MULTILAYER ARTICLE AND METHOD FOR MAKING A MULTILAYER ARTICLE, BLANK, AND INSULATING CUP

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Method of making a multilayer article including providing a first substrate and providing a second substrate. The method further includes disposing an expandable insulating material on an inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material is in a first condition during disposing. The second substrate is adhered to the first substrate with the expandable insulating material therebetween to form a blank, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein and the insulating space includes a first volume. The method further includes forming the blank into the article and expanding the expandable insulating material to a second condition by application of energy, wherein the expandable insulating material in the second condition increases the insulating space to a second volume.
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511

FIG. 10
FIG. 12

| Sample | Diameter | Gage Value | Go | NoGo | Width (mm) | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoGo | Go | NoG
FIG. 13

Main Effects Plot for Weight

- Dry Time (Days)
- Gap (in)
- Oven Temp (°F)
- Expulsion (%)

Mean of Weight

Dry Time (Days) vs. Weight

Gap (in) vs. Weight

Oven Temp (°F) vs. Weight

Expulsion (%) vs. Weight

Compression (N: No, 1: Yes) vs. Weight

Glue (mil) vs. Weight
FIG. 14

Main Effects Plot for Hold Time

Hold Time

Mean of Hold Time (sec)
FIG. 16

Main Effects Plot for Average Gauge

Avg Gauge

Dry Time (Days)

Oven Temp (°F)

Gap (in)

Expansed (%)

Mesh

Glue (ml)

Compression (0-No, 1-Yes)

Oven Time (s)

Mean of Gauge (in)
Ridge Gauge

FIG. 17

Main Effects Plot for Ridge Gauge

Data Means

Dry Time (Days)

Oven Temp (°C)

Gain (°)

Mesh

Expansion (%)

Compress (lbs)

Gage (mils)

Mean of Ridge Gauge (in)
FIG. 18

Main Effects Plot for Appearance

0=Best to 3=Worst

- Dry Time (Days)
- Oven Temp (°F)
- Stripes (in)
- Gap (n)
- Expanse (%)
- Nesh
- Compression (0-No, 1=Yes)
- Over Time (s)

Mean of Appearance

Appearance
Strength

FIG. 19

Main Effects Plot for Strength
Data Means

- Dry Time (Days)
- Oven Temp (F)
- Stripe (in)

- Gap (in)
- Mesh
- Expansion (%)

- Oven Time (s)
- Compression (0-No, 1-Yes)
- Glue (ml)
Straight Expansion Cell

Front View - Fig. 20

Back Seam Side View - Fig. 21
<table>
<thead>
<tr>
<th>Identification - 16oz Cups</th>
<th>Economy Cup Article</th>
<th>Article according to disclosed subject matter</th>
<th>Ultra Premium Cup Article</th>
</tr>
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<tr>
<td>Weight (g)</td>
<td>13.9</td>
<td>14.8</td>
<td>6.6</td>
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<tr>
<td>Avg Temp Hold Time (°F)</td>
<td>162</td>
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<td>128</td>
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<tr>
<td>Hot Fill Strength (lb/f)</td>
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<td>1.22</td>
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<tr>
<td>Empty Strength (lb/f)</td>
<td>0.55</td>
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</tr>
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</table>

**FIG. 26**

*Article Insulation Characteristics*
MULTILAYER ARTICLE AND METHOD FOR
MAKING A MULTILAYER ARTICLE, BLANK,
AND INSULATING CUP

CROSS-REFERENCE TO RELATED
APPLICATION

[0001] This application claims priority to U.S. Application No. 61/726,446, entitled “Multilayer Article and Method for Making a Multilayer Article, Blank, and Insulating Cup” and filed on Nov. 14, 2012, the disclosure of which is incorporated herein by reference in its entirety. Other examples of cups include U.S. Pat. No. 3,941,634; U.S. Pat. No. 4,477,518; U.S. Pat. No. 6,509,384; U.S. Pat. No. 6,749,913; U.S. Pat. No. 6,908,651; U.S. Pat. No. 7,956,096; U.S. Publication 2007/0228134; U.S. Publication 2009/0321508, the contents of which each incorporated by reference in their entirety. However, there remains an opportunity for improvement for a disposable cup that is strong, well-insulated and inexpensive to manufacture.

SUMMARY

[0009] The purpose and advantages of the disclosed subject matter will be set forth in and apparent from the description that follows, as well as will be learned by practice of the disclosed subject matter. Additional advantages of the disclosed subject matter will be realized and attained by the methods and systems particularly pointed out in the written description and claims hereof, as well as from the appended drawings.

[0010] To achieve these and other advantages and in accordance with the purpose of the disclosed subject matter, as embodied and broadly described, the disclosed subject matter includes a method of making a multilayer article, comprising providing a first substrate having an inner surface and an outer surface and providing a second substrate having an inner surface and an outer surface. The method further includes disposing an expandable insulating material on the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material is in a first condition during disposing. The second substrate is adhered to the first substrate with the expandable insulating material therebetween to form a blank, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein and the insulating space includes a first volume. The method further includes forming the blank into the article and expanding the expandable insulating material of the article to a second condition by application of energy, wherein the expandable insulating material in the second condition increases the insulating space to a second volume.

[0011] As embodied herein, the disclosed subject matter further includes a multilayer article, comprising a first substrate having an inner surface and an outer surface and a second substrate having an inner surface and an outer surface. The article further including an expandable insulating material applied to the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material includes a first condition at ambient temperature and a second condition upon application of energy. The expandable insulating material is in the first condition and the insulating space has a second volume when the expandable insulating material is in the second condition.

[0012] In another embodiment, an insulating cup is provided. The insulating cup, comprising a sidewall defining a top opening and a bottom portion. The sidewall includes a multilayer article having a first substrate having inner surface and an outer surface and a second substrate having an inner surface and an outer surface. An expandable insulating material is applied to the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material includes a first condition at ambient tem-
perature and a second condition upon application of energy. The second substrate is adhered to the first substrate with the expa-

[0013] It is to be understood that both the foregoing general descrip-
tion and the following detailed description are exemplary and are intended to provide further explanation of the disclosed subject matter claimed.

[0014] The accompanying drawings, which are incorpo-
rated in and constitute part of this specification, are included to illustrate and provide a further understanding of the method

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a top view of a multilayer blank according to a representative embodiment of the disclosed subject mat-

[0016] FIG. 2 is a cross-sectional view of the multilayer blank of FIG. 1 along detail line A-A, according to the disclosed subject matter.

[0017] FIG. 3A depicts a photograph of the expandable insulating material printed in a diamond pattern on a first substrate of a multilayer blank, according to an embodiment of the disclosed subject matter.

[0018] FIG. 3B depicts an enlarged photograph of the expandable insulating material of FIG. 3A after the applica-
tion of energy, according to an embodiment of the disclosed subject matter.

[0019] FIG. 4A depicts a photograph of the expandable insulating material printed in a dot pattern on a first substrate of a multilayer blank, according to an embodiment of the disclosed subject matter.

[0020] FIG. 4B depicts an enlarged photograph of the expandable insulating material of FIG. 4A after the applica-
tion of energy, according to an embodiment of the disclosed subject matter.

[0021] FIG. 5A depicts a photograph of the expandable insulating material printed in a lined pattern on a first sub-
strate of a multilayer blank, according to an embodiment of the disclosed subject matter.

[0022] FIG. 5B depicts an enlarged photograph of the expandable insulating material of FIG. 5A after the applica-
tion of energy, according to an embodiment of the disclosed subject matter.

[0023] FIG. 6 is a schematic cross-sectional view of the multilayer blank of FIG. 1 at ambient temperature along
detail line A-A, according to an embodiment of the disclosed subject matter.

[0024] FIG. 7 is a schematic cross-sectional view of the multilayer blank of FIG. 6 after application of suitable energy, according to an embodiment of the disclosed subject matter.

[0025] FIG. 8 is an exploded view of an insulating cup having a multilayer blank, according to an embodiment of the disclosed subject matter.

[0026] FIG. 9 is the insulating cup of FIG. 8, according to an embodiment of the disclosed subject matter.

[0027] FIG. 10 depicts a flow chart of a method of making a multilayer article, according to an embodiment of the disclosed subject matter.

[0028] FIG. 11A depicts a photograph of an insulating cup formed according to the disclosed subject matter, and FIG. 11B depicts a photograph of the cup of FIG. 11A with the outer substrate removed, according to an embodiment of the disclosed subject matter.

[0029] FIG. 12 depicts a table of samples and experiment data of the samples, according to embodiments of the disclosed subject matter.

[0030] FIG. 12A depicts an infrared image of the temperature of the sidewall of a cup measured with a Flir 15 infrared camera, according to embodiments of the disclosed subject matter.

[0031] FIG. 13 demonstrates the data means for the effects plot for weight of the samples of FIG. 12, according to embodiments of the disclosed subject matter.

[0032] FIG. 14 demonstrates the data means for the effects plot for hold time in seconds of the samples of FIG. 12, according to embodiments of the disclosed subject matter.

[0033] FIG. 15 demonstrates the data means for the effects plot for the sidewall of the samples of FIG. 12, according to embodiments of the disclosed subject matter.

[0034] FIG. 16 demonstrates the data means for the effects plot for the average gauge of the samples of FIG. 12, according to embodiments of the disclosed subject matter.

[0035] FIG. 17 demonstrates the data means for the effects plot for the ridge gauge of the samples of FIG. 12, according to embodiments of the disclosed subject matter.

[0036] FIG. 18 demonstrates the data means for the effects plot for the appearance of the samples of FIG. 12, according to embodiments of the disclosed subject matter.

[0037] FIG. 19 demonstrates the data means for the effects plot for the strength of the samples of FIG. 12, according to embodiments of the disclosed subject matter.

[0038] FIG. 20 shows a front view of the blank and corresponding cup, according to embodiments of the disclosed subject matter.

[0039] FIG. 21 shows a back seam side view of the blank and corresponding cup of FIG. 20, according to embodiments of the disclosed subject matter.

[0040] FIG. 22 shows a front view of the blank and corresponding cup, according to embodiments of the disclosed subject matter.

[0041] FIG. 23 shows a back seam side view of the blank and corresponding cup of FIG. 22, according to embodiments of the disclosed subject matter.

[0042] FIG. 24 depicts another embodiment of the disclosed subject matter showing a blank, according to embodiments of the disclosed subject matter.

[0043] FIG. 25 and FIGS. 25A-25C depict another embodiment of the disclosed subject matter showing a cup made from a blank, according to embodiments of the disclosed subject matter.

[0044] FIG. 26 demonstrates the insulation characteristics of an article of the disclosed subject matter, according to embodiments of the disclosed subject matter.

DETAILED DESCRIPTION

[0045] The products and methods presented herein may be used for serving, storage and transportation of beverages and food items, and other perishable and nonperishable products. The disclosed subject matter is particularly suited for serving,
storage, and transportation of hot or cold beverages or food items, wherein the multi-layer configuration of the cup provides improved insulating properties to maintain the temperature of the beverage or food item contained therein during consumption, storage and/or transportation.

In accordance with the disclosed subject matter herein, the disclosed subject matter includes a method of making a multilayer article, comprising providing a first substrate having an inner surface and an outer surface and providing a second substrate having an inner surface and an outer surface. The method further includes disposing an expandable insulating material on the inner surface or at least one of the first substrate and the second substrate, wherein the expandable insulating material is in a first condition during disposing. The second substrate is adhered to the first substrate at the expandable insulating material therebetween, forming a blank wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein and the insulating space includes a first volume. The method further includes forming the blank into the article and expanding the expandable insulating material of the article to a second condition by application of energy, wherein the expandable insulating material in the second condition increases the insulating space of a second volume.

As embodied herein, the disclosed subject matter further includes a multilayer article, comprising a first substrate having an inner surface and an outer surface and a second substrate having an inner surface and an outer surface. The article further including an expandable insulating material applied to the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material includes a first condition at ambient temperature and a second condition upon application of energy. The second substrate is adhered to the first substrate with the insulating material therebetween to form a blank. An insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein. The insulating space has a first volume when the expandable insulating material is in the first condition and the insulating space has a second volume when the expandable insulating material is in the second condition.

In another embodiment, an insulating cup is provided. The insulating cup, comprising a sidewall defining a top opening and a bottom portion. The sidewall includes a multilayer article having a first substrate having inner surface and an outer surface and a second substrate having an inner surface and an outer surface. An expandable insulating material is applied to the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material includes a first condition at ambient temperature and a second condition upon application of energy. The second substrate is adhered to the first substrate with the expandable insulating material therebetween, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein. The cup further includes a base coupled to the bottom portion of the sidewall when the expandable insulating material is in the first condition.

Reference will now be made in detail to the various exemplary embodiments of the disclosed subject matter, exemplary embodiments of which are illustrated in the accompanying drawings. The structure and corresponding method of operation of the disclosed subject matter will be described in conjunction with the detailed description of the system.

The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views, serve to further illustrate various embodiments and to explain various principles and advantages all in accordance with the disclosed subject matter. For purpose of explanation and illustration, and not limitation, exemplary embodiments of the multilayer blank in accordance with the disclosed subject matter are shown in FIGS. 1-2. The multilayer blank is suitable for the manufacture of articles such as containers, cups, bowls, and the like. Such articles incorporating the multilayer blank can be used with a wide variety of perishable and non-perishable goods. However, for purpose of understanding, reference will be made to the use of the multilayer blank as an insulating cup disclosed herein with beverages, wherein the insulating cup can be used for transporting, serving, storing, preparing and/or re-using such beverages. As described in further detail below, the insulating cup has suitable insulating properties to assist in maintaining the temperature of a beverage therein. For purpose of illustration, and not limitation, reference will be made herein to a multilayer blank and an insulating cup incorporating a multilayer blank that is intended to contain a relatively hot food or beverage, such as hot water or coffee or other similar beverage, wherein the insulating cup has a multilayer structure to provide improved insulating properties, among other benefits.

The multilayer blank generally includes a first substrate, an expandable insulating material, and a second substrate. However, the subject matter of the application further contemplates a blank having a plurality of substrates and expandable insulating materials and is not herewith limited to two substrates and one insulating material. For example, the multilayer blank could include four substrates and three insulating materials.

As shown FIG. 1, a first substrate 110 and an insulating material 200 of a multilayer blank 100 are depicted, according to an embodiment of the subject matter. For purpose of illustration, FIG. 1 depicts a pattern of insulating material 200 that is positioned between the first substrate 110 and the second substrate 120 of the multilayer blank 100. In the embodiment of FIG. 1, the insulating material is printed between the first substrate 110 and the second substrate 120. However, other application methods of coupling the insulating material to the first substrate and/or the second substrate include, but are not limited to, coating, spraying, laminating, and extruding, as further discussed herein.

FIG. 2 is a cross-section of a multilayer blank that includes the first substrate 110 and insulating material 200 of FIG. 1, the cross-section taken along lines A-A of FIG. 1. As depicted in FIG. 2, the first substrate 110 has an outer surface 112 and an inner surface 114. The first substrate 110 defines a thickness T, between the outer surface 112 and the inner surface 114. The thickness T, of the first substrate 110 can be any suitable dimension, depending on the material used. For example, in one embodiment the thickness T, can range between 0.002 inches and 0.020 inches. Other embodiments include the first substrate 110 as having a value of the thickness T, between approximately 8 to approximately 15 pts and in particular approximately 10 to approximately 11 pts, where a conventional paperboard is used.
The multilayer blank further includes a second substrate. The second substrate has an inner surface and an outer surface. The second substrate defines a thickness between the inner surface and the outer surface. The thickness of the second substrate can be any suitable dimension and can be the same or different than the thickness of the first substrate. For example, in one embodiment the thickness can range between 0.002 inches and 0.020 inches. As embodied herein in one embodiment, the thickness of the second substrate is less than that of the first substrate. In one embodiment, the second substrate has a value of the thickness between approximately 3 to 8 pts. In another embodiment, the second substrate has a value of the thickness of approximately 6 pts.

As depicted in FIG. 2, the first substrate and the second substrate are coupled together such that the inner surface of the second substrate faces the inner surface of the first substrate. As such, in one embodiment, the inner surface of the second substrate is coupled to at least a portion of the inner surface of the first substrate to form the blank. The first substrate and the second substrate define an insulting space therebetween with the expandable insulting material therein, as further discussed herein. The insulting space can additionally be filled with a suitable gas, such as air, or can be filled with a variety of suitable materials to achieve desired insulating properties. The insulting space can further include an adhesive applied randomly or in a pattern within the insulting space, as further discussed herein. Furthermore, the adhesive can be applied about the entire surface area of each of the first substrate and second substrate, if desired.

The first substrate and the second substrate can be coupled together by a plurality of suitable methods. In one embodiment, the first substrate and the second substrate are coupled together along the margin with an adhesive. In another aspect of the disclosed subject matter, the first substrate and the second substrate are coupled together along the surface areas of the first substrate and the second substrates, respectively, including within the insulting space. A plurality of suitable adhesives can be used including, but not limited to, pressure sensitive adhesive, glue, thermal bond, and the like. When the adhesive comprises a glue, certain kinds of glue can be used depending on the level of thickness and material of construction of each of the first and second substrates. For example, for substrates of a smaller thickness dimension, a glue having low moisture content, a non-water-based glue, or a glue having a higher solids content can be better suited for such application. With any kind of suitable adhesive, the adhesive can prevent leaching and be compatible with the insulting material. With respect to the embodiment of FIG. 2, the adhesion of the first substrate with the second substrate about the margin allows for the expandable insulting material to expand independently within the insulting space, as described further below. The blank need not be limited to just a single margin about the entire perimeter of the blank. In additional embodiments, perimeter margins and interior channel breaks are also herein contemplated. The first substrate and the second substrate can be coupled together prior to the application of energy to the blank, further discussed herein.

In another embodiment, the first substrate and the second substrate can be adhered together by adhesion in alternate patterns. For example, the adhesive can be positioned on the first substrate and/or the second substrate in channels alternating with the insulting material adhered thereto. In another example, the adhesive can be positioned within the pattern of the insulting material, such as for purposes of example, within the diamond pattern of the embodiment of FIG. 1. Such embodiments can accommodate for a more controlled expansion of the insulting material. As such, the adhesive can include an adhesive pattern or can have an overall application about the surface area of the first substrate and/or the second substrate. In another aspect of the disclosed subject matter, the adhesive can be applied in a registered application. In registered applications, the adhesive may bond the first substrate with the second substrates in areas devoid of or with limited expandable insulting material in addition to or alternative to the application of adhesive to the margins of the substrates.

The first substrate and the second substrate can have any suitable shape and dimension for the intended purpose. For example, the first substrate and the second substrate can have geometric shapes, such as cylindrical, rectangular, triangular, or any suitable geometrical shape. Generally, although not necessarily, the shape and dimension of the first substrate and the second substrate are substantially similar. In alternative embodiments, the shape and dimension of the first substrate and the second substrate vary dependent on the use of the blank. As depicted in FIG. 1, for purposes of illustration, the first substrate has a semi-rectangular shape with arcuate edges for use in making a cup, such as a wrapped cup. In other embodiments as discussed herein, the first substrate and the second substrate each can comprise a web of material that is later machined, cut, and processed into suitable shapes and dimensions for articles, such as cups and the like as previously disclosed.

The first substrate and the second substrate can also include any suitable material. Examples of such suitable materials include paperboard, polymeric sheets, foil or metallized film, foam sheets (e.g., expanded polystyrene), a water-soluble (e.g., starch-based) material, a foamed heat-insulating layer or coating (e.g., polyethylene, polystyrene, polyvinylchloride, polystyrene, polyester, or nylon), unscored paperboard such as chipboard (plain chip or bending chip), linerboard, virgin paperboard, paperboard with recycled content, SBS board, SUS board, corrugated paper board, polymeric solid sheets, combinations thereof, or the like. The first substrate and the second substrate can further include foil or metallized film laminated paperboard, porous sheets, foam sheets (e.g., expanded polystyrene), combinations thereof, or the like.

Suitable substances and coatings can be applied to the blank as desired. For example, the outer surface of the first substrate can include a coating such as a wax or polyethylene that can cooperate with a liquid such as coffee or a soup, when the blank is incorporated into a cup. For example, the first substrate can include approximately between one-half to 1 mil of polyethylene coating to create a seal in the interior of the cup. Further, the outer surface of the second substrate can include a coating to improve printing graphics on the blank or to improve gripping of the blank. Alternatively or additionally, the blank can be coated with a waterproof coating including, for example, polyethylene. Other suitable coatings such as e.g., polyethylene, polystyrene, polyolefin, polyvinylchloride, polystyrene, polyester, or nylon,
combinations thereof, or the like are furthermore contemplated as known in the art. The blank can furthermore be coated with ink or graphics, as known in the art.

[0061] Turning back to FIG. 1 and FIG. 2, the blank 100 includes an insulating material 200 applied between the first substrate 110 and the second substrate 120 in the insulating space 300. The expandable insulating material 200 is applied on the inner surface of at least one of the inner surface of the 114 of the first substrate and the inner surface 122 of the second substrate 120. The expandable insulating material 200 can be applied to at least one of the inner surface 114 of the first substrate and the inner surface 122 of the second substrate 120 in a plurality of suitable ways and processes, as further discussed herein. For example, and not by limitation, in one embodiment, the expandable insulating material 200 is printed on the inner surface 114 of the first substrate 110 in a pattern. For example, a mesh can be utilized to print the expandable insulating material 200 on at least one of the first substrate 110 and the second substrate 120. In another aspect of the disclosed subject matter, the expandable insulating material 200 is applied by at least one of printing, coating, spraying, laminating, and extruding, as further discussed herein.

[0062] A variety of suitable patterns of the expandable insulating material can suffice, such as, but not limited to, dots, chevrons, diamonds, lines, zigzags, spirals, and the like. The pattern can be in an ordered pattern or can be random, such as in a camouflage pattern. If desired, the pattern can define individual cells, wherein each individual cell of the pattern can be sufficiently spaced from an adjacent cell. In an embodiment, the first substrate can include a pattern on an inner surface area of the substrate whereas the second substrate can include a complementary pattern on the outer surface area of the second substrate for a complementary fit between the first and second substrates. In other embodiments and as depicted herein, the pattern can be printed on an inner surface area of the inner surface of the first substrate while leaving an outer margin surrounding the expandable insulating material, as shown in FIG. 1. Other embodiments do not include a margin free of expandable insulating material. For purposes of illustration, FIG. 1 depicts a diamond pattern of the expandable insulating material 200.

[0063] As previously discussed, the adhesive can be applied within the diamonds on either the first substrate and/or the second substrate. The pattern of the expandable insulating material can influence the shape of the overall container after expansion of the expandable insulating material. The pattern can furthermore influence the structure of the container such as the rigidity and dimensional stability. The pattern can also create an aesthetically pleasing design and decorative graphic. The pattern can also provide different areas of insulation that can be application specific for the intended use of the container. For example, with embodiments of the container used as a hot coffee cup, the center of the cup can include a dense pattern of the insulating material thereof, whereas the peripheral areas at the top and bottom of the cup include a less dense pattern or can be lacking insulating material.

[0064] The expandable insulating material 200 of the disclosed subject matter is formed of expandable beads or microspheres, which expand in size upon the application of sufficient energy, such as heat. As embodied herein, one such suitable expandable insulating material is available from Akzo Nobel, under the trademark Expancel®. Such expandable insulating material can be combined with inks, solution binders, carrier medium, or other additives to allow for disposing onto a substrate surface. The binder can have flexible characteristics and not be a rigid substance. A carrier medium of the insulating material can include a variety of suitable characteristics such as being dry to touch after application, but not cured to the extent to lock in any beads of the expandable insulating material and prevent expansion. The carrier medium can have a predetermined viscosity and predetermined drying time based on the method of disposing the expandable insulating material on the substrate(s).

[0065] The expandable insulating material 200 can have certain expansion properties upon the application of energy. Thus, the expandable insulating material 200 can be printed or disposed in a first condition at a first temperature on the substrate(s), the first and second substrates can be adhered to each other and dried to form a blank and, after forming an article from the blank, can subsequently be processed with energy, such as but not limited to radio frequency (RF), infrared, convection, conduction, laser, heat, microwaves, or the like, such that the expandable insulating material 200 includes a second condition. Depending on the desired article of manufacture, different energy or heating applications of the expandable insulating material have different advantages. For articles having a poly-coated applications, the application of the energy to the article need not exceed the melting point of the poly coating.

[0066] In an example embodiment, at ambient temperature the expandable insulating material 200, such as an expandable ink with microspheres, can include microspheres having pre-expansion diameters ranging from approximately 6 to approximately 12 microns, i.e., the first condition. However, another embodiment contemplates a bead having a pre-expansion diameter ranging from approximately 10 to approximately 16 microns, such as for purposes of example, Akzo Nobel, 031WUF40 Expancel bead used in hot cup applications. The expandable insulating material 200 can be printed or disposed on the substrate in the first condition with the thickness dimension of the expandable insulating material 200 based on the density of the microspheres. For example, but not limited to, the thickness of the expandable insulating material 200 can be printed with a thickness dimension between approximately 0.001 inches to 0.008 inches. For applications desiring more stiffness and less insulation, the thickness dimension of the expandable insulating material 200 can be printed or disposed with a thickness dimension of approximately 0.005 inches in the first condition. For hot cup articles such as hot coffee cups, the thickness dimension of the expandable insulating material 200 can be printed or disposed with a thickness of approximately 0.015 inches to approximately 0.03 inches, in the first condition.

[0067] Upon the application of energy to the microspheres to e.g., approximately 100-500 degrees Fahrenheit (hereinafter, “F”) and for a duration ranging between approximately 5 to approximately 120 seconds, the microspheres permanently expand to increase the original diameter of the microspheres, i.e., the second condition. The expansion of the insulating material can be a function of the application of energy and the associated duration time. For example, in a hot cup application using the Akzo Nobel, 031WUF40 Expancel bead, convective heat can be applied at approximately 400°F. to approximately 500°F. for approximately 30 to approximately 90 seconds, and in some embodiments for approximately 60 seconds. Such expansion can be generally uniform.
across the surface of the substrate so as to increase the dimension or distance between the inner surfaces of the substrates and thus the volume of the insulating space. For example, the microspheres can expand up to 10 times the original diameter and volume. In another example, the printed microspheres can have a thickness dimension of 0.0005 inches in the first condition at ambient temperature and expand to 0.012 inches or greater in the second condition, depending at least on the kind and construction of bead.

In an example of the disclosed subject matter, the expandable insulating material, inclusive of the expandable beads with a carrier medium/coating, can be applied using screen printing technology with a mesh ranging from approximately 60 mesh to approximately 200 mesh size, and in one example, approximately 60 mesh to approximately 100 mesh. With screens of greater mesh dimensions, the lower the amount of insulation material is applied on the substrate. Another factor that can affect the thickness of the expanded insulating material is the ratio of beads to the carrier medium (i.e., the density of the beads within the carrier medium/coating). With a higher density of beads in the carrier medium, the expansion of the beads can be limited due to the lack of space for the beads to expand. However, with a lower density of beads in the carrier medium, there may not be enough expansion of the beads for the insulation of the article and the desired use thereof. Other factors that can affect the expansion of the beads, include but are not limited to, the application of the adhesive material and the flexibility and construction of the substrates.

The spacing of the pattern of the expandable insulating material can accommodate the expansion of the microspheres. Similarly, the first and second substrates are joined or coupled together in a matter to allow for such expansion. Furthermore, a pleat or embossment can be provided in one or both substrates to allow for such expansion. After the energy is applied, the expandable insulating material 200 can be allowed to cure for a suitable time, for example, but not limited to, between approximately 20 and approximately 60 hours. However, curing after the energy is applied is not necessary. It is noted however that the energy can be applied at a suitable time after the insulating material is applied. Long delays between application of insulating material and energizing the insulating material can cause the carrier medium to lock or become rigid, which can be adverse to the expansion of the material. In one embodiment, the blank is allowed to dry up to approximately 2 days, as further discussed herein.

FGS. 3A-5B depict various examples of the expandable insulating material 200 printed on at least one of the inner surface 114 of the first substrate and the inner surface 122 of the second substrate 120. For purpose of illustration and description only, each embodiment depicts the blank with the second substrate removed and the insulating material expanded prior to forming a corresponding article from the blank. FIG. 3A depicts a photograph of the expandable insulating material 200, embodied as microspheres, in an uniform diamond pattern at ambient temperature, similar to the embodiment of FIG. 1. FIG. 3B depicts an enlarged view of the microspheres of FIG. 3A after the application of energy. As shown in FIG. 3B, upon the application of suitable energy, the microspheres have increased in diameter and volume. The expansion of the expandable insulating material 200 further supplements the insulation properties of the blank, such as by increasing the dimension or distance between the facing inner surfaces of the first and second substrates and thus the volume of the insulating space 300.

FIG. 4A depicts the expandable insulating material 200, embodied as microspheres, in an ordered dot pattern at ambient temperature. FIG. 4B depicts an enlarged view of the microspheres of FIG. 4A at a maximized view after the application of energy. As shown in FIG. 4B, upon the application of suitable energy, the microspheres have increased in diameter and volume.

FIG. 5A depicts the expandable insulating material 200, embodied as microspheres, in an ordered lined pattern at ambient temperature. FIG. 5B depicts an enlarged view of the microspheres of FIG. 5A at a maximized view after the application of energy. As shown in FIG. 5B, upon the application of suitable energy, the microspheres have increased in diameter and volume.

The expandable insulating material 200 can also include suitable additives to further enhance the properties of the expandable insulating material. The additives may include suitable binders and/or adhesive substances that do not hinder the subsequent expansion of the expandable insulating material upon the application of energy. The additives may include those as known and customary in the art.

The selective expansion of the article can have additional benefits. For example, the portions of the article with the insulating material can be disposed at any suitable location such as in the bottom of a carton to create wells, as further discussed herein. The insulating material can furthermore be used to increase rigidity at select portions of a container and can facilitate stacking.

For purpose of illustration only, FIG. 6 and FIG. 7 show cross-sections of a multilayer blank 100 prior to the application of suitable energy and after the application of suitable energy, respectively. Again, it is understood that such expansion generally, although not necessarily, would be performed after first forming the multilayer blank into a corresponding article. FIG. 6 is substantially similar to FIG. 2, but reproduced for comparative purposes with FIG. 7.

As depicted in FIG. 6, the blank 100 includes a margin thickness Tm along the margin 116 at ambient temperature. The margin thickness Tm generally is the sum of the thickness T1 of the first substrate 110, the thickness T2 of the second substrate 120, and the thickness of any adhesive and additives between the first substrate 110 and the second substrate 120. The margin thickness Tm can be any suitable dimension such as, but not limited to, for example, 0.002 inches to 0.040 inches.

The blank 100 further includes an original thickness T1 of the first margin 116 along the inner surface area. The original thickness T1 is the sum of the thickness T1 of the first substrate 110, the thickness T2 of the second substrate 120, and the thickness of the expandable insulating material 300 at ambient temperature. The thickness of the expandable insulating material 200 generally defines the dimension or height of the insulating space 300 between the facing inner surfaces of the first and second substrates. As depicted in FIG. 6, the dimensional value of the insulating space 300 is defined by the original blank thickness T3 minus the thickness T1 of the first substrate 110 and the thickness T2 of the second substrate 120. The original thickness T3 can be any suitable dimension such as, but not limited to, for example, approximately 0.001 to 0.008 inches, and particularly approximately 0.0015 to 0.003 inches.
FIG. 7 shows a cross-section of a multilayer blank 100 after the application of suitable energy. As depicted, the margin thickness $T_M$ of the margins 116 stays substantially the same thickness. In other words, the thickness $T_M$ of the first substrate 110 and the thickness $T_2$ of the second substrate 120 remains unchanged and furthermore the adhesive with any additives that binds the first substrate 110 to the second substrate 120 at the margins 116, remains substantially nonreactive to any application of energy.

As previously discussed, the expandable insulating material 200 expands upon the application of suitable energy to increase the dimension, and thus the volume of the insulating space 300. As shown by FIG. 7, the thickness of the blank 100 defined at the inner surface area, i.e., between margins 116 of FIG. 7, changes with the application of suitable energy due to the material characteristics of the expandable insulating material 200. Thus, the original thickness $T_O$ of the blank 100 increases to a second thickness $T_{IR}$ upon application of suitable energy due to the change in size of the expandable insulating material 200 disposed between margins 116. In other words, the second thickness $T_{IR}$ of the blank 100 is greater than the original thickness $T_O$ of the blank 100. The second thickness $T_{IR}$ can be any suitable range, for example, but not limited to, from about 0.007 inches to 0.090 inches. As depicted in FIG. 6 and FIG. 7 for purposes of illustration, the second thickness $T_{IR}$ of the blank 100 is two times the size of the original thickness $T_O$ of the blank 100 whereas the thickness $T_2$ of the margins 116 remains the same before and after application of suitable energy. Although FIG. 7 depicts the expansion of the insulating space 300 outwardly such that the first substrate 110 deforms relative to the second substrate 120, the application further includes embodiments in which both the first substrate 110 and the second substrate 120 deform together and in which the second substrate 120 deforms inwardly with respect to the first substrate 110.

In FIG. 7 after the application of suitable energy, the dimension of the insulating space 300 has increased from its original dimension and is defined by the second thickness $T_{IR}$ minus the thickness $T_M$ of the first substrate 110 and the thickness $T_2$ of the second substrate 120. In one example, an insulating cup including the blank 110 had an original thickness $T_O$ of approximately 0.020 inches at the first condition and a second thickness $T_{IR}$ of approximately 0.080 inches at the second condition such that the thickness increased approximately 4 times. Other embodiments contemplate increases of approximately 0 to 10 times.

As previously noted, and in accordance with another aspect, the blank 100 of the embodiments discussed above can be used to make a plurality of suitable articles, for example, but not limited to, an insulating cup. Particularly, the multilayer blank disclosed herein can be formed into a corresponding article using conventional manufacture techniques, such as rim rolling and the like, and can expanded by the application of energy to form an insulated article. For purpose of illustration and not limitation, the insulating cup comprises a sidewall defining a top opening and a bottom portion. The sidewall includes a multilayer article having a first substrate having inner surface and an outer surface and a second substrate having an inner surface and an outer surface. An expandable insulating material is applied to the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material includes a first condition at ambient temperature and a second condition upon application of energy. The second substrate is adhered to the first substrate with the expandable insulating material therebetween, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein. The cup further includes a base coupled to the bottom portion of the sidewall when the expandable insulating material is in the first condition.

FIG. 8 and FIG. 9 depict an embodiment of the subject matter wherein a blank 100 of the embodiments discussed herein is used to form a sidewall of an insulating cup 400. For purpose of illustration and not limitation, as shown in FIG. 9, the insulating cup 400 comprises a sidewall 415 and a base 435. The sidewall 415 includes a multilayer blank 100 that can include any of the characteristics as previously disclosed. The sidewall 415 is configured, for example, by wrapping a multilayer blank 100 about itself prior to the application of energy to expand the expandable insulating material, such that the blank 100 forms the sidewall 415 of the cup in which the first substrate 110 forms an interior of the insulating cup 400 and the second substrate 120 forms an exterior of the insulating cup 400. Because the article is formed prior to expanding the expandable insulating layer, any of a variety of known manufacturing techniques or processes can be used for each component of cup and assembly of the cup therefrom.

As shown in FIG. 9, the multilayer blank wraps about itself such that a longitudinal portion of the first substrate 110 adheres to a longitudinal portion of the second substrate 120 to form a seam of the insulating cup 400. The sidewall 415 defines a top opening 420 and bottom portion 430, as embodied herein. The sidewall 415 can further comprise a rolled top portion to define a rim 417 about the top opening 420. The rim 417 can be disposed above a top edge of the second substrate 120 of the blank which forms the exterior of the insulating cup 400. Although not shown in the illustrated embodiments, the insulating cup 400 and the sidewall 415 can include additional surface features, such as ribs, dimples, corrugations, scores, pleats, embossing, or the like and combinations thereof, or the like for aesthetics, gripping or other desired characteristics. For example, such characteristics can be formed by the pattern of the insulating material after expansion, as shown in FIG. 7A.

The bottom portion 430 of the sidewall 415 can be folded toward the interior of the cup to form an inwardly folded segment for connection with the base 435 of the insulating cup. The base 435 is coupled to the bottom portion 430 of the sidewall. The base 435 can be spaced from a bottom of the cup such that a bottom circumferential periphery of the sidewall supports the cup and the base is suspended from the bottom of the cup.

The base can include a substantially flat planar portion with a skirt depending therefrom to define a surface-engaging edge with the sidewall 415. The skirt of the base 435 can cooperate with the inwardly folded segment of the sidewall 415 for adhering the base to the sidewall 415 to form the insulating cup 400. The first substrate 110 together with the flat planar portion of the base 435 define the inner volume of the insulating cup 400.

The base 435 can be formed from the blank material or other suitable material, as known in the art. The base 435 can include any suitable material and can be a single substrate or can alternatively include a plurality of substrates. Examples of such suitable materials include paperboard,
polymeric sheets, foil or metalized film, foam sheets (e.g., expanded polystyrene), a water-soluble (e.g., starch-based) material, a foamed heat-insulating layer or coating (e.g., polyethylene, polyolefin, polyvinylchloride, polystyrene, polyester, or nylon), combinations thereof, or the like. The base can further include suitable coatings such as the coatings previously disclosed in relation to the blank.

Once the insulating cup is assembled, the insulating material can be expanded by the application of energy as described in detail above to expand the insulating space and thus provides a region of insulation between the contents of the insulating cup and the air surrounding the sidewall to reduce thermal flow therebetween. In one example, an insulating cup of an embodiment of the disclosed subject matter containing a hot beverage can insulate the heat such that only approximately 50-70% of the heat is transferred to the exterior of the insulating cup. For example, a person holding an insulating cup of the disclosed subject matter containing coffee at 190°F can only feel the insulating cup at approximately 70% to approximately 80% of the coffee temperature, such as at a range of approximately 135°F to approximately 152°F, and in particular approximately 140°F to approximately 150°F, such that approximately 30% to approximately 20% of the temperature is diffused by the insulating properties of the insulating cup. For purposes of example, a person holding a solid paper cup containing coffee at 190°F can feel the exterior surface of the paper cup at a temperature of approximately 162°F, such that only 15% is diffused by the paper cup. In an embodiment of the disclosed subject matter, the multilayer blank includes a total heat flux of approximately 1800 W/m² to 2000 W/m². For purposes of example, an 8 ft paper cup will have a total heat flux of approximately 6890 W/m².

As illustrated, the insulating cup can have a generally frustraconical shape. Alternatively, the cup can have other geometric shapes, such as cylindrical, rectangular, triangular, or any suitable geometrical shape. The insulating cup can include a suitable stiffness to support a hot substance or a cold substance. For example, but not limited to, the stiffness deflection can range from approximately 0.35 lbs. force of deflection to approximately 1.2 lbs. force of deflection.

In accordance with the disclosed subject matter herein, a method of making a multilayer article, comprising providing a first substrate having an inner surface and an outer surface and providing a second substrate having an inner surface and an outer surface. The method further includes disposing an expandable insulating material on the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material is in a first condition during disposing. The second substrate is adhered to the first substrate with the expandable insulating material therebetween to form a blank, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein and the insulating space includes a first volume. The method further includes forming the blank into the article and expanding the expandable insulating material of the article to a second condition by application of energy, wherein the expandable insulating material in the second condition increases the insulating space to a second volume.

FIG. 10 depicts a flow chart of the method of making a multilayer article, according to an embodiment of the disclosed subject matter. The first substrate is provided, as depicted in step 501. The first substrate can be provided on a roll or web of material suitable for inline processing and downstream manufacturing by an apparatus.

The method further includes providing a second substrate as depicted in step 503 of FIG. 10. The second substrate can be provided in a conventional manner similar to the first substrate, i.e. on a roll or web of material as known in the art.

As depicted in step 505 of FIG. 10, an expandable insulating material is printed on the inner surface of at least one of the first substrate and the second substrate. As previously disclosed, the expandable insulating material in a first condition can be printed on the at least portion of the inner surface of at least one of the first substrate and the second substrate, as the webs of the first substrate and the second substrate are transported downstream. The disposing can be in a pattern on the portion of the inner surface of the first substrate, as previously disclosed above. The expandable insulating material can be printed on an inner surface area of the substrates such that an outer margin of the substrates remain free of the expandable insulating material.

As depicted in step 507, the second substrate is adhered to the first substrate. The second substrate can be coupled with the first substrate along the outer margin of the inner surface of the first substrate with an adhesive to form the blank. However, other embodiments of the disclosed subject matter as further discussed herein, contemplate the first substrate coupled with the second substrate along the entire surface area thereof. In such embodiments, the adhesion can be between any pattern of expandable insulating material attached thereto. The second substrate can be coupled with the first substrate by conventional methods as known in the art, for example, pressure sensitive adhesion, glue, thermal bonding, or the like. The first substrate and the second substrate define an insulating space therebetween with the expandable insulating material wherein the insulating space includes a first volume when the first substrate and the second substrate are adhered together. As previously discussed, the adhesive can be positioned within the insulating space.

The method can also include forming the blank into an article, as depicted in step 509 of FIG. 10. For example, the multilayer blank can be manufactured to a desired shape or dimension as known in the art. Furthermore, a method of making an insulating cup including the multilayer blank as disclosed is also herewith contemplated. Conventional methods of making a cup are known. For example, the following patents include such conventional methods, the contents of which are herein incorporated by reference in their entirety: U.S. Pat. No. 5,569,143; U.S. Pat. No. 5,624,367; and U.S. Pat. No. 5,556,364. In one embodiment, the application further includes embodiments where a mandrel, heated or otherwise, fits within the insulating cup to form the structure of the cup. In other embodiments, the application further includes embodiments where a mandrel, heated or otherwise, fits exterior to the insulating cup to form the structure of the cup and further embodiments include using a system of mandrels, heated or otherwise, fits within and exterior to the insulating cup to form the structure of the cup.

As depicted in step 511 of FIG. 10, the method further includes the application of energy to expand the expandable insulating material in the insulating space to a second condition. The expandable insulating material in the second condition increases the insulating space to a second volume. The application of energy can be applied by any
conventional methods as known in the art, for example but not limited to, by use of an open/closed oven, hot air application, microwave, laser device, heated mandrel, radio frequency (RF), infrared, convection, conduction or the like. [0097] The method can further include coating the blank with a substance, such as a coating material. For instance, the outer surface of the first substrate can be coated with coating substance, as previously discussed. The method can also include coating the blank with ink or graphics, as known in the art.

[0098] Solely for purpose of illustration, FIGS. 11A-B depicts an insulating cup 400, according to an embodiment of the disclosed subject matter. In this example, the insulating cup 400 was formed by wrapping, in lieu of the line processing described with respect to FIG. 10, to show the different phases and substrates of an insulating cup 400 for purposes of illustration. FIG. 11A depicts a final article of an insulating cup 400 having a sidewall 415 of the multilayer blank with the expandable insulating material 200 in the second condition having the first substrate 110 coupled to the second substrate 120.

[0099] FIG. 11B depicts the insulating cup 400 of FIG. 11A after the application of suitable energy, with the second substrate removed for purposes of illustration. The insulating cup 400 was baked in an oven at approximately 230°F, in this embodiment. In this FIG. 11B, the expandable insulating material 200 is in the second condition. In other embodiments of the disclosed subject matter, the article is placed in a convective heat tunnel at approximately 400°F to approximately 500°F for a duration of approximately 60 seconds.

EXPERIMENTS

[0100] The disclosed subject matter is further described by means of the examples and experiments, presented below. The use of such examples is illustrative only and in no way limits the scope and meaning of the disclosed subject matter or of any exemplified term. Likewise, the disclosed subject matter is not limited to any particular preferred embodiments described herein. Indeed, many modifications and variations of the disclosed embodiments will be apparent to those skilled in the art upon reading this specification.

[0101] Experimentation was conducted to determine optimal characteristics of the article and blanks, specifically for a hot cup application, according to the embodiments of the disclosed subject matter. A plurality of variables can affect the performance and characteristics of the article and blank, including but not limited to dimension of the screen mesh, the content of the beads and carrier medium, the pattern of the expandable insulating material upon the substrates inclusive of any width dimension between stripes of expandable insulating material, the length of the drying time of the article or blank prior to the application of energy, the kind of energy applied, the intensity of the energy applied including the temperature of heat application, the duration of the energy or heat applied, whether the articles were loosely stacked during application of energy, whether the articles were stacked as a compressed unit during application of energy, the positioning of the adhesive upon the substrate(s), the thickness dimension of the adhesive upon the substrate(s), and the like.

[0102] In an embodiment of the disclosed subject matter, the expandable insulating material can be disposed on the substrate(s) by using a screen mesh of at least one of approximately 50 Mesh, approximately 86 Mesh, approximately 110 Mesh, and any Mesh dimension therebetween, wherein the higher the Mesh screen dimension, the lower the density of the beads within the carrier medium of the expandable insulating material, as previously discussed. In another embodiment, the expandable insulating material includes a bead content of at least one of approximately 15 percent of the expandable insulating material, approximately 20 percent of the expandable insulating material, approximately 25 percent of the expandable insulating material, or combinations thereof. In another embodiment, the substrate(s) include stripes of expandable insulating material having a width dimension of at least one of approximately 0.23 inches, approximately 0.30 inches, approximately 0.45 inches, or combinations thereof. In another embodiment, the stripes of the expandable insulating material are spaced at a width dimension of at least one of approximately 0.04 inches, approximately 0.07 inches, approximately 0.09 inches, or combinations thereof. In another embodiment, the adhesive (s) are applied at a setting range between approximately 3 mil gap to approximately 7.5 mil gap, and in particular at least one of approximately 4 mil gap, approximately 5 mil gap, approximately 6 mil gap, or any setting therebetween. As such, a thickness dimension of the adhesive can range according to the setting parameter, and in particular for purposes of example, the adhesive can have a thickness dimension of approximately 2.4 mil, approximately 2.9 mil, and approximately 3.5 mil for a glue adhesive having approximately 54% solids. In another embodiment of the disclosed subject matter, the article or blank is allowed to dry up to approximately 2 days prior to the application of energy.

[0103] In another embodiment, heat energy is applied to the article or blank at a temperature of at least one of approximately 400°F, approximately 450°F, approximately 500°F, or anywhere therebetween for a duration of at least one of approximately 40 seconds, approximately 60 seconds, approximately 90 seconds or anywhere therebetween. In another embodiment, the articles are stacked after the application of energy to minimize distortion whereas other embodiments of the disclosed subject matter contemplate unstacked articles during the application of energy.

[0104] Based on the plurality of combinations of the embodiments discussed above, the article and blank can be customized for a variety of articles and blanks of varying needs. For example, by combining any of the plurality of combinations of the embodiments discussed above, the following characteristics can be customized: weight of the article or blank, strength of the article or blank, the thickness dimension of the glue, the sidewall gauge of the article, the average sidewall temperature of an article, the average temperature at the portions of insulating material, the duration of the article within the article at 185°F, the appearance of the article or blank such as but not limited to a person of ordinary skill in the art judgment regarding aesthetics, wrinkles, distortion, and delamination. Based on the plurality of combinations of the embodiments discussed above, fractional factorial design experiments were conducted to demonstrate the customized characteristics of articles produced, according to aspects of the disclosed subject matter.

[0105] FIG. 12 provides characteristics of 36 samples of articles of the disclosed subject matter, in particular cups, and a sampling of data from experiments conducted thereto. As evident from FIG. 12, controlling certain variables provides certain characteristics, which can be used for article and blank customization, as desired. The test protocols include gauge of
the sidewall in which an automated equipment measures 18 thickness points starting 1 inch from the bottom of the article spaced \( \frac{3}{4} \) of an inch apart. The average gauge is an average of all points along the sidewall, whereas the ridge gauge is a maximum gauge measured along the sidewall of the cup. The strength protocol includes strength wherein the force required to deflect a cup 0.25 inch at a location \( \frac{1}{3} \) of the total cup height from the top using JS-1 rigidity tester is measured. The sidewall and temperature protocol is measured with a Flir 15 infrared camera and water at a temperature of approximately 185\(^\circ\)F, placed in an un-lidded cup and the sidewall temperature image is taken from a 20 inch distance from the cup after a duration of approximately 60 seconds. The average temperature is within approximately a 1 inch by 1 inch square (15 pixels by 15 pixels) in a center of the cup opposite the seam, as shown in the example of FIG. 12A. The hold time protocol test includes a cup handled from above the area where the sidewall temperature measurement was conducted, picked up and held such that the hand of the tester did not contact the seam. The cup was held until a tester determined the cup was too uncomfortable to hold by a reasonable hand sensitivity of the tester. The appearance protocol includes a qualitative evaluation of cup appearance, wherein the 0 signal is the best and the 3 signal is the worst, such that a good quality is marked for the 0 signal, wrinkles appear on the inner and/or outer surface of the cup for a 1 signal, the cup is distorted for the 2 signal, and the cup experienced delamination of glued areas for the 3 signal.

[0106]. FIG. 13-FIG. 19 demonstrate various trends of the data gathered from experimentation of the 36 samples of FIG. 12. FIG. 13 demonstrates the data means for the effects plot for weight of the samples, wherein the dimension of the screen mesh and the thickness dimension of the glue weight exhibit the greatest variable changes. As understood by persons of ordinary skill in the art, the data means referred to herein and in the figures is the mean value of the data collected. FIG. 14 demonstrates the data means for the effects plot for hold time in seconds of the samples containing a substance of 185\(^\circ\)F, wherein the temperature of the oven, the dimension of the screen mesh and the duration of the articles in the oven exhibit the greatest variable changes. FIG. 15 demonstrates the data means for the effects plot for the sidewall of the samples containing a substance of 185\(^\circ\)F, wherein the dimension of the screen mesh, the density of the Expancel beads of the expandable insulating material, and the duration of the articles in the oven exhibit the greatest variable changes.

[0107]. FIG. 16 demonstrates the data means for the effects plot for the average gauge of the samples, wherein the dimension of the screen mesh, the density of the Expancel beads of the expandable insulating material, and the duration of the articles in the oven exhibit the greatest variable changes. FIG. 17 demonstrates the data means for the effects plot for the ridge gauge of the samples, wherein the dimension of the screen mesh, the density of the Expancel beads of the expandable insulating material, and the duration of the articles in the oven exhibit the greatest variable changes. FIG. 18 demonstrates the data means for the effects plot for the appearance of the samples such as distortion, delamination and the like, wherein the dimension of the screen mesh, the density of the Expancel beads of the expandable insulating material, and the duration of the articles in the oven exhibit the greatest variable changes. FIG. 19 demonstrates the data means for the effects plot for the strength of the samples, wherein the thickness dimension of the stripe of expandable insulating material, the dimension of the screen mesh, the density of the Expancel beads of the expandable insulating material, and the duration of the articles in the oven exhibit the greatest variable changes.

[0108]. As evident from the plots of FIG. 13-FIG. 19, by controlling certain variables and varying other variables of the samples, customized articles are contemplated with the aspects of embodiments of the disclosed subject matter.

[0109]. FIG. 20-FIG. 21 depict an embodiment of the disclosed subject matter showing a blank juxtaposed with a frustoconical cup made from the blank. For purposes of illustration only, the blank is shown with only a first substrate and the second substrate is not shown in the figure. FIG. 20 shows a front view of the blank and corresponding cup and FIG. 21 shows a back seam side view of the blank and corresponding cup of FIG. 20. As depicted, the expandable insulating material is disposed in ridges at an angle of approximately 45\(^\circ\) F, with respect an axis perpendicular to the center longitudinal axis of the frustoconical cup. FIG. 21 depicts the back seam side view of the frustoconical cup and blank of FIG. 20. Due to the frustoconical shape of the cup and the positioning of the ridges having no degrees of curvature, the angle of the striped expandable insulation material ridges is approximately 29.3\(^\circ\) F. on the left side of the cup and 60.7\(^\circ\) F. on the right side of the cup. The parallelograms of expandable insulating material disposed at the bottom of the cup can comprise stacking lugs and can facilitate stacking and/or securment of cups.

[0110]. FIG. 22-FIG. 23 depict another embodiment of the disclosed subject matter showing a blank juxtaposed with a frustoconical cup made from the blank. For purposes of illustration only, the blank is shown with only a first substrate and the second substrate is not shown in the figure. FIG. 22 shows a front view of the blank and corresponding cup and FIG. 23 shows a back seam side view of the blank and corresponding cup of FIG. 22. As depicted, the expandable insulating material is disposed in ridges at an angle of approximately 45\(^\circ\) F, with respect the center longitudinal axis of the frustoconical cup and disposed at a substantially constant radius of curvature of approximately 17.13 inches. The substantially constant curve line can be generated and manipulated based on an involute curve of the blank. The involute curve can in turn be used to design a curve on the top of the teeth for the machine gears of the apparatus manufacturing the blank and corresponding article. For purposes of example, in manufacturing a 16 ounce cup according to an embodiment of the disclosed subject matter, the expansion cell curve line of the blank can have an increment of approximately 0.26 inch in the radius, every time the angle turns approximately 0.784\(^\circ\) F. However, the increment can have any suitable range dimension depending on the blank and article being manufactured, as different size articles and blanks can have different angles and shapes which impact the specifications of the involute curves and any matching substantially constant curve lines.

[0111]. FIG. 23 depicts the back seam side view of the frustoconical cup and blank of FIG. 22. Due to the frustoconical shape of the cup and the degree of curvature of the ridges of expandable insulating material, the angle of the striped expandable insulation material ridges at the seam is still approximately 45\(^\circ\) F. Such embodiment can facilitate better aesthetic appearance than the embodiment of FIG. 20-21 and can increase strength for the cup.
FIG. 24 depicts another embodiment of the disclosed subject matter showing a blank, similar to the embodiment of FIGS. 22-23. The ridges of FIG. 24 are disposed at a predetermined radius of curvature, as shown.

FIGS. 25 and detail FIGS. 25A-25C depict another embodiment of the disclosed subject matter showing a cup made from a blank. The ridges of FIG. 25 are disposed at a predetermined radius of curvature, as shown. The cup is depicted after the application of energy to the cup such that the expandable insulating material has expanded to the second condition. As shown in the details FIGS. 25A-25C and along the side of cup of FIGS. 25A and 25B, adhesive has been disposed between the ridges of the insulating material such that the first and second substrate are coupled to each other at areas lacking the insulating material. According to the embodiment of FIG. 25, the cup has a rolled rim and there is no insulating material at the top of the cup, as apparent in detail A. The insulating ridges create a unique topography about the surface area of the sidewalls of the cup.

FIG. 26 demonstrates the insulation characteristics of the article of the disclosed subject matter of FIGS. 20-21, in comparison with an economy level cup and in comparison with an ultra premium cup. An example of an ultra premium cup can be found in the disclosure of U.S. Pat. No. 7,552,841, entitled "Reinforced plastic foam cup, method of and apparatus for manufacturing same", the contents of which is incorporated herein by reference in its entirety.

While the disclosed subject matter is described herein in terms of certain preferred embodiments, those skilled in the art will recognize that various modifications and improvements may be made to the disclosed subject matter without departing from the scope thereof. Moreover, although individual features of one embodiment of the disclosed subject matter may be discussed herein or shown in the drawings of the one embodiment and not in other embodiments, it should be apparent that individual features of one embodiment may be combined with one or more features of another embodiment or features from a plurality of embodiments.

In addition to the specific embodiments claimed below, the disclosed subject matter is also directed to other embodiments having any other possible combination of the dependent features claimed below and those disclosed above. As such, the particular features presented in the dependent claims and disclosed above can be combined with each other in other manners within the scope of the disclosed subject matter such that the disclosed subject matter should be recognized as also specifically directed to other embodiments having any other possible combinations. Thus, the foregoing description of specific embodiments of the disclosed subject matter has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosed subject matter to those embodiments disclosed.

It will be apparent to those skilled in the art that various modifications and variations can be made in the method and system of the disclosed subject matter without departing from the spirit or scope of the disclosed subject matter. Thus, it is intended that the disclosed subject matter include modifications and variations that are within the scope of the appended claims and their equivalents.

1. A method of making a multilayer article, comprising:
   providing a first substrate having an inner surface and an outer surface;
   providing a second substrate having an inner surface and an outer surface;
   disposing an expandable insulating material on the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material is in a first condition during disposing;
   adhering the second substrate to the first substrate with the expandable insulating material therebetween to form a blank, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein and the insulating space includes a first volume;
   forming the blank into the article; and
   expanding the expandable insulating material of the article to a second condition by application of energy, wherein the expandable insulating material in the second condition increases the insulating space to a second volume.

2. The method of claim 1, wherein the disposing includes printing the expandable insulating material in a pattern on the inner surface of the first substrate.

3. The method of claim 1, wherein the disposing includes printing the expandable insulating material on an interior region of the inner surface of the first substrate, wherein an outer margin of the inner surface of the first substrate remains free of the expandable insulating material.

4. The method of claim 1, wherein the adhering includes adhering the second substrate along the inner surface of the first substrate with an adhesive.

5. The method of claim 1, wherein the adhering includes coupling the first substrate to the second substrate with adhesive along surface areas of the first substrate and second substrate free of expandable insulating material.

6. The method of claim 1, further comprising coating the outer surface of the first substrate with a substance.

7. The method of claim 1, further comprising coating the outer surface of the second substrate with a substance.

8. The method of claim 1, wherein expanding the expandable insulating material of the article to a second condition with application of energy includes heating the article at approximately 400° F. to approximately 500° F. for a duration of at least approximately 30 seconds to approximately 60 seconds.

9. The method of claim 1, wherein the disposing comprises at least one of printing, coating, spraying, laminating, and extruding.

10. The method of claim 1, wherein the disposing the expandable insulating material includes disposing the expandable insulating material with a mesh screen ranging in dimension between approximately 60 Mesh and approximately 110 Mesh.

11. The method of claim 1, wherein the disposing the expandable insulating material includes disposing the expandable insulating material in a ridge at an angle of approximately 45° F. with respect to a center longitudinal axis of the article.

12. A multilayer article, comprising:
   a first substrate having an inner surface and an outer surface;
   a second substrate having an inner surface and an outer surface; and
   an expandable insulating material applied to the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material
includes a first condition at ambient temperature and a second condition upon application of energy, and wherein the second substrate is adhered to the first substrate with the expandable insulating material therebetween to form a blank, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein, the insulating space having a first volume when the expandable insulating material is in the first condition and the insulating space having a second volume when the expandable insulating material is in the second condition.

13. The article of claim 12, wherein the expandable insulating material includes an expandable material.

14. The article of claim 13, wherein the expandable material includes microspheres.

15. The article of claim 13, wherein the expandable insulating material further includes additives and is free of adhesive.

16. The article of claim 12, wherein the expandable insulating material is in the second condition upon the application of energy between approximately 40°F and approximately 500°F and remains in the second condition thereafter.

17. The article of claim 12, wherein the second substrate is adhered to the first substrate by adhesive.

18. The structure of claim 12, wherein the article includes a total heat flux of approximately 1900 W/m².

19. The article of claim 12, wherein the article transfers approximately between approximately 70% and approximately 80% of heat energy.

20. The article of claim 12, wherein the article has a stiffness deflection that ranges from approximately 0.35 lbs. force to 1.2 lbs. force.

21. An insulating cup, comprising:
   a sidewall defining a top opening and a bottom portion, the sidewall including a multilayer article having:
   a first substrate having inner surface and an outer surface,
   a second substrate having inner surface and an outer surface, and
   an expandable insulating material applied to the inner surface of at least one of the first substrate and the second substrate, wherein the expandable insulating material includes a first condition at ambient temperature and a second condition upon application of energy, and wherein the second substrate is adhered to the first substrate with the expandable insulating material therebetween, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therewith, wherein an insulating space is defined between the first substrate and the second substrate with the expandable insulating material therein; and
   a base coupled to the bottom portion of the sidewall when the expandable insulating material is in the first condition.

22. The insulating cup of claim 21, wherein the insulating space has a first volume when the expandable insulating material is in the first condition and the insulating space has a second volume when the expandable insulating material is in the second condition, the expandable insulating material being expanded to the second condition after forming the cup.

23. The insulating cup of claim 21, wherein the sidewall further comprises a rolled top portion to define a rim about the top opening.

24. The insulating cup of claim 23, wherein the rim is disposed above a top edge of the second substrate of the structure.

25. The insulating cup of claim 21, wherein the base comprises a skirt to define a surface-engaging edge with the sidewall.

26. The insulating cup of claim 21, wherein the expandable insulating material is applied to the inner surface of at least one of the first substrate and the second substrate in a ridge at an angle of approximately 45° F with respect a center longitudinal axis of the cup.

27. The insulating cup of claim 21, wherein the expandable insulating material is applied to the inner surface of at least one of the first substrate and the second substrate at a density corresponding to a mesh screen size dimension ranging between approximately 60 Mesh and approximately 110 Mesh.

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