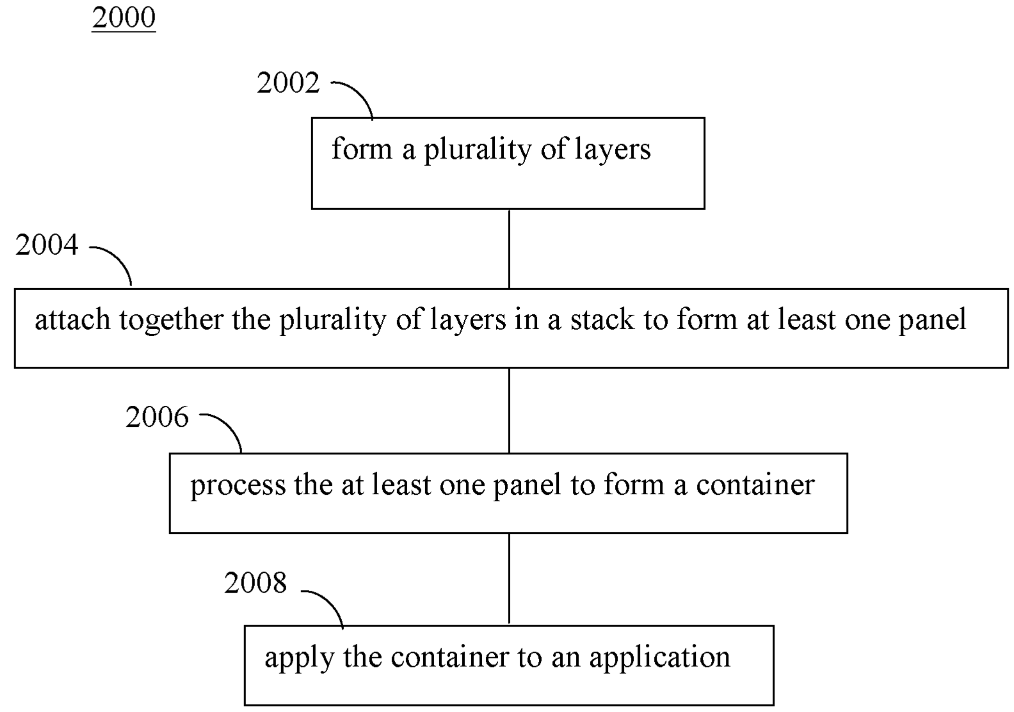
2000
2002
form a plurality of layers
2004
attach together the plurality of layers in a stack to form at least one panel
2006
process the at least one panel to form a container
2008
apply the container to an application

FIG. 20

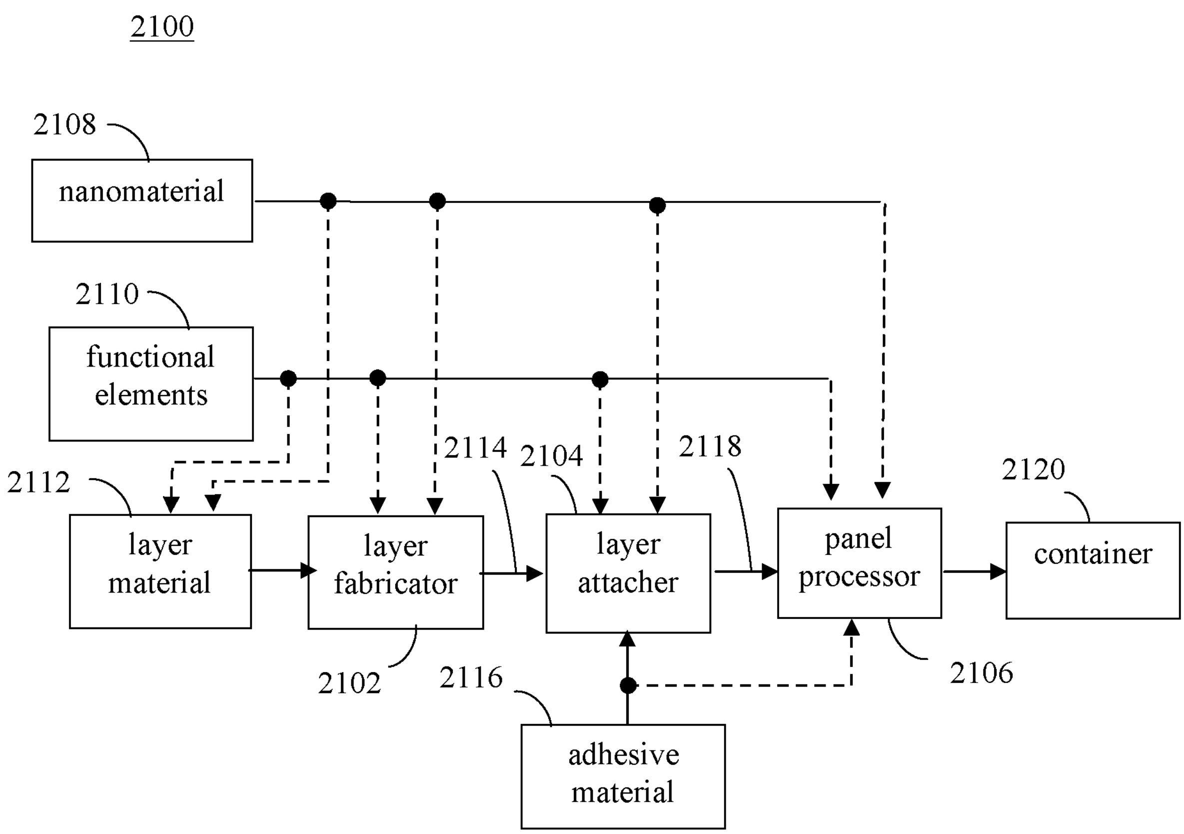
2100
2108
nanomaterial
2110
functional elements
2112
layer material
layer fabricator
2102
2114
2104
layer attacher
2118
panel processor
2106
2120
container
2116
adhesive material

FIG. 21

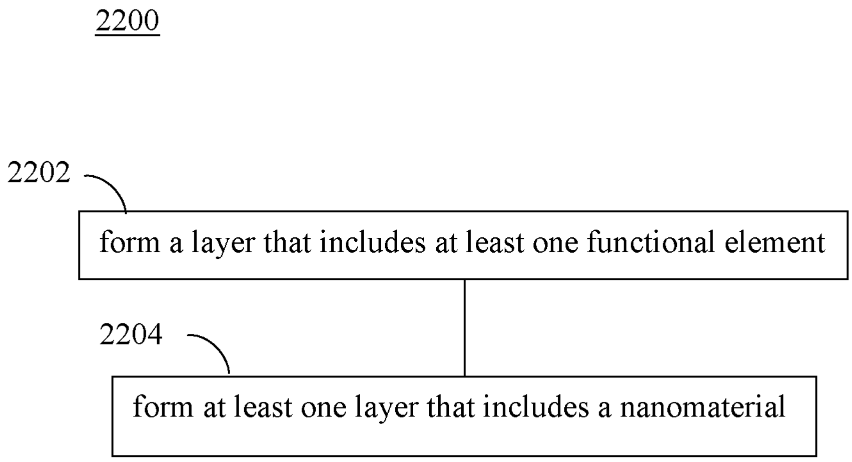
2200
2202
form a layer that includes at least one functional element
2204
form at least one layer that includes a nanomaterial

FIG. 22

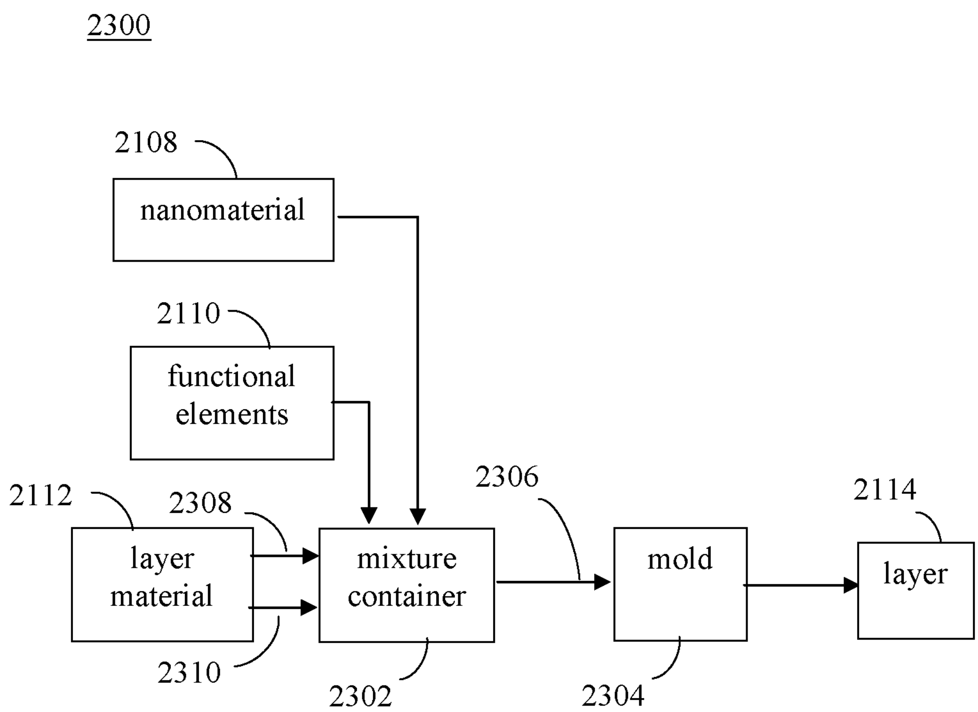
2300
2108
nanomaterial
2110
functional elements
2112
2308
layer material
2310
mixture container
2302
2306
mold
2304
2114
layer

FIG. 23

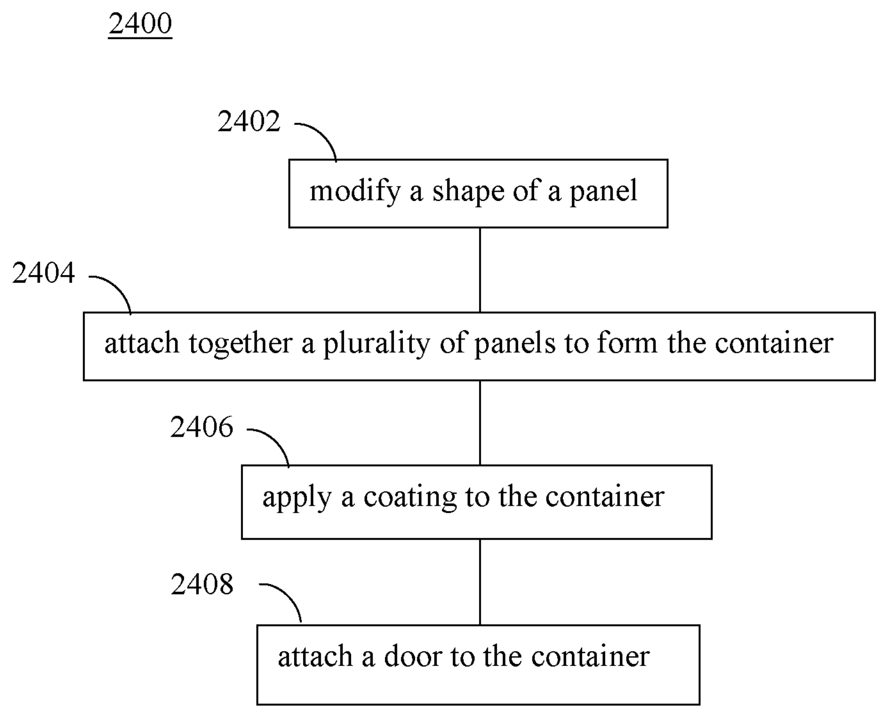
2400
2402
modify a shape of a panel
2404
attach together a plurality of panels to form the container
2406
apply a coating to the container
2408
attach a door to the container

FIG. 24

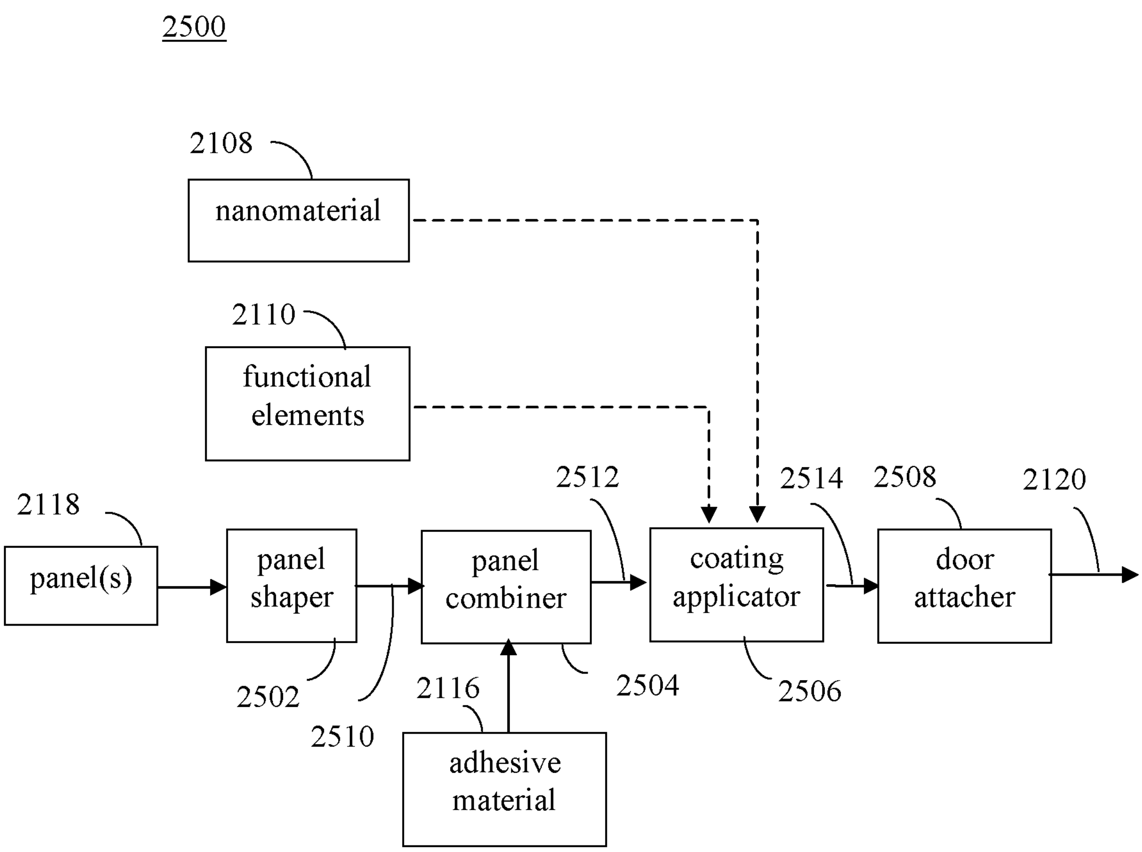
2500
2108
nanomaterial
2110
functional elements
2118
panel(s)
panel shaper
2502
2510
panel combiner
2512
2504
2116
adhesive material
coating applicator
2514
2506
2508
door attacher
2120

FIG. 25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/072826

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B32B 19/00 (2008.04)
USPC - 428/357
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) - B32B 19/00 (2008.04)
USPC - 428/357-407

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO EAST System (US, USPG-PUB, EPO, JPO, DERWENT), GoogleScholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2,558,940 A (DUNNING) 03 July 1951 (03.07.1951) entire document	1-18
Y	US 2004/0137233 A1 (TRANI et al) 15 July 2004 (15.07.2004) entire document	1-19
Y	US 4,807,299 A (NATTRASS et al) 21 February 1989 (21.02.1989) entire document	5, 14
Y	US 6,478,229 B1 (EPSTEIN) 12 November 2002 (12.11.2002) entire document	7, 8, 16
Y	US 5,077,064 A (HUSTAD et al) 31 December 1991 (31.12.1991) entire document	9, 17
Y	US 4,233,361 A (FULTZ) 11 November 1980 (11.11.1980) entire document	15
Y	US 3,774,812 A (LEMELSON) 27 November 1973 (27.11.1973) entire document	19

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

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2008	10 NOV 2008

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774