



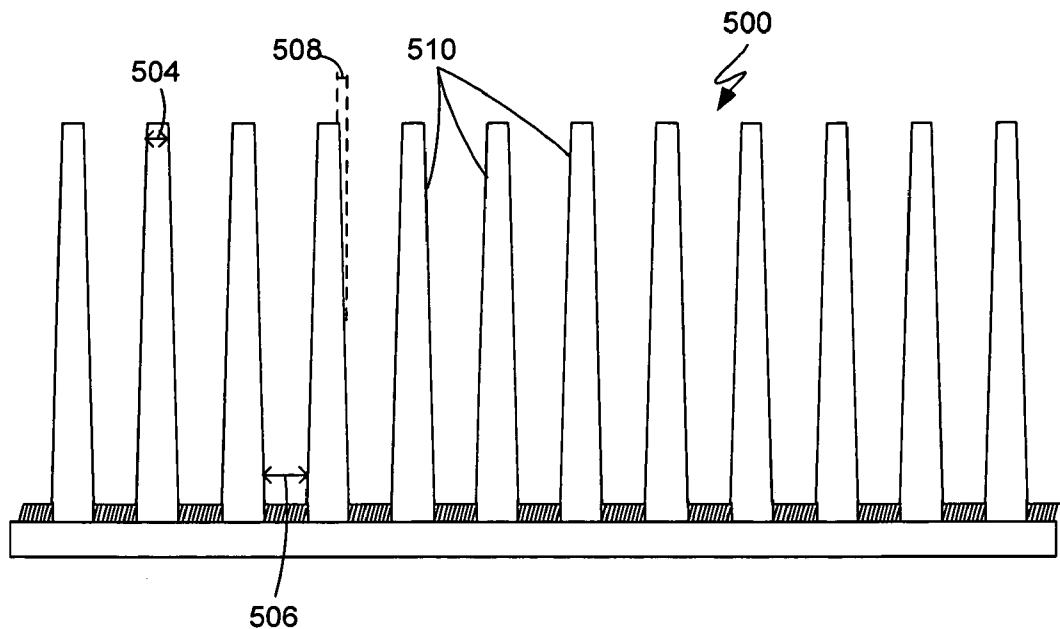
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WELLS et al.(10) **Pub. No.: US 2010/0154788 A1**(43) **Pub. Date: Jun. 24, 2010**(54) **SOLAR RECEIVER****Publication Classification**(75) Inventors: **Jason R. WELLS**, San Francisco,
CA (US); **Khiem B. DO**, San Jose,
CA (US)(51) **Int. Cl.**
F24J 2/24 (2006.01)
(52) **U.S. Cl.** **126/658**(57) **ABSTRACT**

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CA (US)(21) Appl. No.: **12/340,379**(22) Filed: **Dec. 19, 2008**

In one embodiment, a solar receiver has a base plate having a first surface and a second surface, a plurality of solar cells positioned over and supported by the first surface of the base plate, and a multiplicity of fins extending outwardly from the second surface of the base plate. Each of the multiplicity of fins has a fin height axis extending generally perpendicular relative to the base plate, a fin length axis extending generally in parallel with the base plate, and a bottom end attached to the second surface of the base plate, wherein each of the multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration, and wherein each of the multiplicity of fins have a plurality of undulations along the length axis of the fin.



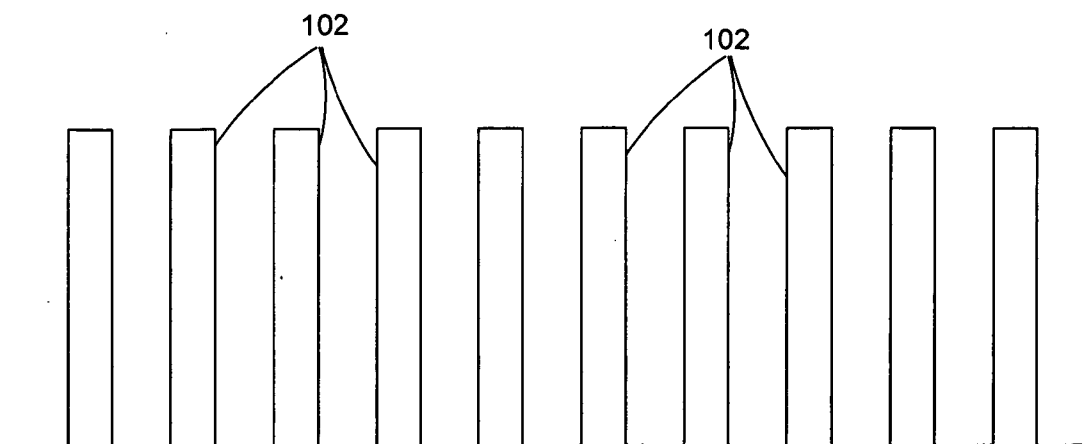


FIG. 1A

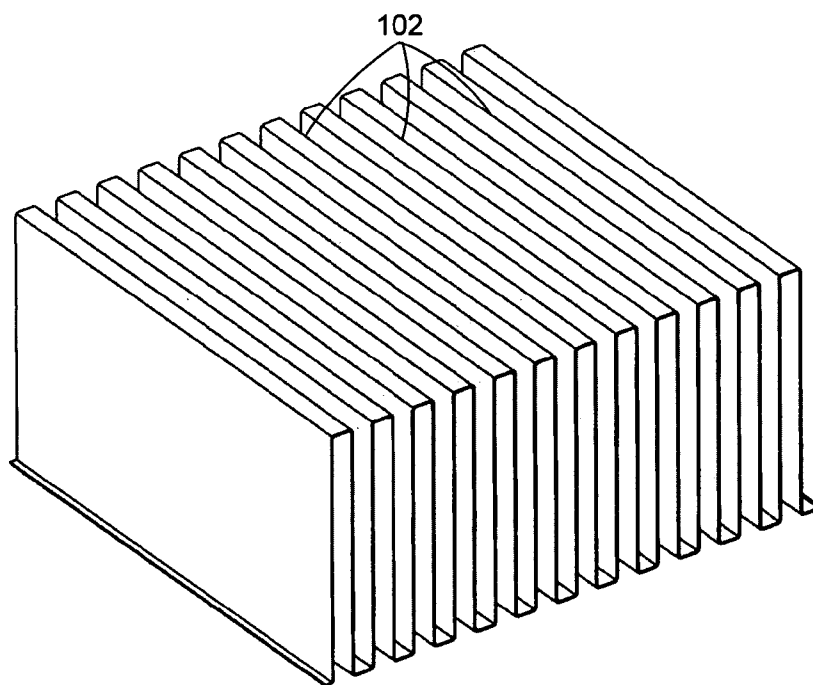


FIG. 1B

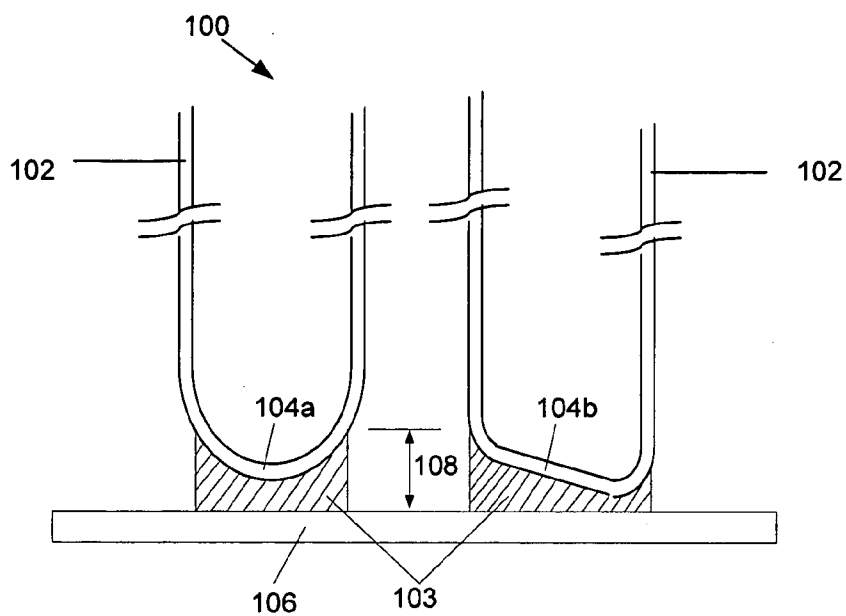


FIG. 1C

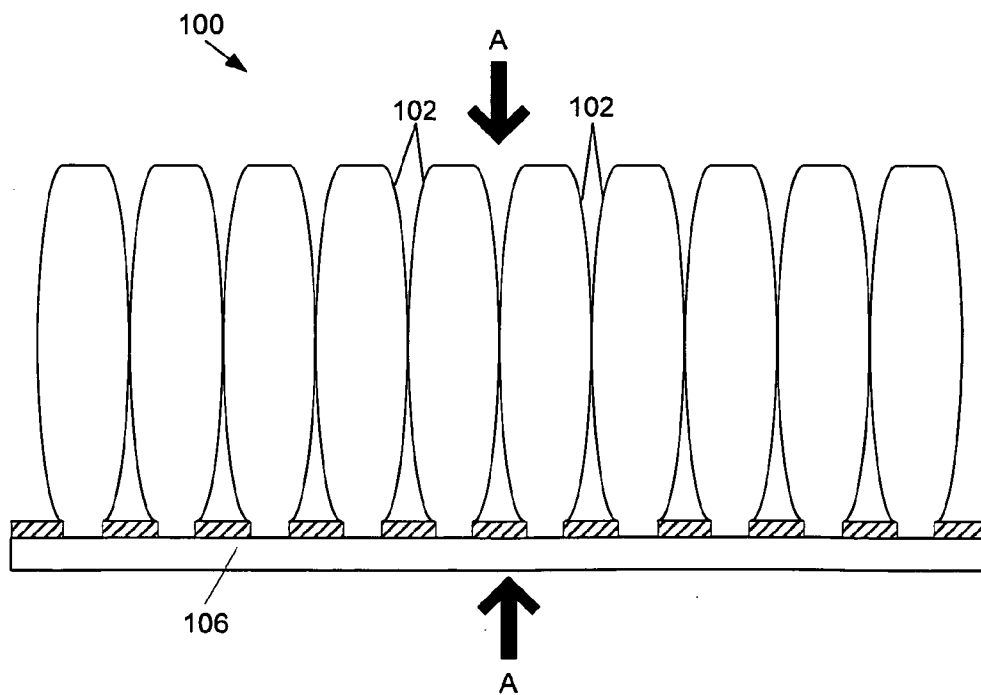


FIG. 1D

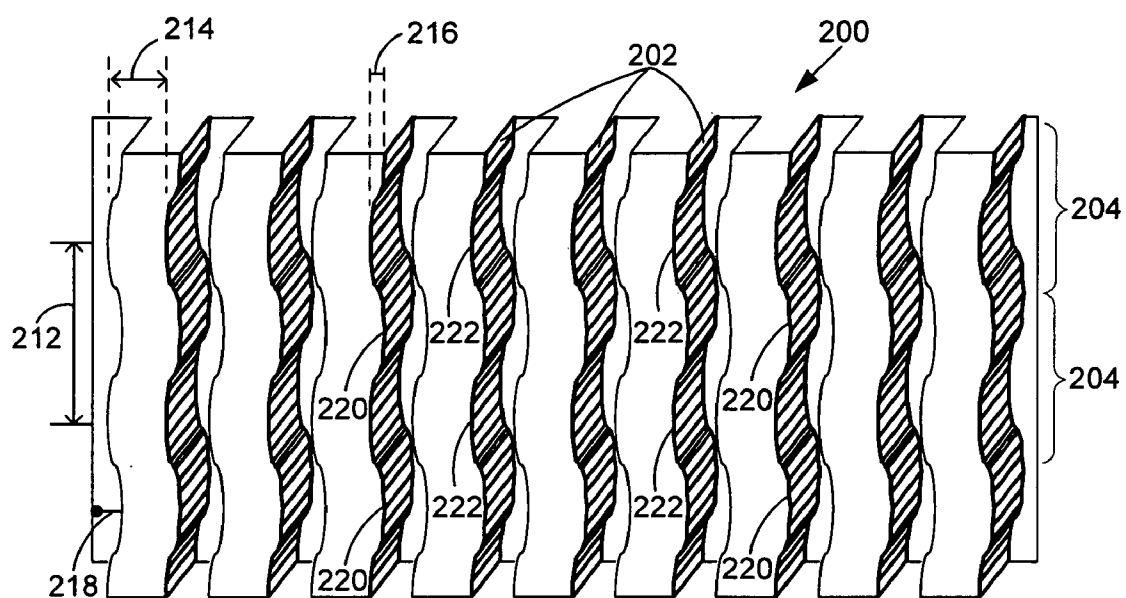
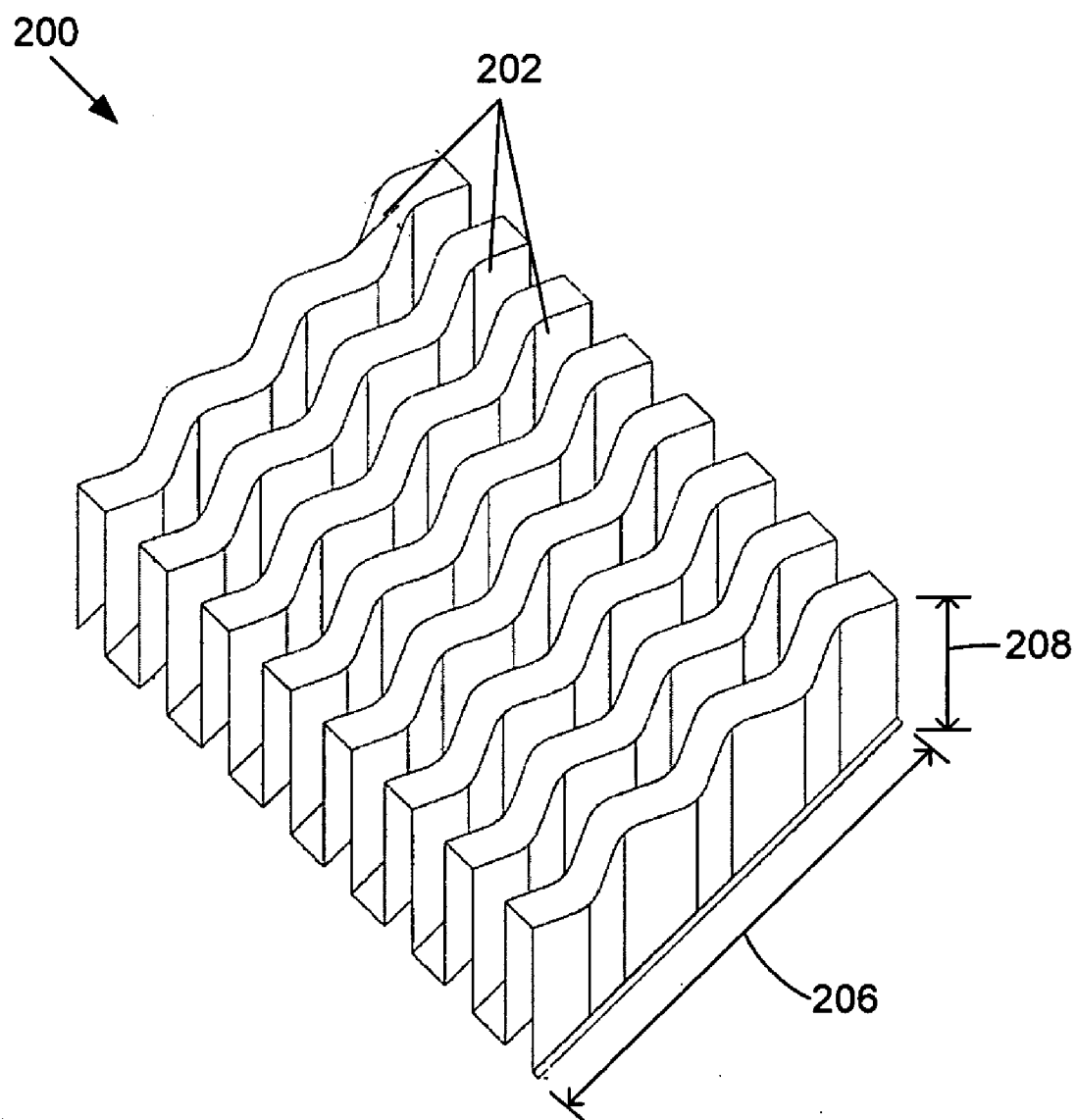


FIG. 2A

**FIG. 2B**

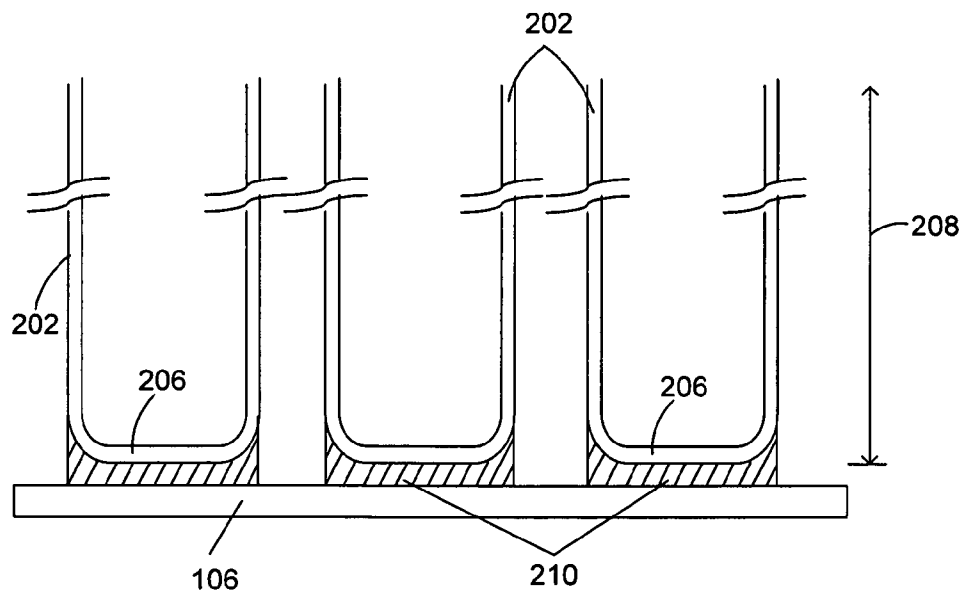


FIG. 2C

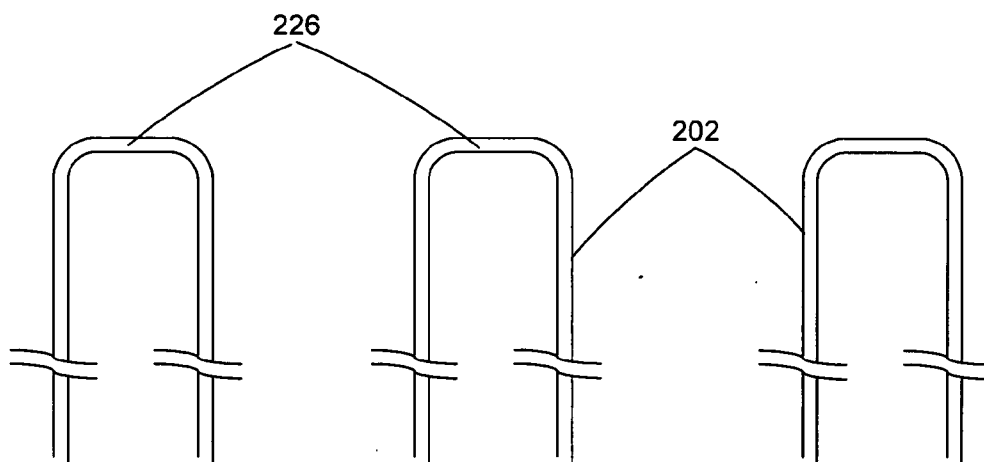


FIG. 2D

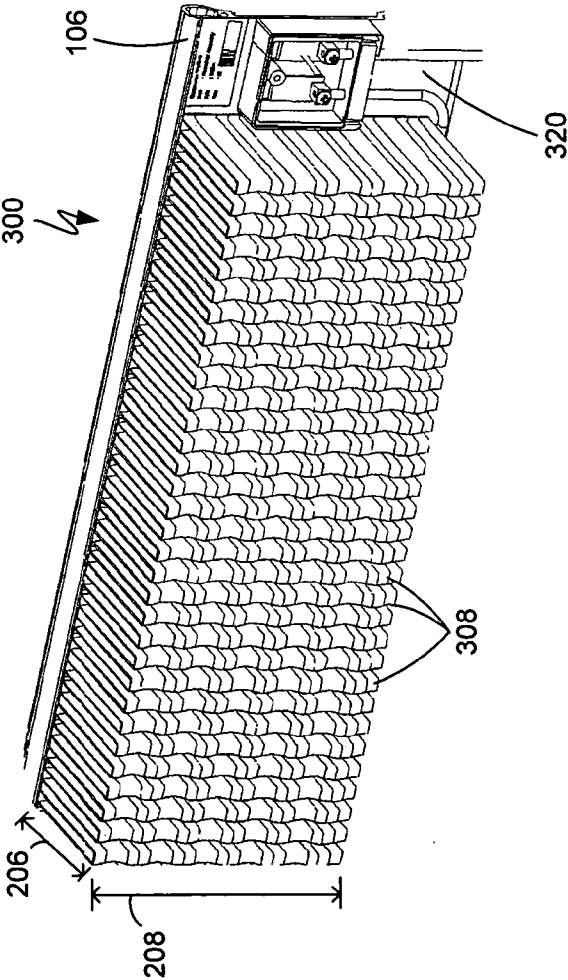


FIG. 3A

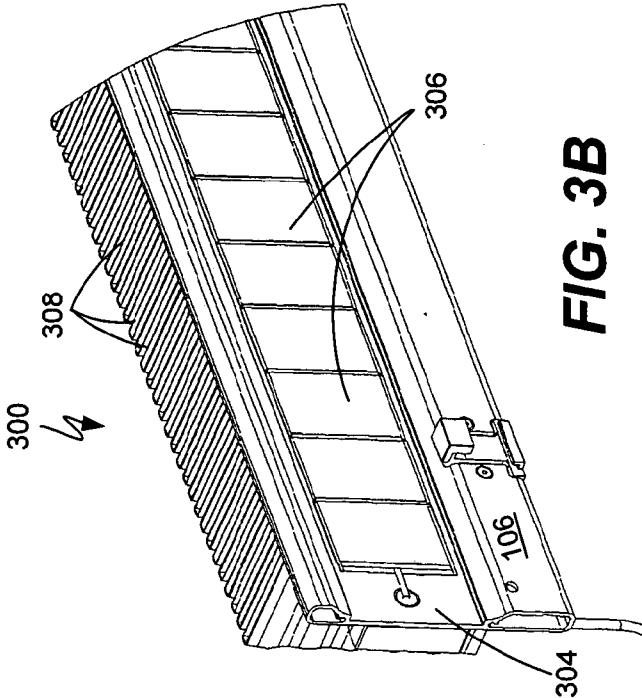
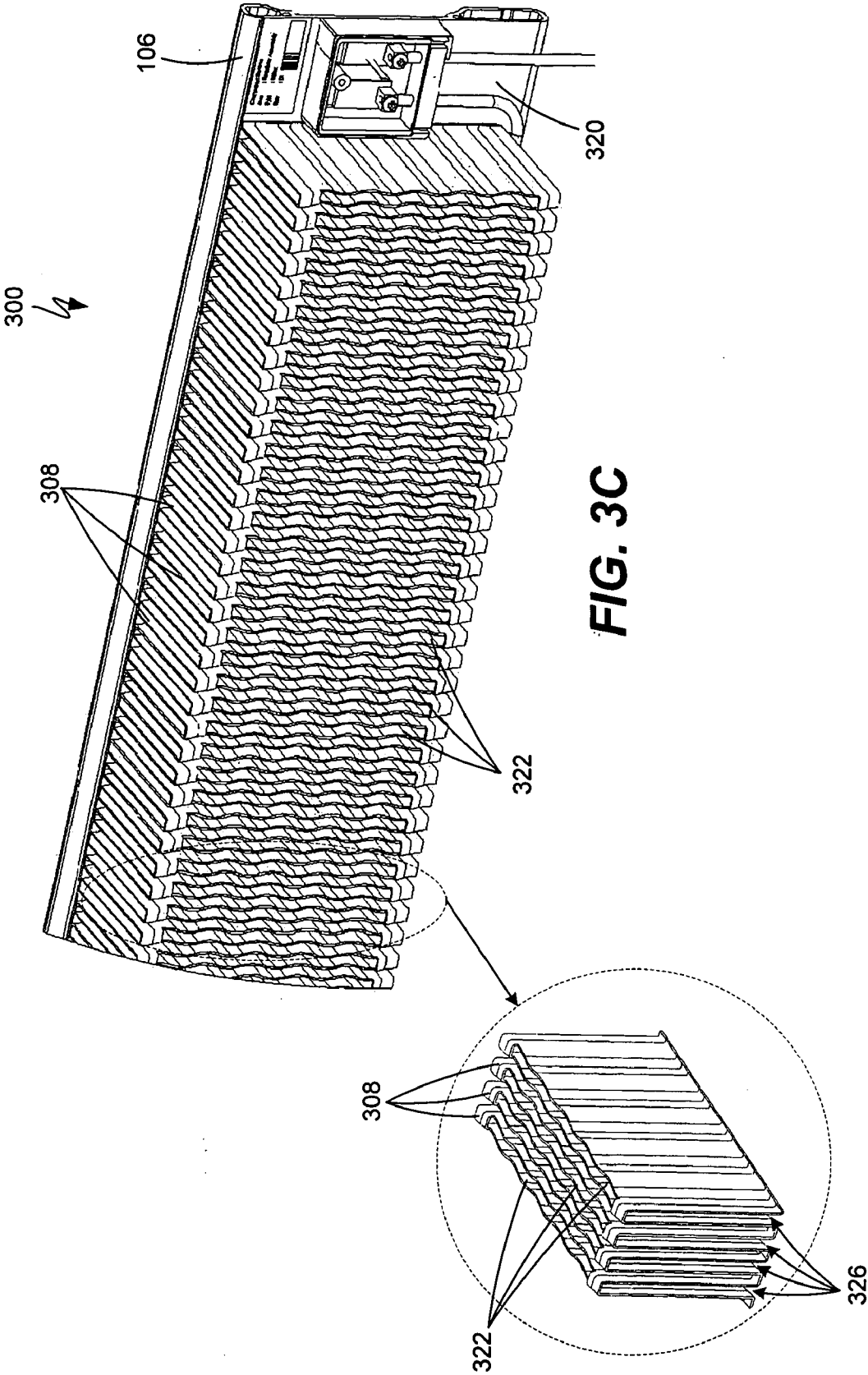


FIG. 3B



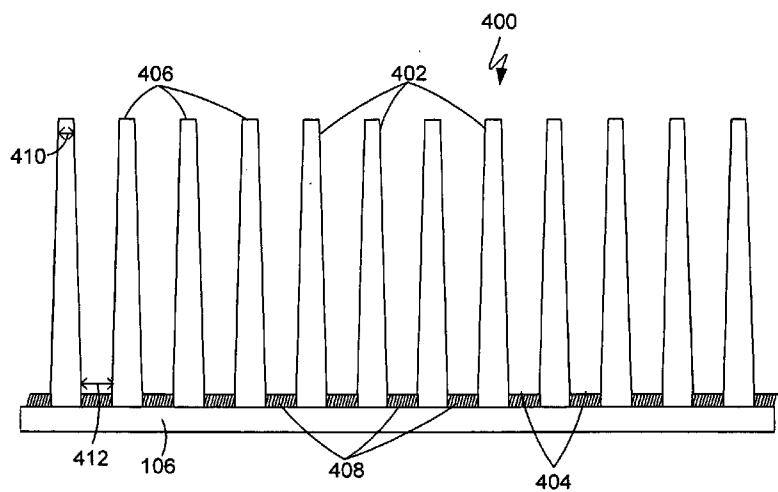


FIG. 4A

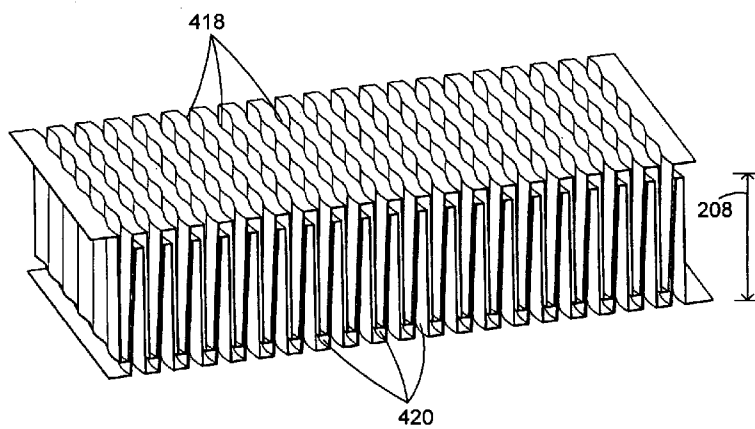


FIG. 4B

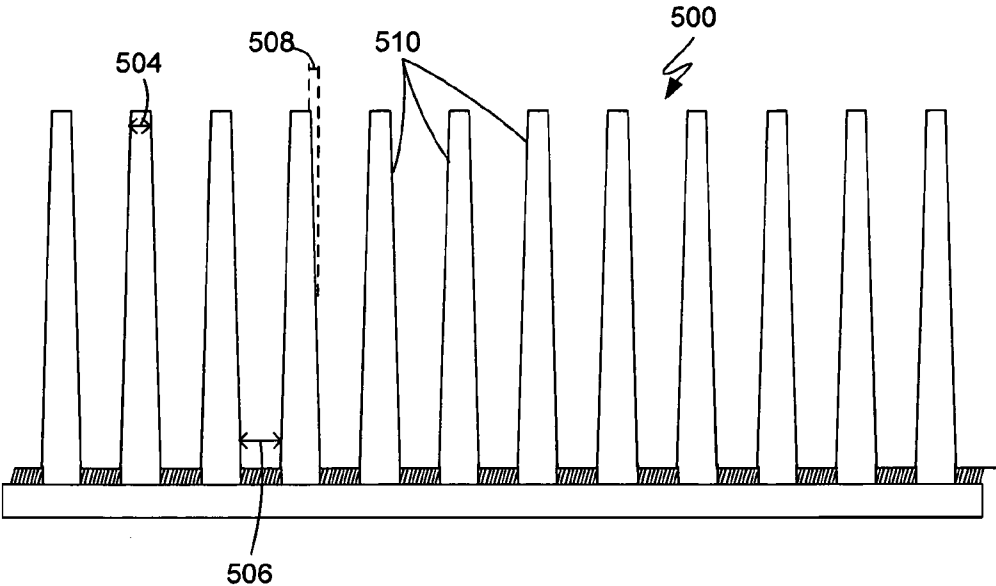


FIG. 5A

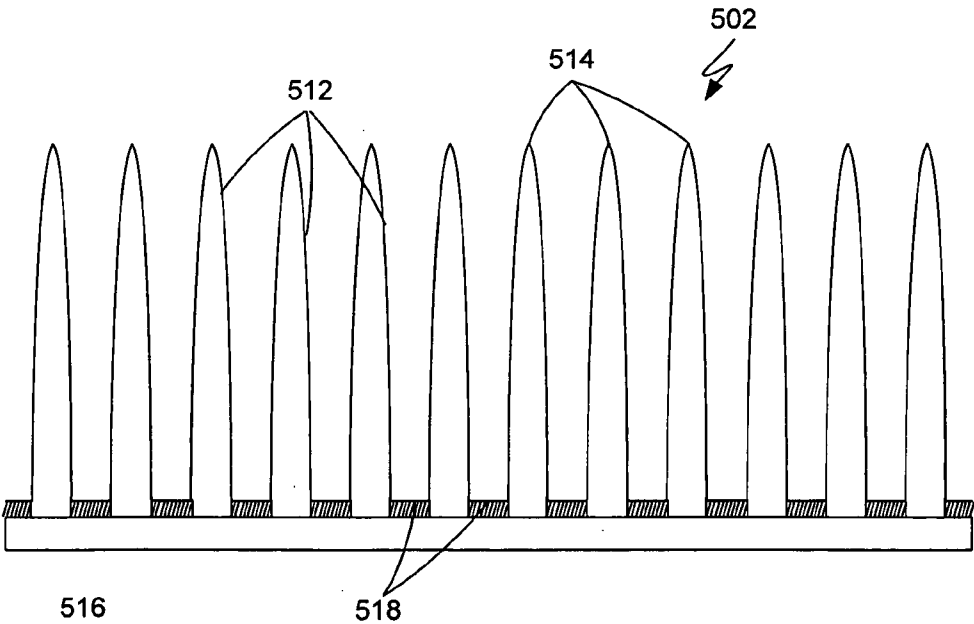


FIG. 5B

SOLAR RECEIVER

FIELD OF THE INVENTION

[0001] The present disclosure relates generally to solar receivers. More particularly, the present disclosure relates generally to solar receivers having a heat sink.

BACKGROUND OF THE INVENTION

[0002] The highest cost components of a solar photovoltaic (PV) system are the solar cells that convert sunlight to electricity by the photoelectric effect. To use these cells more effectively, concentrating photovoltaic (CPV) systems focus sunlight from a larger aperture onto a smaller cell area. The waste heat generated in the solar receivers used in CPV systems may raise the cell temperature subjecting the solar cells to thermal stresses causing malfunction, inefficiencies, and increased costs.

[0003] Heat sinks may be used to absorb and dissipate the heat from the solar receivers. However, current solar receivers are not sufficiently efficient from a thermal energy transfer standpoint while at the same time sufficiently simple, rugged, compact, and lightweight to be transportable, susceptible to on-site assembly, or efficiently stored.

Overview

[0004] A solar receiver is described having a base plate having a first surface and a second surface, a plurality of solar cells positioned over and supported by the first surface of the base plate, each solar cell having a cell face suitable for receiving solar radiation that faces away from the base plate, and a multiplicity of fins extending outwardly from the second surface of the base plate. Each of the multiplicity of fins has a fin height axis extending generally perpendicular relative to the base plate, a fin length axis extending generally in parallel with the base plate, and a bottom end attached to the second surface of the base plate, wherein each of the multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration, and wherein each of the multiplicity of fins have a plurality of undulations along the length axis of the fin.

[0005] In another embodiment, the solar receiver may have a base plate having a first surface and a second surface, a plurality of solar cells positioned over and supported by the first surface of the base plate, each solar cell having a cell face suitable for receiving solar radiation that faces away from the base plate, and a multiplicity of fins extending outwardly from the second surface of the base plate. Each of multiplicity of fins has a bottom end opposite a top end, the bottom end attached to the first surface of the base plate, wherein the top end has a width less than a width of the bottom end, wherein each of the multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration, and wherein each of the multiplicity of fins have a plurality of undulations along a length axis of the fin.

[0006] Stackable solar receivers are also described with a first solar receiver having a first base plate having a first surface and a second surface, a first plurality of solar cells positioned over the first surface of the first base plate, each solar cell having a cell face suitable for receiving solar radiation that faces away from the first base plate, and a first multiplicity of fins extending outwardly from the second surface of the first base plate, each of the first multiplicity of fins are formed from a single, continuous sheet of metal

arranged in a serpentine configuration having a bottom end opposite a top end, the bottom end attached directly to the second surface of the first base plate, wherein the top end has a width less than a width of the bottom end.

[0007] The stackable solar receiver also has a second solar receiver having a second base plate having a first surface and a second surface, a second plurality of solar cells positioned over the first surface of the second base plate, each solar cell having a cell face suitable for receiving solar radiation that faces away from the second base plate, and a second multiplicity of fins extending outwardly from the second surface of the second base plate, each of the second multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration having a bottom end opposite a top end, the bottom end attached directly to the second surface of the second base plate, wherein the top end has a width less than a width of the bottom end, wherein the first multiplicity of fins is interleaved with the second multiplicity of fins to stack the first solar receiver with the second solar receiver during transport or storage.

[0008] These and other features will be presented in more detail in the following detailed description of the invention and the associated figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more example embodiments and, together with the description of example embodiments, serve to explain the principles and implementations.

[0010] In the drawings:

[0011] FIGS. 1A-1D illustrate one embodiment of a heat sink.

[0012] FIGS. 2A-2D illustrates a heat sink fin in accordance with one embodiment of the invention.

[0013] FIGS. 3A-3C illustrate example solar receivers.

[0014] FIGS. 4A and 4B illustrates an embodiment of a stackable solar receiver.

[0015] FIGS. 5A and 5B illustrate other embodiments of a stackable solar receiver.

DESCRIPTION OF EXAMPLE EMBODIMENTS

[0016] Embodiments are described herein in the context of a solar receiver. The following detailed description is illustrative only and is not intended to be in any way limiting. Other embodiments will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following detailed description to refer to the same or like parts.

[0017] In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine

undertaking of engineering for those of ordinary skill in the art having the benefit of this disclosure.

[0018] Heat sinks can be used to absorb and dissipate heat from solar receivers. Heat sinks have a plurality of fins whereby heat generated by the solar cells dissipates by natural free convection through the plurality of fins. This minimizes the temperature rise experienced by the solar cells to improve efficiency and prevent warping, electrical shorts, or any other malfunctions due to high temperatures.

[0019] FIGS. 1A-1D illustrate one embodiment of a heat sink. FIG. 1A illustrates a side view of a plurality of heat sink fins and FIG. 1B illustrates a perspective view of the plurality of heat sink fins of FIG. 1A. As illustrated in FIGS. 1A and 1B, the plurality or multiplicity of fins 102 are formed or fabricated from one continuous roll or sheet of material and bent to form a serpentine configuration. This eliminates the need to assemble a heat sink using individual fins and is low cost and easy to manufacture. The sheet of material can be any material that has good thermal conductivity such as aluminum, copper, or the like.

[0020] However, forming the plurality of fins illustrated in FIGS. 1A and 1B has some drawbacks. FIG. 1C illustrates a side view of various imperfect formations of a bottom end of the plurality of heat sink fins of FIGS. 1A and 1B. The plurality of fins can be attached to a base plate 106 of a solar receiver 100 in multiple bonding areas, such as at the bottom end 104a,b of each of the plurality of fins 102. Each of the plurality of fins may be attached to the base plate 106 through any known means, such as with the use of adhesives.

[0021] Forming a flat and/or squared bottom end 104a, 104b is a challenging task when forming the serpentine configuration. The end result may be a rounded bottom end 104a, a skewed bottom end 104b, or any other non-flat or non-planar configuration.

[0022] The various shapes and configurations of the bottom end 104a, b result in a non-uniform gap 108 between the base plate 106 and each of the plurality of fins 102. Thus, more adhesive is necessary to bond the fins 102 to the base plate 106, which increases thermal resistance to the fins 102. Adhesives have less thermal conductivity than the material used to form the base plate and/or the plurality of fins. Thus, the amount of adhesive should be minimized to form a very thin layer of adhesive between the base plate and the heat sink fin to minimize thermal resistance of the bonding layer. Although the use of an adhesive has been used to describe the bond or attachment between the heat sink fin and the base plate, it is not meant to be limiting as any suitable means that enables good thermal conductivity contact between the heat sink fin and the base plate may be used, such as the use of bolts, screws, mechanical fasteners, soldering, brazing, welding or the like.

[0023] The thermal conductivity of most adhesives is only approximately 1% that of aluminum. Thus, a larger gap 108 between the base plate 106 and the bottom end 104a, b requires more adhesive to bond the fins 102 to the base plate 106. The use of more adhesive forms a thicker bonding layer 103, which then impedes heat transfer from the base plate 106 to the fins 102. Furthermore, since only a small portion or a small surface area of the bottom end 104a, 104b of the fin 102 is in close contact with the base plate 106, the heat flow or transfer from the base plate 106 to the fin 102 is not symmetric or uniform. More heat flows from the area where the fin 102 is closer to the base plate 106 than the areas where the fin 102 is further away from the base plate 106. As such, there is a

higher thermal resistance in the areas where there is more adhesive, such as the areas where the fin 102 is furthest away from the base plate 106. This undesirably reduces the effectiveness of the heat sink and solar receiver 100.

[0024] FIG. 1D illustrates a side view of the plurality of heat sink fins being attached to the base plate. To bond the plurality of fins 102 to the base plate 106, the plurality of fins 102 may be pressed against the base plate 106 by a force in the direction illustrated by arrows A. As illustrated in FIG. 1D, the plurality of fins 102 easily bow when the pressed against the base plate 106. Although FIG. 1D illustrates a symmetric outwardly bowing of each of the plurality of fins 102, in practice, uneven bowing occurs with each of the plurality of fins 102 such that some fins 102 may bow inward and others bow outward. Additionally, some of the fins 102 may also break or crack as a result of the force or pressure applied when pressed against the base plate 106.

[0025] As such, there is a limit to the amount of force that may be applied to the plurality of fins 102. This makes it difficult to obtain a thin adhesive bonding layer between the base plate 106 and the plurality of fins 102 to obtain high thermal conductivity between the base plate 106 and each of the fins 102.

[0026] FIGS. 2A-2D illustrates a heat sink fin in accordance with one embodiment of the invention. FIG. 2A illustrates a top view of the heat sink fin and FIG. 2B illustrates a perspective view of the heat sink fin of FIG. 2A. The heat sink fins 200 are formed or fabricated from one continuous roll or sheet of material and bent to form a serpentine configuration similar to the fins illustrated in FIG. 1A. This eliminates the need to assemble a heat sink using individual fins and is low cost and easy to manufacture. The sheet of material can be any material that has good thermal conductivity such as aluminum, copper, or the like.

[0027] Each fin 202 may also be bent to form a plurality of undulations 204 along a length axis 206 of each of the fins 202. The length axis 206 can extend generally in parallel with the base plate 106. The plurality of undulations 204 creates a wave-like or ruffled configuration to each of the fins 202. Each fin 202 may also have a fin height axis 208 that extends generally perpendicular relative to the base plate. For example, the fin height and fin height axis may be within 100° of the perpendicular to the base plate. In another embodiment, the fin height axis 208 need not be generally perpendicular to the base plate. For example, the fin height axis 208 may vary from a perpendicular axis to the base plate by about 0°-45°.

[0028] In one embodiment, each fin 202 may have between about 2 to 10 undulations along the length axis 206. In another embodiment, each fin 202 may have between about 3-6 undulations, and in a specific embodiment, each fin 202 may have between about 4-5 undulations along the length axis 206.

[0029] In another embodiment, each fin 202 has between about 2 to 15 peaks 220 and valleys 222 along the length axis 206 of each of the fin 202. In another embodiment, each fin 202 may have between about 3 to 8 peaks 220 and valleys 222 along the length axis 206, and in a specific embodiment, each fin 202 may have at least 4 peaks 220 and valleys 222 along the length axis 206 of each fin 202.

[0030] Each of the plurality of undulations 204 may have an undulation pitch 212, which is the distance between each undulation. In one embodiment, the undulation pitch is no greater than approximately one undulation per inch. An undulation amplitude 216 is the depth of the undulation parallel to the base plate 106 and an undulation radius 218 is the radius

of the curvature associated with the undulation **204**. The heat sink fin **200** may have a fin pitch **214**, which is the distance between similar structures on an adjacent fin.

[0031] The plurality of undulations **204** forms a heat sink fin **200** having an overall higher stiffness or rigidity that is able to withstand additional pressure during bonding or attachment to the base plate without bowing or breaking of the fins **202**. The resulting heat sink fin **200** is more stabilized and able to withstand bending and distortions.

[0032] FIG. 2C illustrates the bottom ends of the heat sink fin of FIGS. 2A and 2B and FIG. 2D illustrates the top ends of the heat sink fin of FIGS. 2A and 2B. The formation of the fins with the plurality of undulations **204** results in each fin **202** having a bottom end **206** that is substantially planar or flat which facilitates an efficient bond with the base plate **106**. The bottom ends **206** of each of the fins **202** are substantially perpendicular to the fin height **208** and parallel to the base plate **106**. As illustrated in FIG. 2D, a top end **226** of each fins **202** may also be substantially planar or flat and substantially perpendicular to the fin height **208** and parallel to the base plate **106**.

[0033] This results in little to no gap between the base plate **106** and the fin **202**, which in turn increases thermal conductivity between the base plate **106** and the heat sink fins **200**. Furthermore, substantially the entire surface area of the bottom end **206** of each fin **202** is in close contact with the base plate **106**.

[0034] Since the heat sink fin **200** has an overall higher stiffness or rigidity, it may be bonded or attached to the base plate **106** using a greater force or pressure between the heat sink fin **200** and the base plate **106**. This results in a thinner bonding layer **210**. Additionally, since each of the bottom ends **206** are substantially planar, the heat sink fin **200** may be bonded to the base plate **106** with a uniform bonding layer **210**. Both the thinner and more uniform bonding layer **210** results in decreased thermal resistance at the bonding layer **210** between the heat sink fin **200** and the base plate **106**.

[0035] The formation of the plurality of undulations along the fin length axis also allows for the use of thinner material to form the heat sink fin since the heat sink fin has an overall higher stiffness or rigidity. This enables the formation of a lighter and less expensive heat sink and solar receiver. Moreover, it has been unexpectedly determined that the fin height may be increased without compromising the mechanical integrity of the heat sink fin. Thus, the fin height **208** to fin length **206** ratio may increase which results in high thermal conductivity since there is more surface area for heat transfer. In one embodiment, the fin height to fin length ratio may be greater than 0.5.

[0036] FIGS. 3A-3C illustrate example solar receivers. Referring to FIGS. 3A and 3B, FIG. 3A is a perspective view of the back of one example solar receiver and FIG. 3B is a perspective view of the front of the example solar receiver using an embodiment of the heat sink fin. The solar receiver **300** may have a base plate **106** having a first surface **304** and a second surface **320** opposite the first surface **304**. The solar receiver **300** may have a plurality of solar cells **306** positioned over and supported by the first surface **304** of the base plate **106**. Each solar cell **306** has a cell face, facing away from the base plate **106**, which is suitable for receiving solar radiation.

[0037] The solar receiver **300** has a multiplicity of fins **308** extending outwardly from the second surface **320** of the base plate **106**. Each of the multiplicity of fins **308** has a fin height axis **208** and a length axis **206**. The fin height axis **208** can

extend generally perpendicular relative to the base plate **106** and the fin length axis **206** can extend generally parallel with the base plate **106**. A bottom end of each of the fins **308** can be attached to the second surface of the base plate **106**.

[0038] The solar cells **306** and multiplicity of fins **308** may be attached or assembled to the base plate by any known means such as those described in co-pending application Ser. No. 12/124,121, entitled "Photovoltaic Receiver", filed May 20, 2008, which is incorporated herein by reference in its entirety.

[0039] In use, the solar cells **306** produce waste heat that must be removed from the solar receiver. The heat may be transferred or transmitted to the base plate **106**, through the bonding layer **210** (FIG. 2C), and to the heat sink fins **308** via conduction. In one embodiment, the heat can then be dissipated into the surrounding environment or air via natural convection along the length axis **206** of the multiplicity of fins **308**.

[0040] FIG. 3C illustrates a perspective view of another example solar receiver. A portion of the top end **226** (FIG. 2D) of the heat sink fins **308** may be removed thereby forming an opening **322** on the top end of the fin **308**. The entire surface of the top end **226** is not removed to retain the serpentine shape of the heat sink and to allow the heat sink to be formed from one continuous sheet of material. This embodiment allows for additional air flow paths in the region below the top end **226**, for example, the area enclosed by the heat sink fin and the base plate as illustrated by arrow **326**. These additional air flow paths may improve thermal conductance of the heat, reduce photovoltaic cell temperature, and improve solar cell efficiency.

EXAMPLE

[0041] Examples are described herein for exemplary purposes only and not intended to be limiting. An example heat sink fin may be made from a continuous sheet of material, such as aluminum. The sheet of material may have a thickness of about 0.020 inches. Each fin may have a fin length of about 5.50 inches and a fin height of about 3 inches. Thus, the ratio of fin height to fin length may be 3 inches/5.5 inches=0.55.

[0042] Each fin may have a fin pitch of about 0.25 inches and about 5.5 undulations along the fin length axis. Each fin may have an undulation amplitude of about 0.050 inches, an undulation period of about 1 inch, and an undulation radius of about 1.262 inches. The heat sink may be formed to any desired length. In one embodiment, the heat sink may have a length of about 52 inches, which results in the formation of about 208 fins.

[0043] FIGS. 4A and 4B illustrates an embodiment of a stackable solar receiver. FIG. 4A illustrates a cross-sectional side view of a solar receiver. The solar receiver **400** may have a plurality of fins **402** having a bottom end **404** and a top end **406** opposite the bottom end **404**. The bottom end **404** may be attached to the base plate **106** via a bonding layer **408** as discussed above. Each fin **402** may have a top end width **410** and a bottom end width **412**. Current heat sinks have a top end width **410** that is equal to the bottom end width **412**. This does not allow for the ability of heat sink fins of two opposing heat sinks to nest or stack within each other for efficient transport or storage because the spacing between each fin is equal to the bottom end width. The fins would simply interfere with each other and not be able to nest or stack within each other.

[0044] FIG. 4A illustrates a solar receiver **400** having a plurality of fins **402** with a top end width **410** less than the

bottom end width **412** thereby forming fins **402** with a trapezoidal or tapered cross-section. This allows for the fins of two opposing solar receivers to nest, stack, or be interleaved within each other as illustrated in FIG. 4B. FIG. 4B illustrates a perspective view of the nested, stacked, or interleaved solar receivers. Although the figure illustrates nested heat sinks, this is not intended to be limiting as the heat sinks may be attached to the base plate forming a complete receiver the base plates are not illustrated for clarity to illustrate how the fins stack or nest within each other. A first solar receiver **414** having a first multiplicity of fins **418** may be flipped and nested or stacked within a second solar receiver **416** having a second multiplicity of fins **420**. The undulation pitch and undulation phase of each fin, as discussed above, should be matched and/or substantially similar in order for the solar receivers **414**, **416** to nest within each other.

[0045] The first multiplicity of fins **418** may extend substantially the entire fin height **208** of the second multiplicity of fins **420** when the first multiplicity of fins **418** are nested within the second multiplicity of fins **420**. The combined height of the first solar receiver **414** and the second solar receiver **416** is only slightly greater than the height of one of the solar receivers.

[0046] The ability to nest solar receivers increases the packing density of the solar receivers during transportation or storage. In fact, the shipping and storage volume of the solar receivers may be reduced by a factor of two as compared to current shipping and storage volumes where nesting of solar receivers are not possible. As such, concomitant shipping and storage costs may be reduced which can influence the commercial viability of CPV systems.

[0047] Furthermore, nesting the solar receivers reduces the probability of fin damage during transportation or storage. The fins form a mechanical protection layer for each opposing fin thereby increasing the mechanical robustness of the structure.

[0048] FIGS. 5A and 5B illustrate other embodiments of a stackable solar receiver. FIGS. 5A and 5B illustrate side views of alternative embodiments of a stackable solar receiver. Referring to FIG. 5A, the solar receiver **500** has a plurality of tapered heat sink fins **510**. Each fin **510** has a top end width **504** that is less than a bottom end width **506**. The tapered angle **508** of each fin **510** may be between about 2° to about 30°.

[0049] FIG. 5B illustrates another embodiment of a stackable solar receiver. The solar receiver **502** may have a plurality of heat sink fins **512**. Each fin **512** may have a rounded taper at the top end **514** such that the bottom end width **516** is greater than a width of the tapered top end **514**. The difference in width between the bottom end **518** and the top end **514** of the fins **512** allows two solar receivers to nest within each other for transport or storage.

[0050] Although FIGS. 5A and 5B are illustrated with the top end width less than the bottom end width, this is not limiting as the opposite may be possible. The top end width may be greater than the bottom end width. In this embodiment, one heat sink may slideably engage another heat sink in order to nest or stack the heat sink fins.

[0051] While embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art having the benefit of this disclosure that many more modifications than mentioned above are possible without departing from the inventive concepts herein.

What is claimed is:

1. A solar receiver, comprising:

a base plate having a first surface and a second surface;
a plurality of solar cells positioned over and supported by the first surface of the base plate, each solar cell having a cell face suitable for receiving solar radiation that faces away from the base plate; and

a multiplicity of fins extending outwardly from the second surface of the base plate, each of the multiplicity of fins having a fin height axis extending generally perpendicular relative to the base plate, a fin length axis extending generally in parallel with the base plate, and a bottom end attached to the second surface of the base plate, wherein each of the multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration, and wherein each of the multiplicity of fins have a plurality of undulations along the length axis of the fin.

2. The solar receiver of claim 1, wherein there are at least four undulations along the length axis of each fin.

3. The solar receiver of claim 1, wherein the plurality of undulations have at least four peaks and four valleys along the length axis of each of the multiplicity of fins.

4. The solar receiver of claim 1, wherein a pitch of each of the plurality of undulations is no greater than approximately one undulation per inch.

5. The solar receiver of claim 1, wherein the multiplicity of fins are made from a metal.

6. The solar receiver of claim 5, wherein the multiplicity of fins are made from aluminum.

7. The solar receiver of claim 1, wherein the bottom end is substantially flat whereby substantially all of a surface area of the bottom end is attached with the second surface of the base plate.

8. The solar receiver of claim 7, wherein the bottom end is attached to the second surface of the base plate with an adhesive.

9. The solar receiver of claim 1, wherein each of the plurality of fins has a top end opposite the bottom end and wherein a width of the top end is less than a width of the bottom end.

10. The solar receiver of claim 1, wherein the top end further comprises an opening to facilitate convective air flow.

11. A solar receiver, comprising:

a base plate having a first surface and a second surface;
a plurality of solar cells positioned over and supported by the first surface of the base plate, each solar cell having a cell face suitable for receiving solar radiation that faces away from the base plate; and

a multiplicity of fins extending outwardly from the second surface of the base plate, each of multiplicity of fins having a bottom end opposite a top end, the bottom end attached to the second surface of the base plate, wherein the top end has a width less than a width of the bottom end, wherein each of the multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration, and wherein each of the multiplicity of fins have a plurality of undulations along a length axis of the fin.

12. The solar receiver of claim 11, wherein the bottom end is substantially flat whereby substantially all of a surface area of the bottom end is attached with the second surface of the base plate.

13. The solar receiver of claim **11**, wherein there are at least four undulations along the length axis of each fin.

14. The solar receiver of claim **11**, wherein the plurality of undulations have at least four peaks and four valleys along the length axis of each of the multiplicity of fins.

15. The solar receiver of claim **11**, wherein the bottom end is attached to the base plate with an adhesive.

16. The solar receiver of claim **11**, wherein the multiplicity of fins are made from a metal.

17. The solar receiver of claim **11**, wherein the top end further comprises an opening to facilitate convective air flow.

18. Stackable solar receivers, comprising:

a first solar receiver, having:

a first base plate having a first surface and a second surface;

a first plurality of solar cells positioned over the first surface of the first base plate, each solar cell having a cell face suitable for receiving solar radiation that faces away from the first base plate; and

a first multiplicity of fins extending outwardly from the second surface of the first base plate, each of the first multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration having a bottom end opposite a top end, the bottom end attached directly to the second surface of the first base plate, wherein the top end has a width less than a width of the bottom end;

a second solar receiver, having:

a second base plate having a first surface and a second surface;

a second plurality of solar cells positioned over the first surface of the second base plate, each solar cell having

a cell face suitable for receiving solar radiation that faces away from the second base plate; and

a second multiplicity of fins extending outwardly from the second surface of the second base plate, each of the second multiplicity of fins are formed from a single, continuous sheet of metal arranged in a serpentine configuration having a bottom end opposite a top end, the bottom end attached directly to the second surface of the second base plate, wherein the top end has a width less than a width of the bottom end,

wherein the first multiplicity of fins is interleaved with the second multiplicity of fins to stack the first solar receiver with the second solar receiver during transport or storage.

19. The solar receivers of claim **18**, wherein each of the first and second multiplicity of fins have a plurality of undulations along a length axis of the fin.

20. The solar receivers of claim **19**, wherein an undulating pitch and an undulating phase of each of the plurality of undulations are substantially similar.

21. The solar receivers of claim **18**, wherein each of the first multiplicity of fins having a first fin height axis extending generally perpendicular relative to the first base plate and wherein each of the second multiplicity of fins having a second fin height axis extending generally perpendicular relative to the second base plate.

22. The solar receivers of claim **21**, wherein the first multiplicity of fins extend substantially the entire second fin height of the second multiplicity of fins when the first multiplicity of fins are interleaved within the second multiplicity of fins.

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