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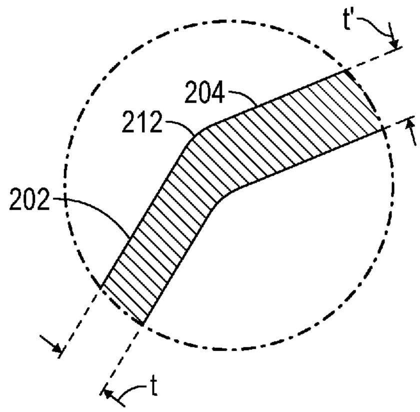

FIG. 2A

(57) **Abstract:** A passive skylight dome and method of making the dome. The dome is unitarily formed from a diffusive material. The dome has a plurality of sides each with an average thickness, a roof limit, and a top limit. The roof limits collectively, when installed, circumscribe a roof opening. The top limit defines a top perimeter. The dome has a top portion extending from the top perimeter, the top portion having an average thickness 10% to 60% thicker than the average thickness of the sides. The projected area onto the plane of the portion of the dome where the incidence angle onto the dome of 90-degree sun elevation angle light is greater than or equal to 55° exceeds half of the projected area onto the plane of the entire dome.

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PASSIVE SKYLIGHT

FIELD OF THE INVENTION

Embodiments of the invention relate to passive skylights. More specifically, embodiments relate to passive skylight domes having favorable critical ratios and method of making such domes.

BACKGROUND

In the skylight industry there has been an ongoing pursuit of inexpensive skylights that provide more consistent lighting through the day. To accomplish this goal, it is necessary that the skylight efficiently capture early morning and late afternoon sunlight when the sun elevation angle is quite low and inhibit the capture of midday sunlight when the sun elevation angle is high. Various active systems have been proposed to address this issue often requiring expensive mechanical parts that increase not only the cost of original fabrication and installation but also ongoing maintenance. Some attempts have also been made in passive skylights to mitigate the intensity of high elevation angle sunlight. However, a cost effective passive dome that both increases the amount of low elevation light captured and mitigates high elevation light capture has remained elusive.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that different references to "an" or "one" embodiment in this disclosure are not necessarily to the same embodiment, and such references mean at least one.

FIG. 1 is a perspective view of a skylight dome according to one embodiment of the invention.

FIG. 1A is a cross section of the dome of **Figure 1** showing relative thickness of a side and the top portion.

FIG. IB is a plan view of one side of the embodiment of **Figure 1**.

FIG. 2 is a perspective view of a skylight dome according to a second embodiment of the invention.

FIG. 2A is a cross section of the dome of **Figure 2** showing relative thickness of a side and the top portion.

Fig. 2B is a plan view of one side of the embodiment of **Figure 2.**

FIG. 3 is a perspective view of a skylight dome according to a third embodiment of the invention.

FIG. 3A is a plan view of one side of the embodiment of **Figure** 3.

FIGs. 4A and 4B are schematic side and top plan views, respectively, of a dome of one embodiment of the invention.

FIG. 5 is a schematic view of a manufacturing process according to one embodiment of the invention.

FIG. 6 is a flow diagram of a manufacturing process according to one embodiment of the invention.

FIG. 7 is a flow diagram of a manufacturing process according to a second embodiment of the invention.

FIG. 8 is an exploded view of a dome of one embodiment of the invention made in accordance with the process of **Figure** 7.

DETAILED DESCRIPTION

Several embodiments of the invention with reference to the appended drawings are now explained. Whenever the shapes, relative positions and other aspects of the parts described in the embodiments are not clearly defined, the scope of the invention is not limited only to the parts shown, which are meant merely for the purpose of illustration.

Various embodiments of the invention described below provide a cost effective passive skylight dome with a significantly enhanced critical ration when compared to traditional passive skylight domes. As used herein, “critical ratio” refers to the ratio of light captured at the beginning and end of the day relative to the light captured at midday. In general, the higher the critical ratio the more consistent the lighting provided by the skylight dome.

FIG. 1 is a perspective view of a skylight dome according to one embodiment of the invention. Skylight domes are typically installed over openings in roofs of buildings to provide natural interior lighting. The installation of domes is a well understood practice and does not form a part of the invention claimed herein. Dome 100 is formed from a unitary sheet of synthetic diffusive material. In some embodiments, the sheet has a nominal thickness in the range of 5mm to 7 mm prior to being formed into the domelOO. Typical acrylics with coloration to increase the light diffusion over clear acrylic have been found suitable. Some embodiments use Acrylite® OD010-DF available from Evonik Cryo LLC of Parsippany NJ or Plaskolite® 2067 available from **Plaskolite Inc of Columbus, OH** other similar martials may be used. Acrylite® OD010-DF has a half angle of 20° at a nominal thickness of 2 mm. As used herein, "half angle" is defined as the angle having half the light intensity of a collimated beam shone through a sample perpendicular to the light source. Half angles greater than 10° at a nominal thickness of 2mm have be found useful of embodiment of the invention.

The dome 100 has a plurality of steeply sloping sides 102-1, 102-2... 102-η (generically 102). While four sides are shown, domes with more sides e.g. 6, 8, or 10 are also contemplated. Each side has a roof limit 122 and a top limit 112. As used herein, "limit" is synonymous with "edge" however, in the context of real world manufacturing, the limit will tend to be a smooth arcing transition rather than a hard edge. Roof limit 122 transitions into a flange 106 that continues around the lower periphery of the base of the dome. As used herein, "base" refers to the portion of the dome above the flange and below the top portion. In this embodiment the base has a gross geometry of a frustum. While a four sided frustum is shown, other shaped frustums including without limitation hexagonal frustums and octagonal frustums are contemplated as other embodiments of the invention. The flange 106 provides the attachment mechanism to allow the dome 100 to be coupled to a roof during installation. Generally, the flange 106 reside in a plane (horizontal when resting on a horizontal surface).

The upper limit 112 of sides 102 transitions into a top portion 104 of the dome 102. In this embodiment, the top portion 104 is substantially planar and parallel to the plane defined by the flange 106. Top portion 104 is on average thicker than the sides 102 and made of the same material. The increased thickness reduces the transmissiveness of the top portion 104 relative to the sides 102. In some embodiments, a transmissiveness reducing material is further applied to the top portionl04 to further reduce the transmissiveness of the top portion 104 relative to the sides. This transimissiveness reducing material 110 may be in the form of a paint on or spray on coating or for example an adhesive film or decal. It may be applied to all or only part of the top portion. White paint and aluminum or other specularly reflecting films have been found effective. Other types of coatings or films that reduce the light transmitted are deemed within the scope and contemplation of the invention.

FIG. 1A is a cross section of the dome of Figure 1 showing relative thickness of a side and the top portion. Sides 102 have an average thickness t. In some embodiments, t is in the range of 3 to 5 mm. Top portion 104 has an average thickness t' that is in the range of 10% to 60% thicker than t. In one embodiment, t' is approximately l.3t.

FIG. IB is a plan view of one side of the embodiment of figure 1. Side 102-1 is visible, while sides 102-2 and 102-4 would extend into the page. In this embodiment, top portion 104 is substantially planar and parallel to the plane defined by the flange 106. The sides 102 each define an angle Θrelative to the plane (defined by the flange 106). The angle Θ is preferably in the range of 55° to 76°. Thus, the intersection of the side 102 with the top portion 104 defines an angle of 180°- Θ. The relative steepness of the sidesl02 causes low elevation angle sunlight to strike the sides 102 with a small incidence angle resulting in most of that light being transmitted into the dome. Conversely high elevation angle sun light strikes the sides with a much higher incidence angle causing less of that light to be transmitted into the dome. Furthermore, the increased thickness t' of the top portion reduces the high elevation light transmitted there through.

FIG. 2 is a perspective view of a skylight dome according to a second embodiment of the invention. The dome 200 is again formed from a unitary sheet of diffusive synthetic material. The same material as discussed relative to Figure 1 are used. The dome 200 has a plurality of steeply sloping sides 202-1, 202-2. .. 202-n (generically 102). Each side has a roof limit 222 and a top limit 212. The sides 202 transition into a top portion 204 at the top limit 212. In this embodiment, top portion 204 is substantially pyramidal. By appropriately selecting the slope of the top accumulation of condensation on the inside of the top portion 204 can be avoided. Accumulation of condensation can negatively affect the optical properties of a planar topped dome.

Other than the difference in gross geometry of the top portion 204 this embodiment is like that of Figure 1. Again, the top portion 204 has an average thickness greater than an average thickness of the sides 202. Similarly, materials may be added to reduce the transmissiveness of some or all of the top portion 204.

FIG. 2A is a cross section of the dome of Figure 2 showing relative thickness of a side and the top portion. Sides 202 have an average thickness t. In some embodiments, t is in the range of 3 to 5 mm. Top portion 204 has an average thickness t' that is in the range of 10% to 60% thicker than t. In one embodiment, t' is approximately 1.3t.

FIG. 2B is a plan view of one side of the embodiment of figure 2. Side 202-1 is visible, while sides 202-2 and 202-4 would extend into the page. In this embodiment, top portion 204 slopes relative to the plane through the top limit 212 which is parallel to the plane defined by the flange 206. The sloping panels of top portion 204 define an angle ϕ off the plane through the top limit 212. The angle ϕ is preferably greater than 25°. The sides 202 each define an angle Θrelative to the plane (defined by the flange 106). The angle Θagain is preferably in the range of 55° to 76°. The optical properties are analogous to those described with reference to Figure 1B. The pyramidal top portion 204 does not meaningfully impact light transmission relative to a flat top.

FIG. 3 is a perspective view of a skylight dome according to a third embodiment of the invention. Dome 300 is again formed from a unitary sheet of synthetic diffusive material. The embodiment of figure 3 differs from the embodiment of figure 2 in that the sides 302-1, 302-2 …302-n (generically 302) have a discontinuous slope. In this example, sides 302 still have a roof limit 322 and a top limit 312. But each side is made up of a plurality of subpanels 314 and 316. While in this example each side is formed of two subpanels 314, 316, other embodiments may have each side formed of more subpanels. As shown subpanel 314 has a steeper slope than subpanel 316. The side 302 has two distinct slopes between the roof limit 322 and the top limit 312. Other embodiments may for example have a continuously varying slope between the limits. However, while the slope at between points on the side can vary, the side 302 should be formed such that the projection onto the plane of the portion of the dome where the incidence angle onto the dome of 90-degree sun elevation angle light exceeds 55° is greater than half the projected area onto the plane of the entire dome. This is explained further in connection with figures 4A and 4B below.

FIG. 3A is a plan view of one side of the embodiment of **Figure 3**. Side 302 has subpanels 314, 316. The subpanels 314 each define an angle Θrelative to the plane and subpanel 316 defines an angle Ω relative to the plane (defined by the flange 106). The angle Θand Ω are both preferably in the range of 55° to 76° with Θ>Ω. In this embodiment, top portion 304 slopes relative to the plane through the top limit 312 of side 302, which is parallel to the plane defined by the flange 306. The base has a gross geometry of a first frustum stacked on a second frustum. The top portion 304 has the gross geometry of a pyramid. Other embodiments may have a flat top portion, or the top portion may have some arcuate shape. The sloping panels of top portion 304 define an angle ϕ off the plane through the top limit 312. The angle ϕ is preferably greater than 25°. The cross section at the upper limit 312 would be similar to that shown in figure 2A with the top portion 304 having an average thickness t' and the sides 302 having an average thickness t, where t' is l0%-60% greater than t.

FIGs. **4A and 4B** are schematic side and top plan views, respectively, of a dome of one embodiment of the invention. For ease of discussion we will assume the dome in on a horizontal surface. For the proper functioning of embodiments of the invention one parameter is particularly important, that is the ratio of a) the projected area onto the plane of the part of the dome where the incidence angle is greater than or equal to 55° to b) the projected area onto the plane of the part of the dome where it is not, based on a sun elevation angle of 90°; that is for vertically directed sunlight. That ratio should exceed 0.5. In figure 4A, the side 402 is trapezoidal with a bottom of length b_2 and a top of length bi. Then the total projected area of the dome in the horizontal plane is A=b2xb2. The projected area of the top portion 404 in the horizontal plane is A_t=bixbi. Accordingly, the projected area of the sides 402-1, 402-2, 402-3 and 402-4 is given by A_S=A-A_t. Incidence angle p is given by 90°-angle off the vertical at which the side slopes. For example, a planar side with 0=75° slopes 15° off the vertical and would have an incidence angle equal to 90º-l5°=75°. For a planar side with a uniform slope the incidence angle will be the same for all points on the side. If for all points on the side 402 the incidence angle p of vertical light (again assuming the dome is on a horizontal surface) is greater than or equal to 55° and $A_s \geq 0.5A$ then the dome will have a high critical ratio and function properly. Some additional examples are illustrative.

For a dome with a 60"x60" base and height 39" with sides slanted at 26.44 degrees off the vertical with a flat top that is 21"x21", the projected area onto the plane of the part of the dome where the incidence angle of 90-degree sun elevation angle light onto the dome is greater than or equal to 55 degrees is 3600-21x21 =3159 square inches and 3159/3600 = 88% of the projected area onto the plane of the entire dome.

For a dome with a 60"x60" base and 39" tall with sides slanted at 21 degrees off the vertical and a flat top that is 30"x30", the projected area onto the plane of the part of the dome where the incidence angle of 90-degree sun elevation angle light onto the dome is greater than or equal to 55 degrees is 3600-900 = 2700 square inches and 2700/3600 = 75% of the projected area onto the plane of the entire dome.

For a dome with a 60"x60" base and 39" tall with sides slanted at 17 degrees off the vertical and a flat top that is 36"x36", the projected area onto the plane of the part of the dome where the incidence angle of 90-degree sun elevation angle light onto the dome is greater than or equal to 55 degrees is 3600-1296 = 2304 square inches and 2304/3600 = 64% of the projected area onto the plane of the entire dome.

For a dome with a 60"x60" base and 39" tall with sides slanted at 14 degrees off the vertical and a flat top that is 40"x40", the projected area onto the dome of the part of the dome where the incidence angle of 90-degree sun elevation angle light onto the dome is greater than or equal to 55 degrees is 3600-1600 = 2000 square inches and 2000/3600 = 56% of the projected area onto the plane of the entire dome.

All of these examples presume a square pyramidal shape, but the invention is no so limited, it should be understood that rectangular pyramids e.g. where the length and width are not the same as well as other shaped frustums may also be used. It is important to maintain in the various embodiments a ratio that exceeds .5 of a) the projected area onto the plane of the portion of the dome where the incidence angle is greater than 55° for 90-degree sun elevation angle to b) the projected area onto the plane of the entire dome. While the simple formula for continuously sloping sides is set forth above, the more general case which applies even for sides with discontinuous slopes, requires that the projected area of the portion of the sides where the incidence angle is not greater than or equal to 55° be subtracted from the total. Thus, in such cases, $A_s = A_{s>55} + A_{s<55}$ for proper functioning of the dome $A_{s>55} \geq 0.5A$.

Figure 5 is a schematic view of a manufacturing process according to one embodiment of the invention. A sheet 502 of diffusive synthetic material, e.g colored acrylic is clamped into a frame 506. The sheet 502 is selected to provide the desired ultimate perimeter dimension of the dome. For example, if a 60”x60” dome is desired a 66”x66” sheet 502 of material may be used. The extra material beyond the dome dimensions is clamped into the frame and forms the flange (e.g. 106, 206, 306 from Figures 1, 2 and 3 respectively). As another example, if a 50”x70” rectangular dome is desired, a sheet 502 having dimensions 56”x76” may be used.

Once clamped into the frame 506, sheet 502 is heated into the plastic state of the material used. Generally, the center of the sheet 502 will begin to sag under the influence of gravity. “Plastic state” as used herein refers to the state of a material where the material can be deformed within a range without either breaking or returning to its original shape once the deformation force is removed. Heating may be done in an oven, kiln or any other appropriate way that will heat the entire sheet 502.

Once appropriately heated, the sheet is held in a substantially horizontal plane and a tool 520 is advanced vertically into contact with the sheet 502. In one embodiment the tool 520 is a frame model made of tube steel, the frame model has the desired gross geometry of the finished dome. Steel provide a durable structure with efficient heat sink characteristics, but other heat conductive materials could be used to form the tool 520. The portion of the tool 520 corresponding to the top portion of the finished dome is initially advanced into the sheet 502. The thermodynamic interaction between the tool acting as a heat sink and the top portion causes that portion of the sheet 502 to leave the plastic state and return to a rigid state. “Rigid state” as used herein refers to a state where the material is no longer subject to meaningful plastic deformation. Once the top portion has returned to the rigid state, the tool 520 is advanced fully with in the frame forming the sides of the dome by plastic deformation of the remaining part of the sheet 502 that remains in a plastic state. As the tool 520 advances it acts as a heat sink for the portion of the sheet it contacts. Once the entire sheet 502 has returned to a rigid state from the plastic state, the tool is removed and the dome has been fully formed.

FIG. 6 is a flow diagram of a manufacturing process according to one embodiment of the invention. At block 602, a sheet of diffusive synthetic material is clamped into a frame. The size of the sheet and the dimensions of the frame are selected based on the dimensions of the dome desired. Generally 3” of the sheet will be clamped into the frame and will be used for a flange around the base of the dome created. At block 604, the sheet is then heated until it enters the plastic state of the material being used. Generally, it is desirable to maintain the sheet in a horizontal orientation both during and after heating. The sheet will sag in the center when in the plastic state.

At block 606, the sheet in the plastic state is position under a tool having the desired gross geometry of the finished dome and the tool is advanced into the sheet until the portion of the tool representing the entire top portion is in contact with the sheet. As used herein "advancement" of the tool refers to relative motion between the tool and the sheet. Thus, the tool is deemed advance if it moves and the sheet remains stationary or if the sheet moves and the tool remains stationary. The tool is preferably maintained at ambient temperature, which is below the temperature of the heated sheet. The top portion is then allowed to cool at block 608. The cooling is facilitated by a local heat sink function of the tool and may occur quite rapidly where the tool contacts the sheet. This cooling takes the top portion out of the plastic state and fixes the thickness of the top portion. Additionally, the sheet tends to adhere to the tool at the point of contact similar to a pressure adhesive. This adhesion eliminates or substantially eliminates stretching forces on the parts of the top portion more remote from contact with the tool even if they have not fully achieved a rigid before the tool advances further to form the base. For a flat top, the thickness will be generally be on the order of 60% of the nominal thickness of the sheet - this is a result of the sagging of the heated material prior to introduction of the tool. For e.g. a pyramidal top there will be some elongation of the material, but the final thickness will still be quite close to approximately 60% of the nominal thickness of the original sheet as the additional stretching to form the pyramid is small compared to the original sag.

Once the top has returned to a rigid state, at block 610, the tool is advanced into the sheet to form the base. The advancement caused the material that forms the sides to stretch and elongate becoming thinner in the process. The average thickness of the sides is a function of the height of the dome and the original thickness of the sheet. This generally results in an average thickness l0%-60% less than the original thickness of the sheet. Once the tool is flush with the frame the desired base dimension has been formed. At that point the base portion of the dome is fully in contact with the tool and is allowed to cool at block 612.

FIG. 7 is a flow diagram of a manufacturing process according to a second embodiment of the invention. In this process, a sheet of diffusive synthetic material is clamped and heated as describe with reference to figure 6. Then, at block 702, a base tool is advanced into the clamp heated sheet. The sheet is then cooled at block 704 to form a prebase. The base tool has the gross geometry of the desired base and may be constructed as described above. At block 706, the top of the prebase is cut off to form the base. Cutting may be perform using a laser, precision saw or the like. In the case of acrylic, laser cutting is particularly efficient as acrylic vaporizes when exposed to the appropriate laser energy and allows for a high precision cut. At block 708, the top portion is formed by advancing a top tool into a second heated clamped sheet and cooling the sheet. The second sheet may be the same thickness or be thicker than the first sheet. The sheet could also have a different level of inherent diffusiveness than the sheet from which the base was formed. In some cases, the sheet forming the top portion could be transparent. In other cases, it may have greater innate diffusiveness than the base. Top tool has the gross geometry of the desired top and operates on the same thermodynamic principles as described with reference to Figures 5 and 6. At block 710, the top portion is cut to fit the base. This cutting removes the residual flange from the clamping and ensure the top portion and base will match. Again, this can be performed using a laser or other precision cutting mechanism. At block 712, the top portion is attached to the base to form the final dome. Attachment may be by way of adhesive connection, fusing, heat welding or the like. Notably, the base and top portion may be formed in parallel and then brought together for final assembly. Similarly, a large stock of the sub elements may be produced serially (or in parallel) and then final assembly performs subsequently on that stock.

FIG. 8 is an exploded view of a dome of one embodiment of the invention made in accordance with the process of Figure 7. As described above the dome 800 is formed in two parts: a top portion 804 and a base having sides 802 and flange 806. Sides 802 have a slope of the flange plane in the range of 55° to 76°. Because dome is manufactured in two parts there are fewer constraints on the gross geometry of the top portion. To avoid condensation accumulation, it is desirable for the top portion 804 to have a slope of at least 25° but embodiments of the invention may have slopes up to the slope of the sides 802. It is also within the scope of the invention for the top portion 804 to be planar or have a slope of less than 25°. In the case of a planar top portion 804, it could be cut directly from an acrylic sheet without the heating and forming discussed above. Additionally, the top portion can be formed from synthetic material having different transmissveness. For example, the top portion 804 could be formed from transparent acrylic or acrylic having a greater diffusiveness than the base 802. Regardless of the top configuration, the finished dome should meet the projected area requirements explained with reference to Figures 4A and 4B above.

In the foregoing specification, the embodiments of the invention have been described with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes can be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

CLAIMS

What is claimed is:

1. A passive skylight comprising:

a unitarily formed dome of diffusive material, the dome having a plurality of sides, each side of the plurality having an average thickness, a roof limit, and a top limit, wherein the roof limits collectively, when installed, circumscribe a roof opening having a first area in a plane and wherein the top limits define a top perimeter;

the dome having a top portion extending from the top perimeter, the top portion having an average thickness 10% to 60% thicker than the average thickness of the sides;

wherein the projected area onto the plane of the portion of the dome where the incidence angle onto the dome of 90-degree sun elevation angle light is greater than or equal to 55° exceeds half of the projected area onto the plane of the entire dome.

2. The passive skylight of claim 1 further comprising:

a material on at least a region of the top portion that reduces transmissiveness of the top portion.

3. The passive skylight of claim 1 wherein the sides are each substantially planar and each have a substantially uniform slope in the range of 55-76 degrees off the plane.

4. The passive skylight of claim 1 wherein the top portion is substantially planar.

5. The passive skylight of claim 1 wherein the top portion is pyramidal with sides sloping greater than 21 degrees and less than 55 degrees off the plane.

6. The passive skylight of claim 1 wherein the diffusive material has a half-value angle greater than 10 degrees at 2 mm nominal thickness.

7. The passive skylight of claim 1 wherein the dome further comprises a flange circumscribing the roof limit.

8. A passive skylight comprising:

a base portion having a gross geometry of a frustum with having a plurality of sides, each side of the plurality having an average thickness, a roof limit, and a top limit, wherein the roof edges collectively, when installed, circumscribe a roof opening having a first area in a plane and wherein the top edges define a top perimeter; and

a top portion formed separately from the base portion and having and average thickness greater than the average thickness of the base portion, the top portion coupled to the base portion along the top edges;

wherein projected area onto the plane of the portion of the dome where the incidence angle of 90-sun elevation angle light onto the dome is greater than or equal to 55° exceeds half of the projected area onto the plane of the entire dome.

9. The passive skylight of claim 8 wherein the average thickness of the top portion is in the range of l0%-60% thicker than the average thickness of the base.

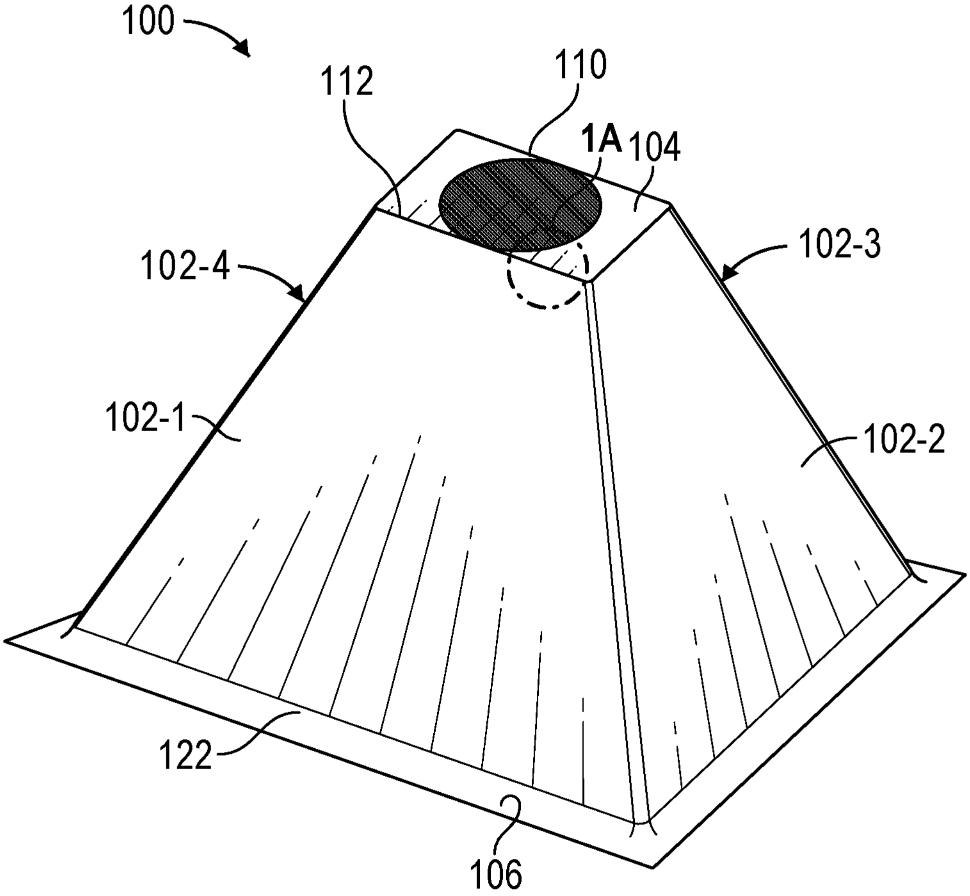


FIG. 1

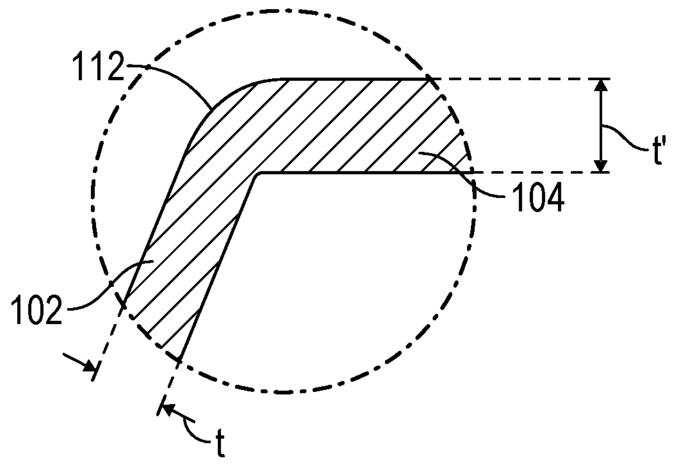
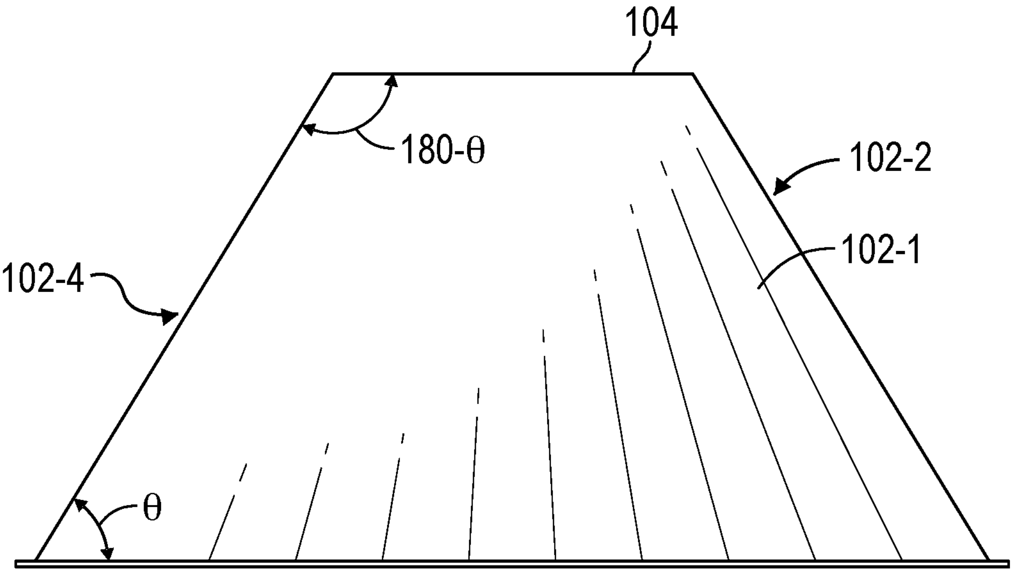


FIG. 1A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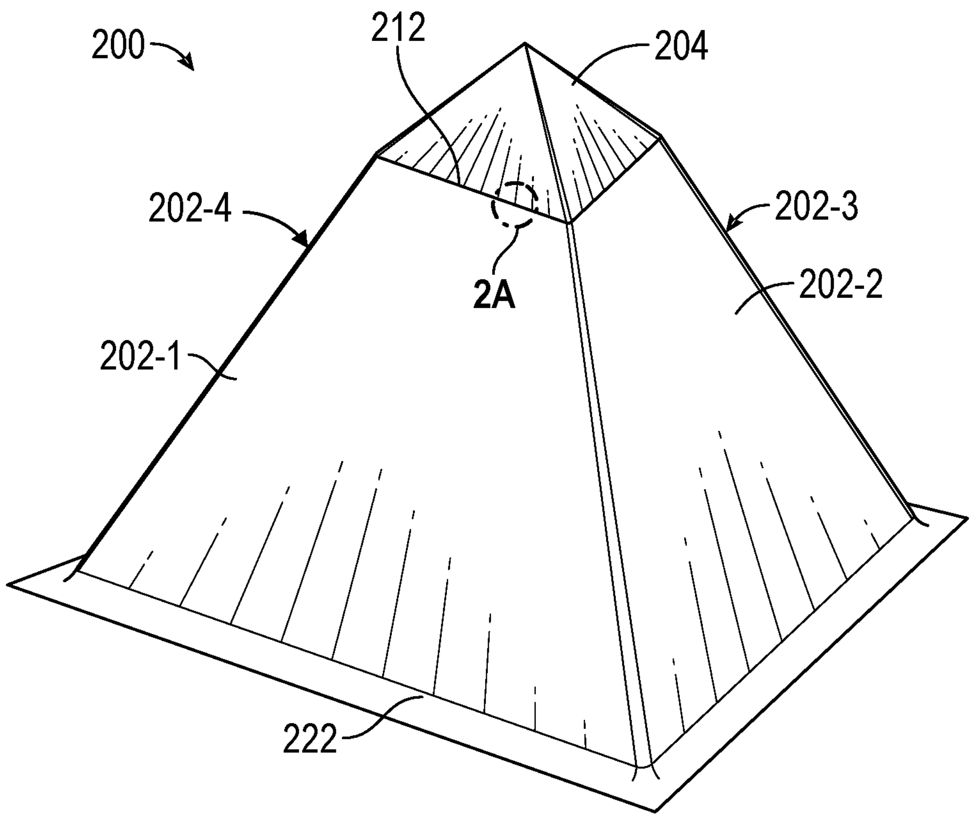
180-θ
102-2
102-1
102-4
θ

FIG. 1B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202-4
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2A
202-2
202-1
222

FIG. 2

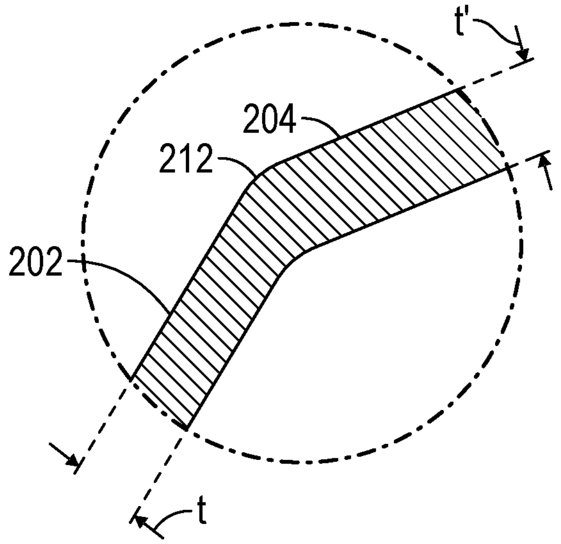

FIG. 2A

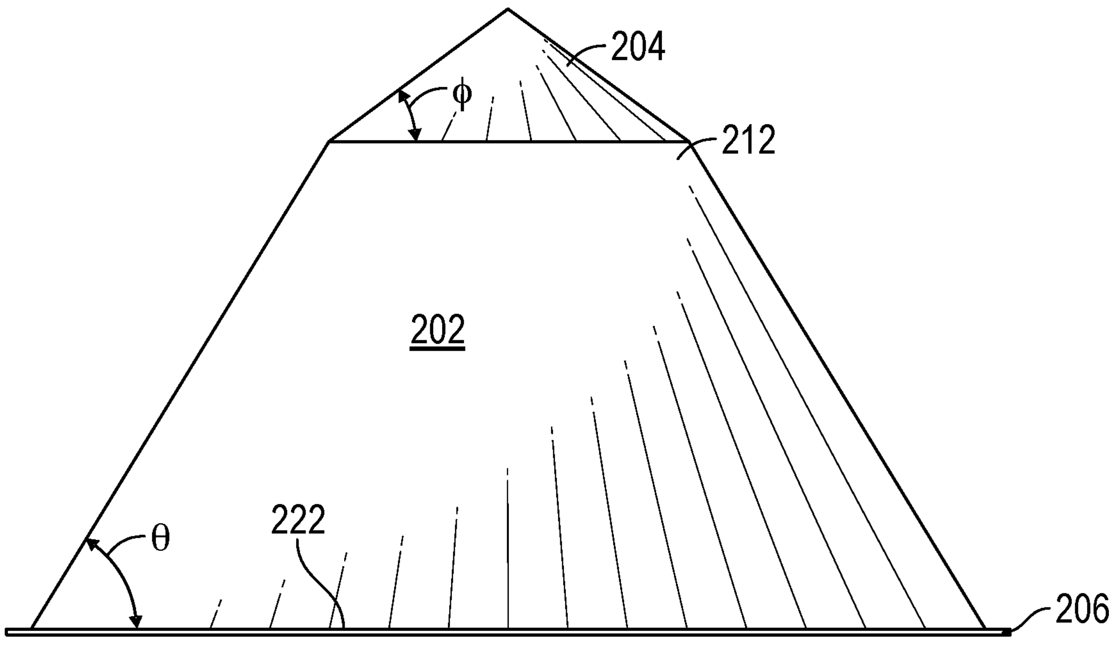

FIG. 2B

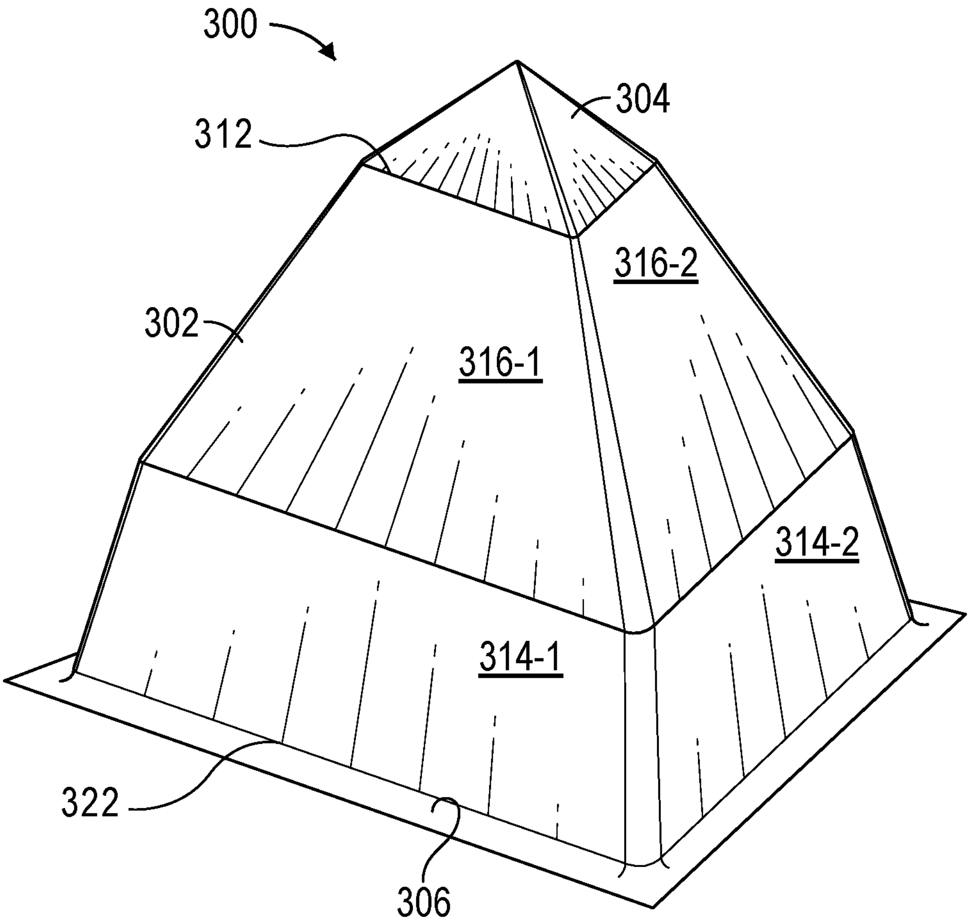

FIG. 3

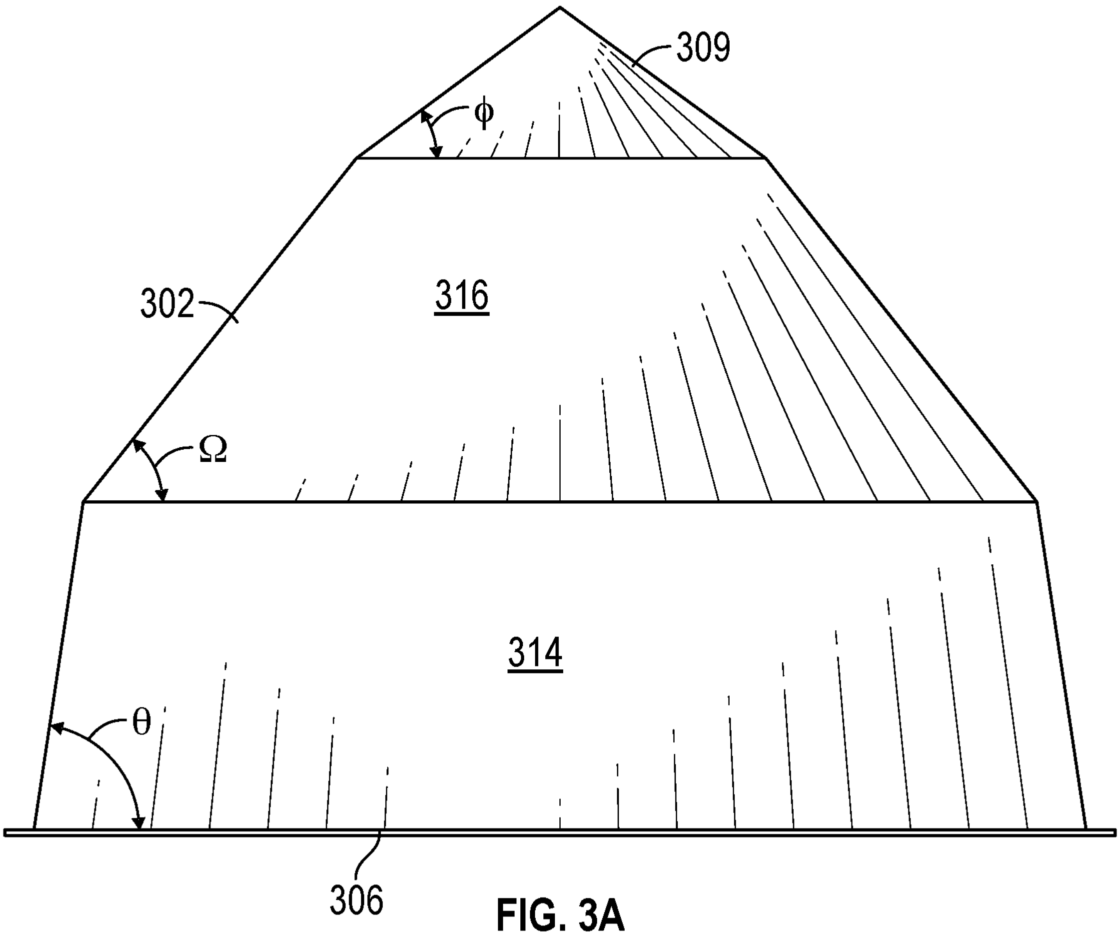

FIG. 3A

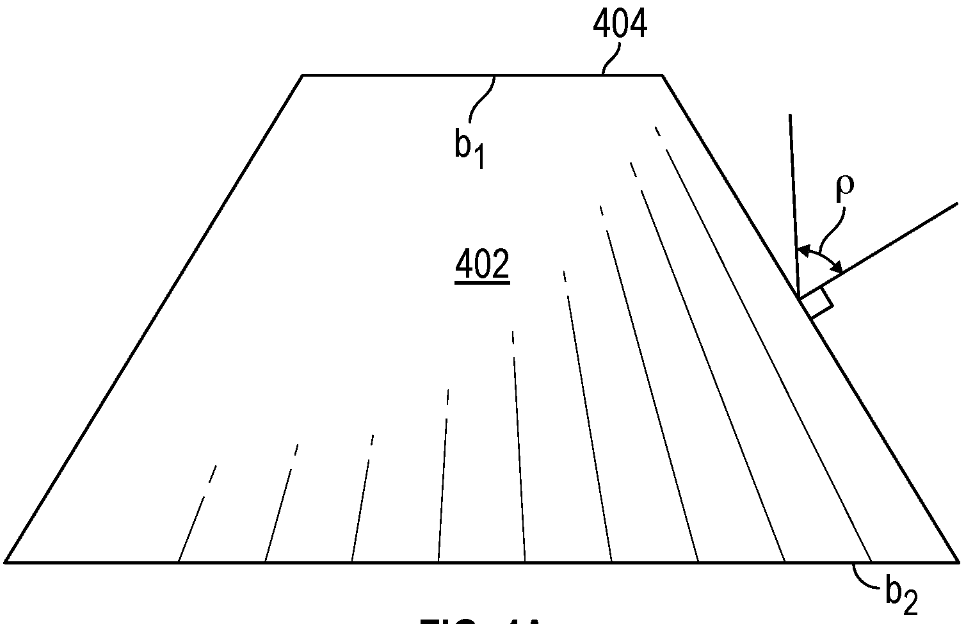

FIG. 4A

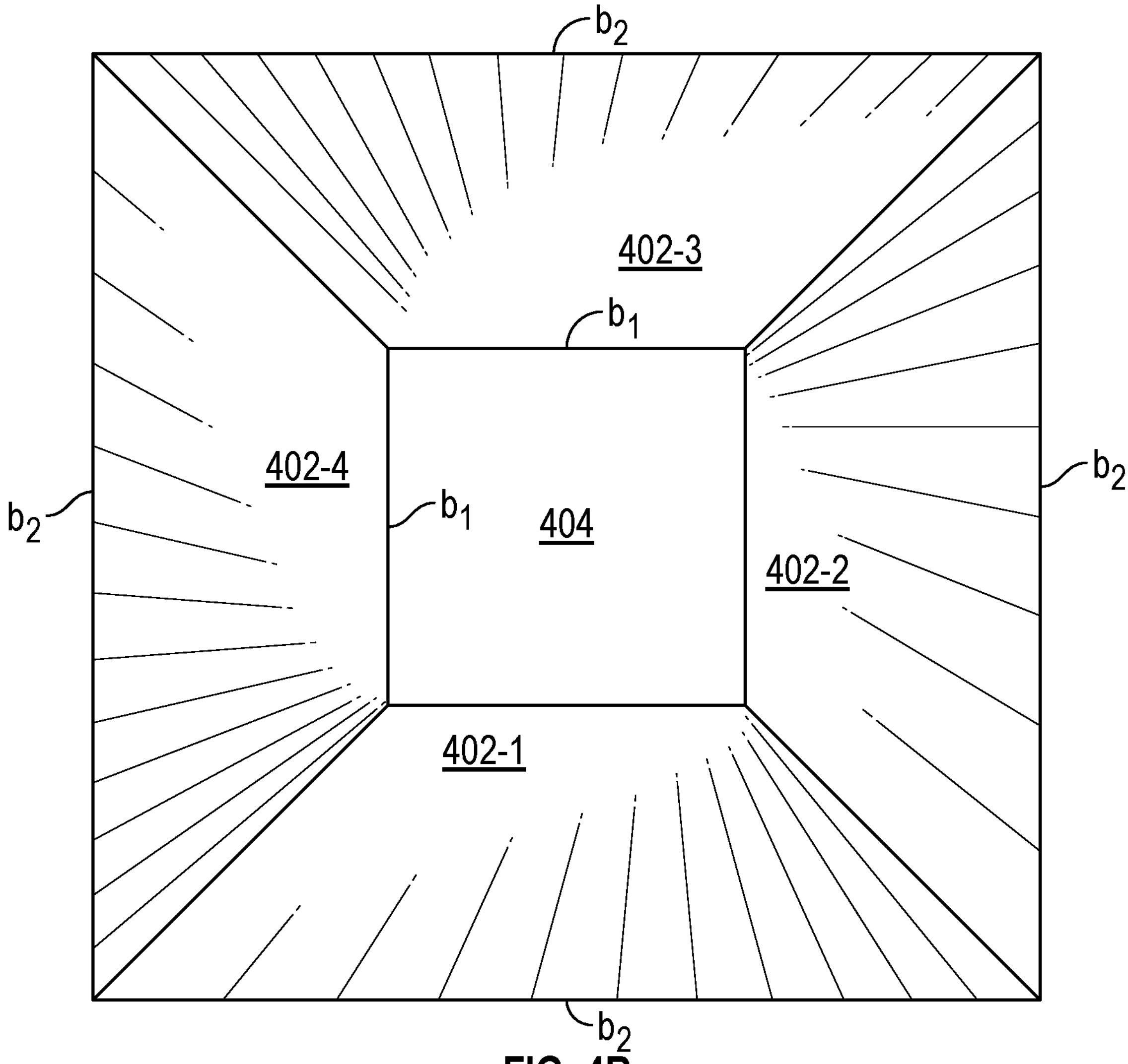

FIG. 4B

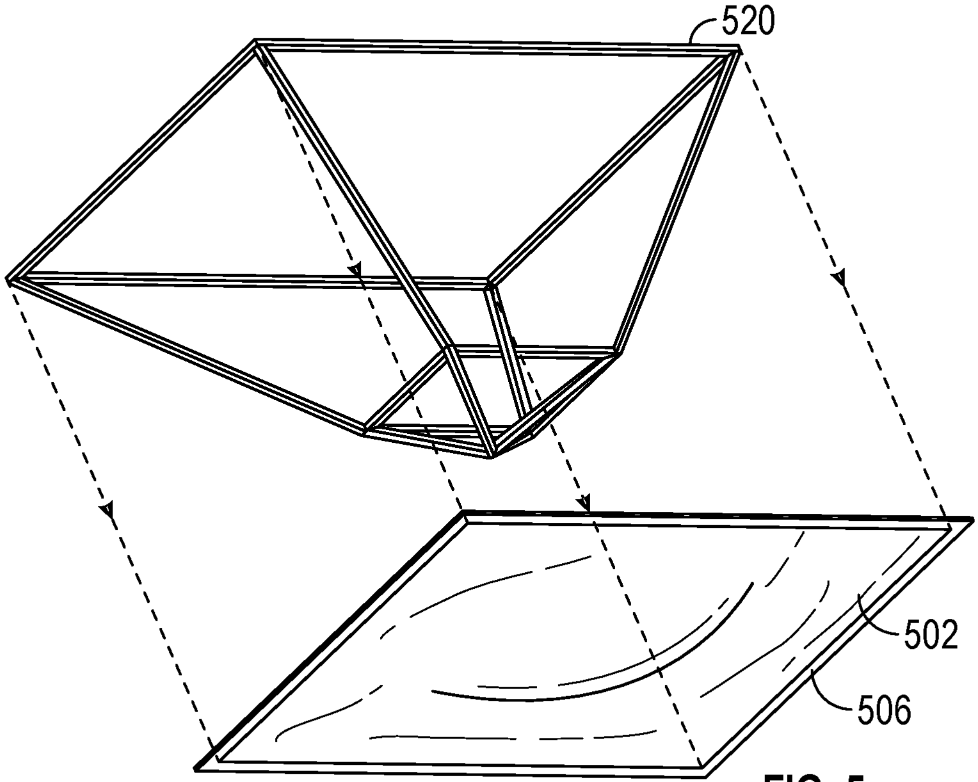

FIG. 5

Start

602 Clamp sheet in frame

604 Heat sheet to SAG temp

606 Advance top portion of tool into sheet

608 Allow top portion to cool

610 Advance tool into sheet to form base

612 Allow to cool

614 Remove tool

End

FIG. 6

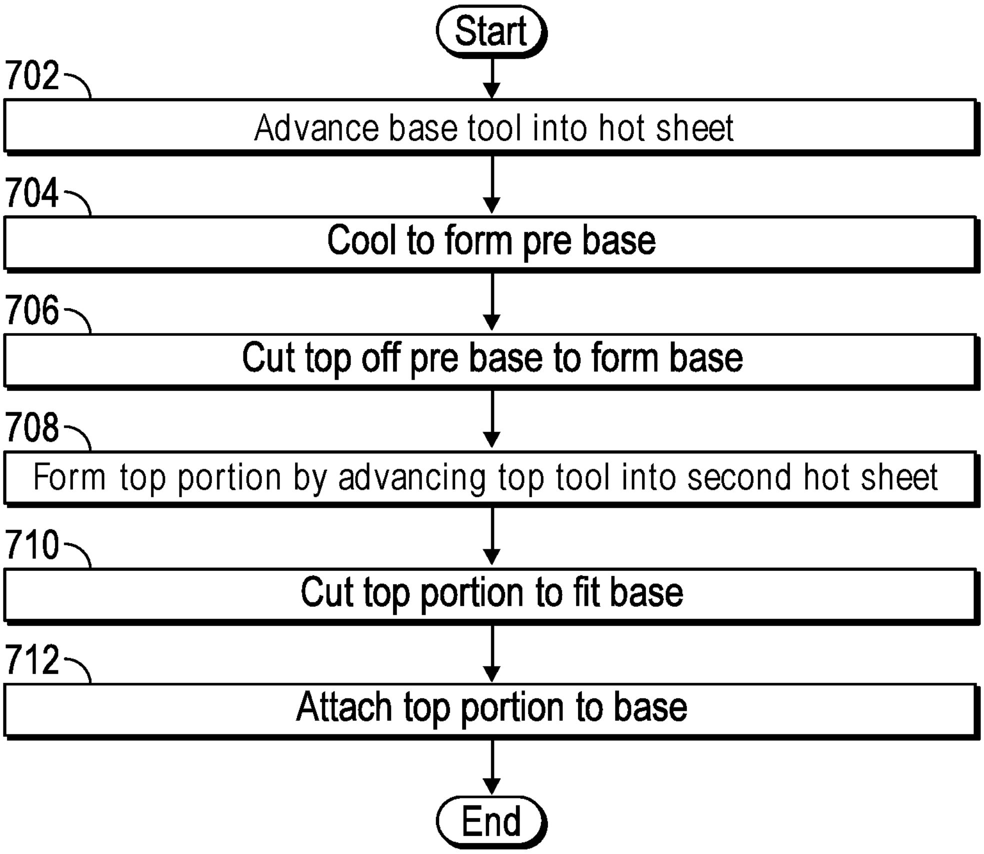
Start
702
Advance base tool into hot sheet
704
Cool to form pre base
706
Cut top off pre base to form base
708
Form top portion by advancing top tool into second hot sheet
710
Cut top portion to fit base
712
Attach top portion to base
End

FIG. 7

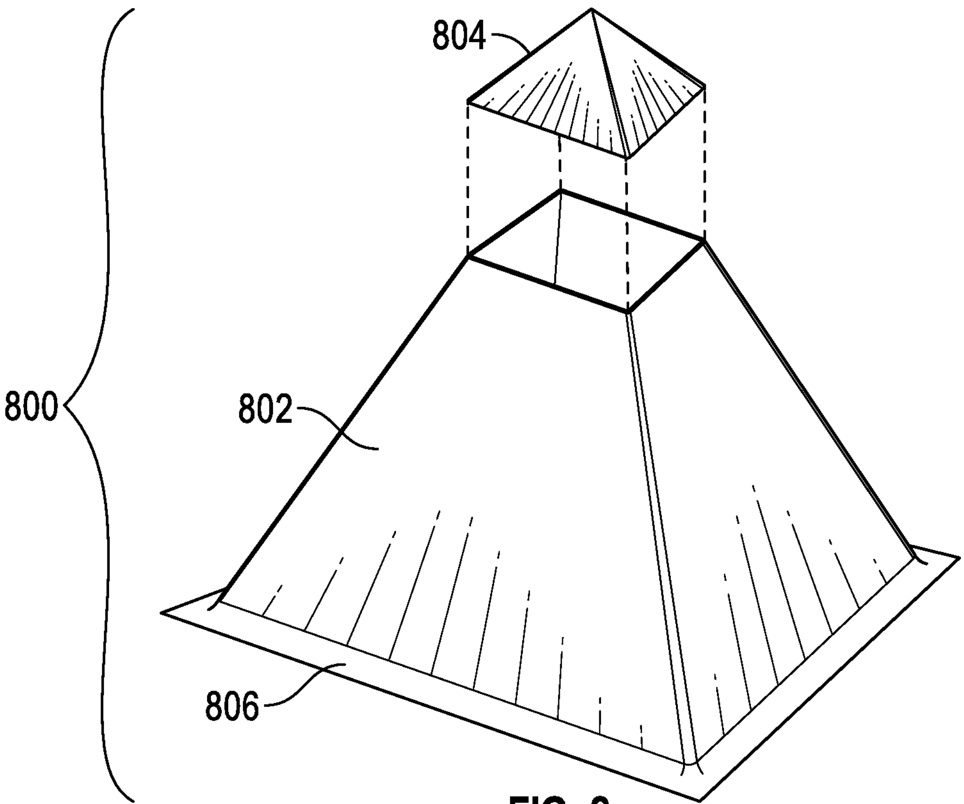
804
800
802
806

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/051365

A. CLASSIFICATION OF SUBJECT MATTER
INV. E04D13/03 F21S11/00
ADD.

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)
E04D F21S

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 896 712 A (CHAO BING-LING [US]) 27 April 1999 (1999-04-27) column 4, line 1 - line 26; figure 2	1-9
A	US 2016/076252 A1 (GELBAUM DAVID [US]) 17 March 2016 (2016-03-17) paragraphs [0011], [0027]; figure 1a	1-9
A	CN 205 480 785 U (HOWARD RAYCHIYJLIN HUANG) 17 August 2016 (2016-08-17) figures 4-8	1-9
A	US 5 648 873 A (JASTER PAUL A [US] ET AL) 15 July 1997 (1997-07-15) column 3, line 47 - line 57; figures 1-2	1-9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"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

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"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
24 January 2019	04/02/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Demeester, Jan

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2018/051365

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US 5896712	A	27-04-1999	NONE			
US 2016076252	A1	17-03-2016	NONE			
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US 5648873	A	15-07-1997	AU	4581297	A	05-01-1998
			US	5648873	A	15-07-1997
			WO	9746836	A2	11-12-1997