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(54) **FLOW DIVERTERS TO ENHANCE HEAT SINK PERFORMANCE**

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(57) **ABSTRACT**

A heat sink includes a base and fins attached to the base. A flow diverter is in contact with the base or at least one of the fins and is configured to disturb a laminar flow region of a fluid flowing adjacent to at least one of the fins or the base.

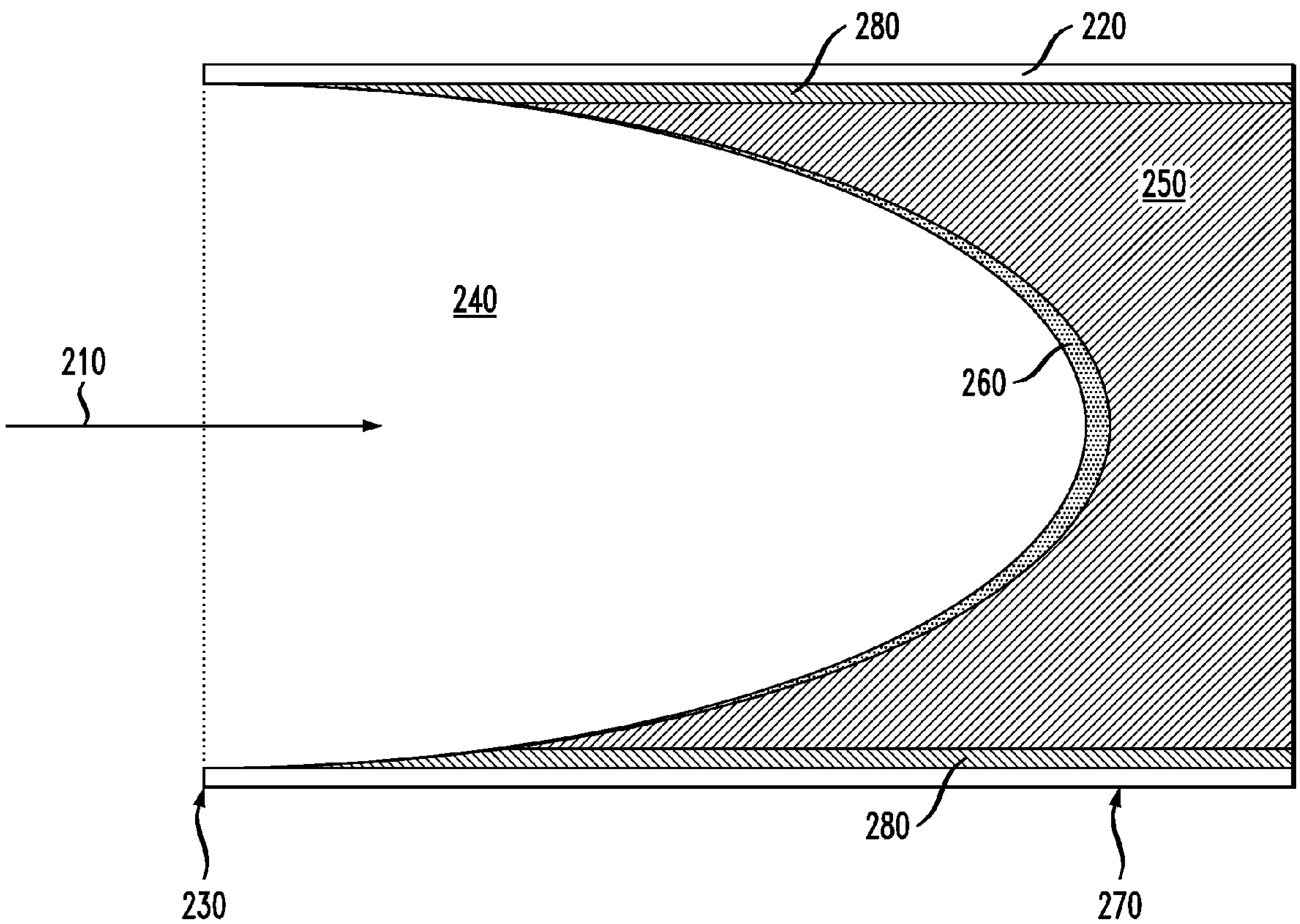
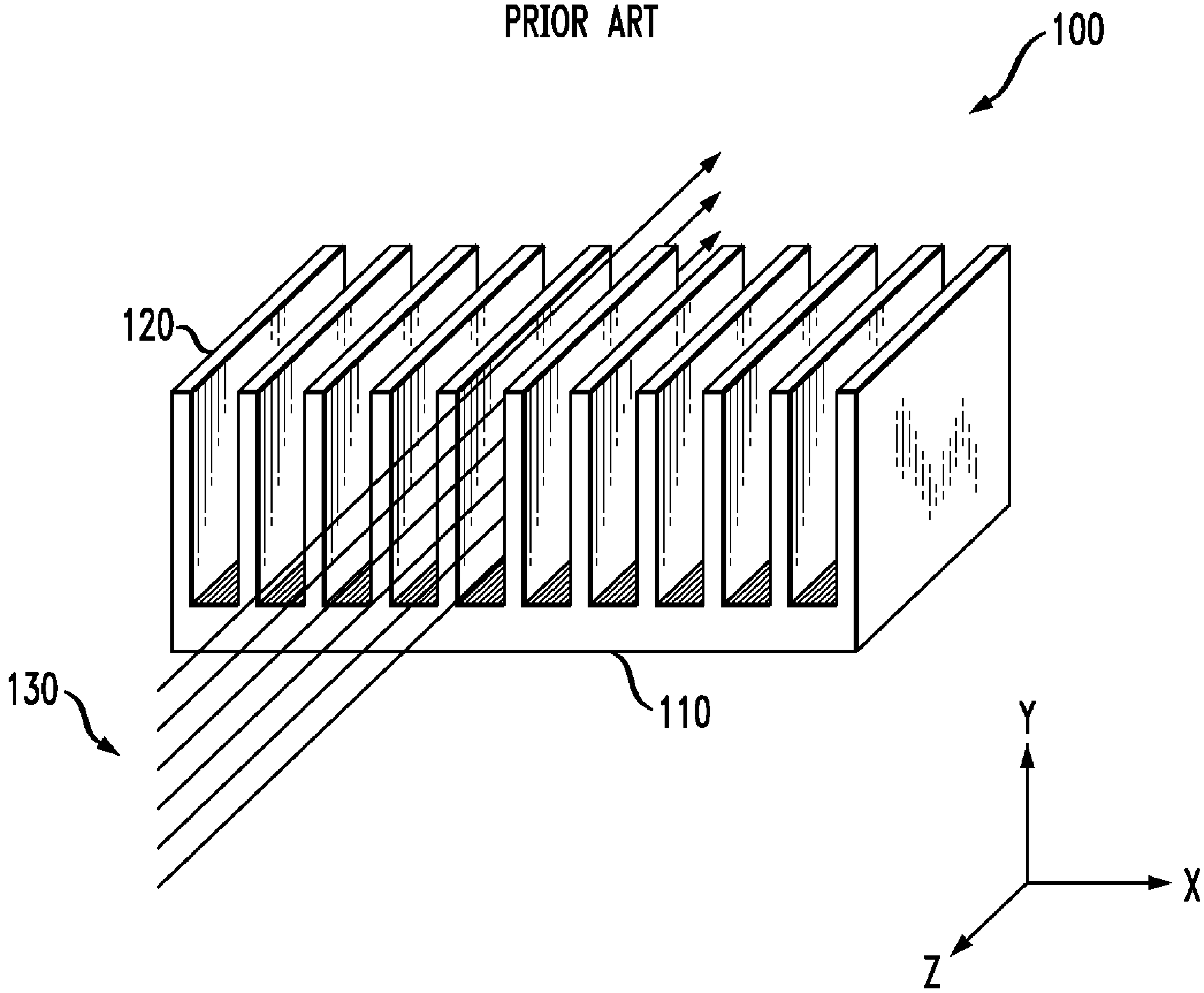


FIG. 1

PRIOR ART



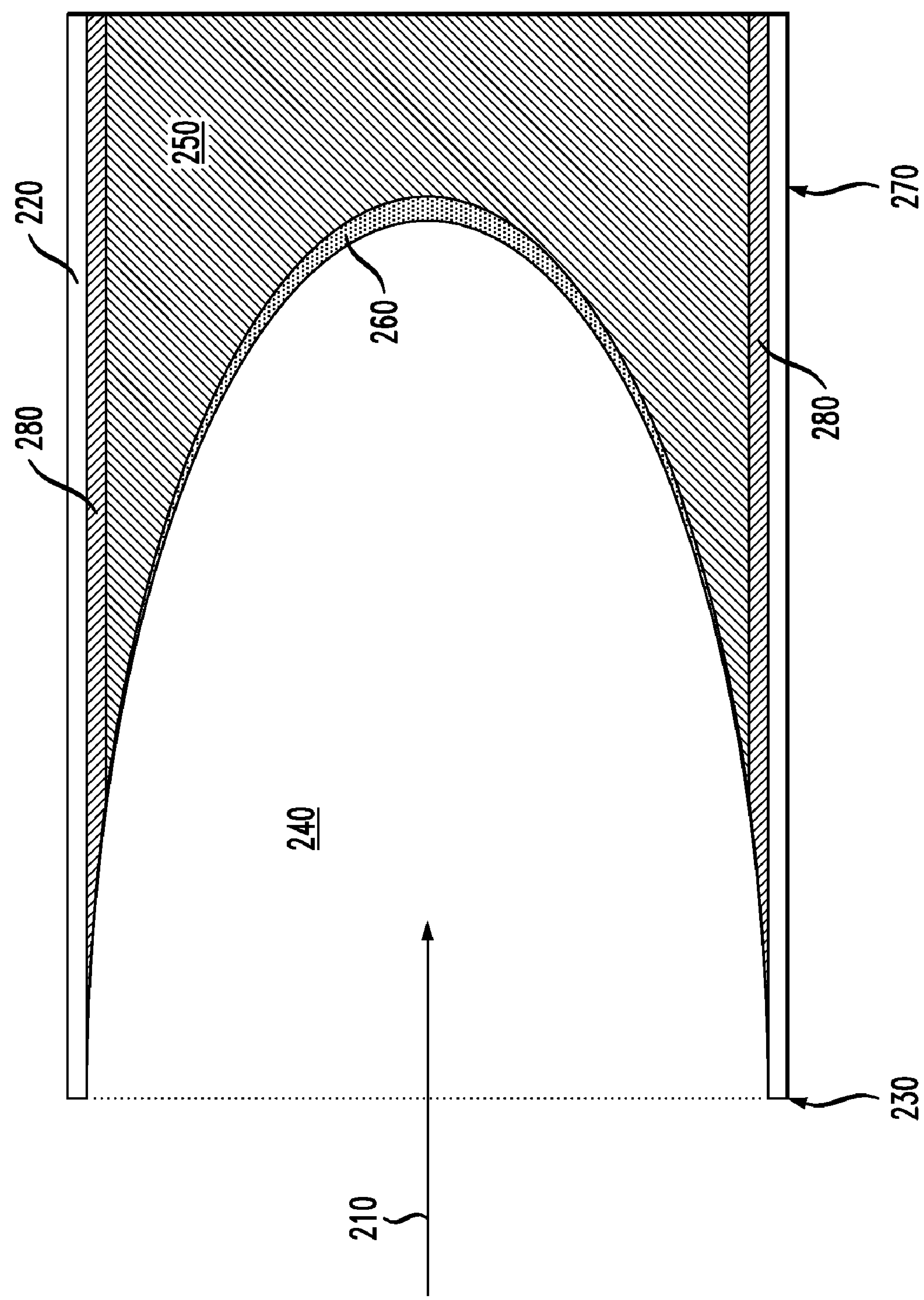


FIG. 2

FIG. 3A

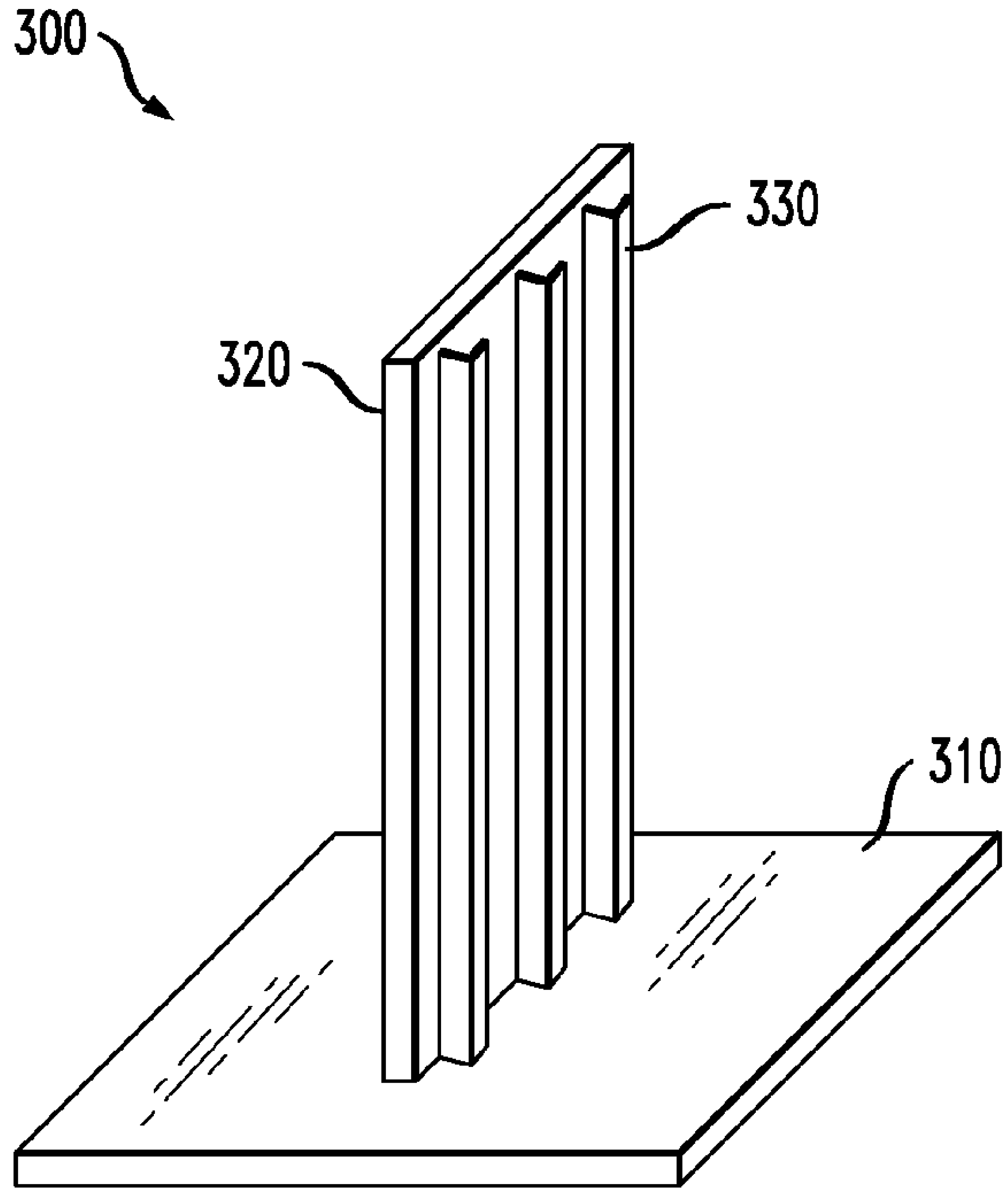


FIG. 3B

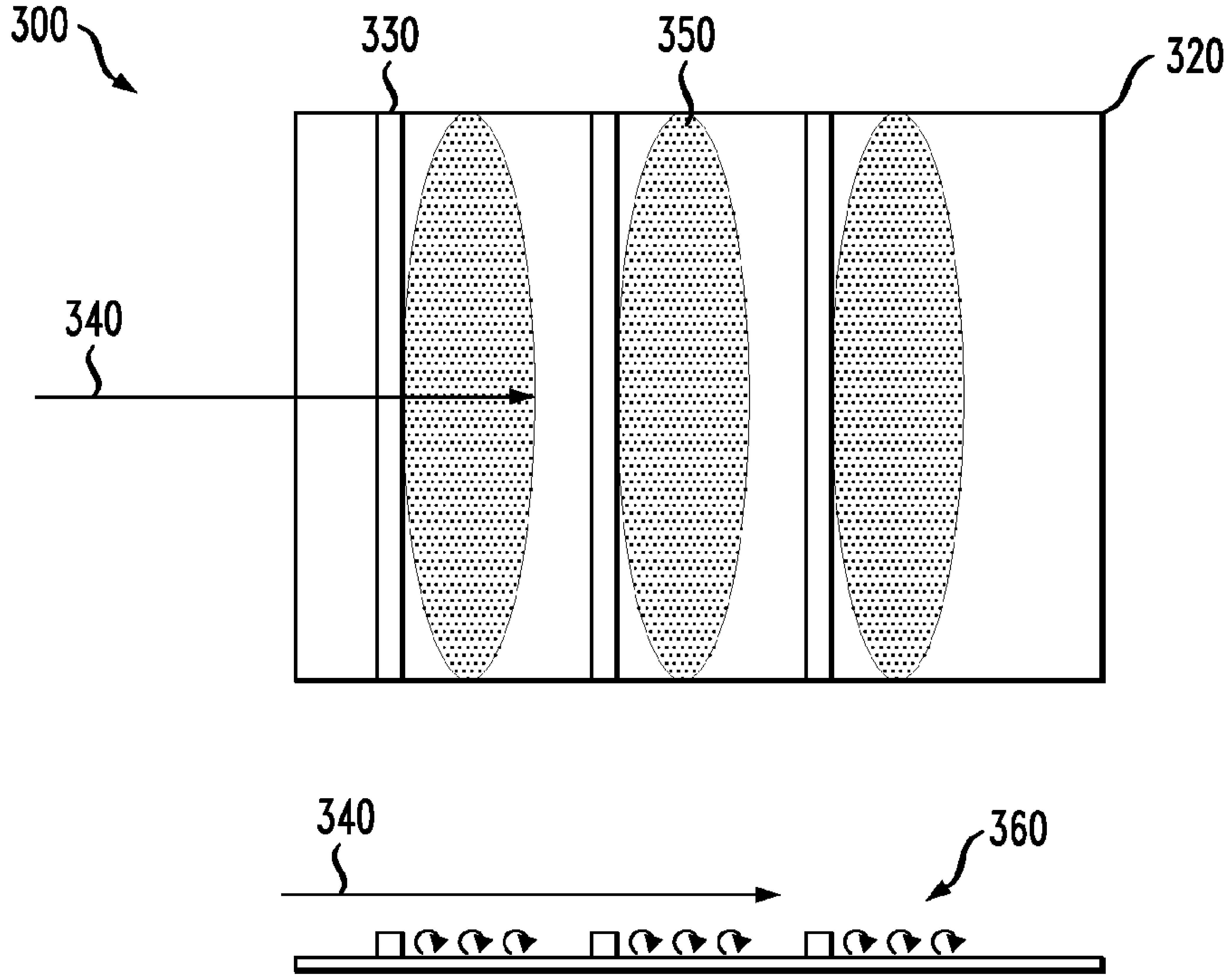


FIG. 3C

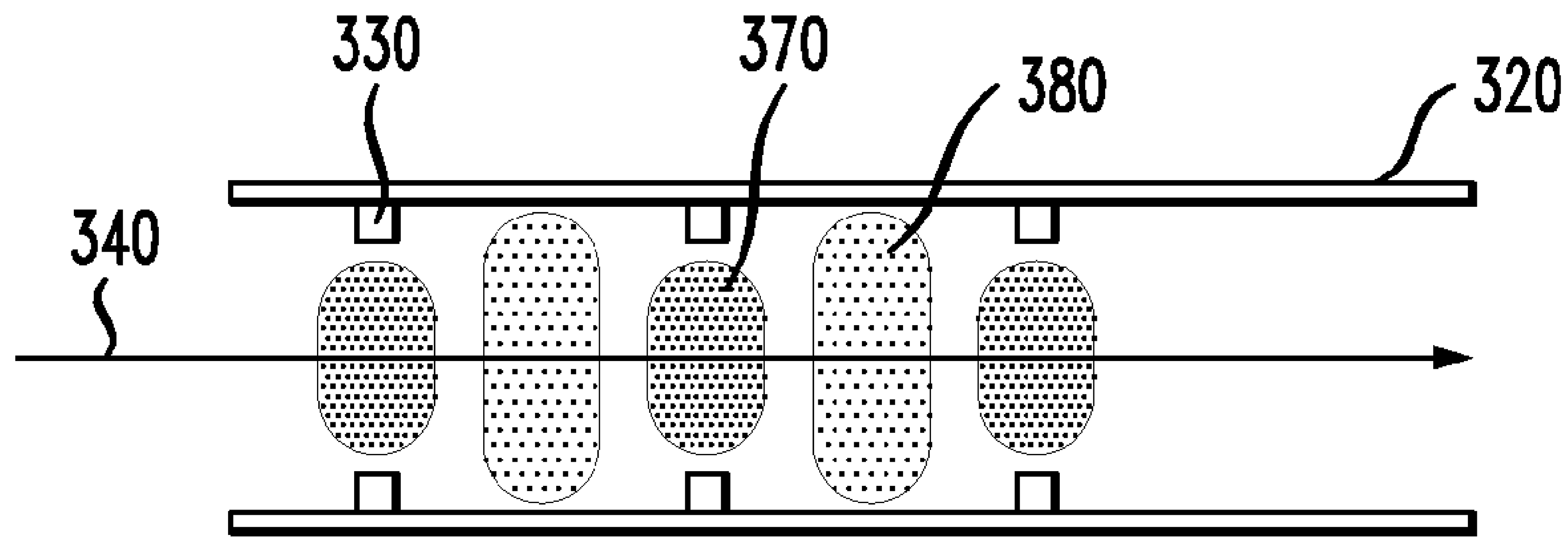


FIG. 3D

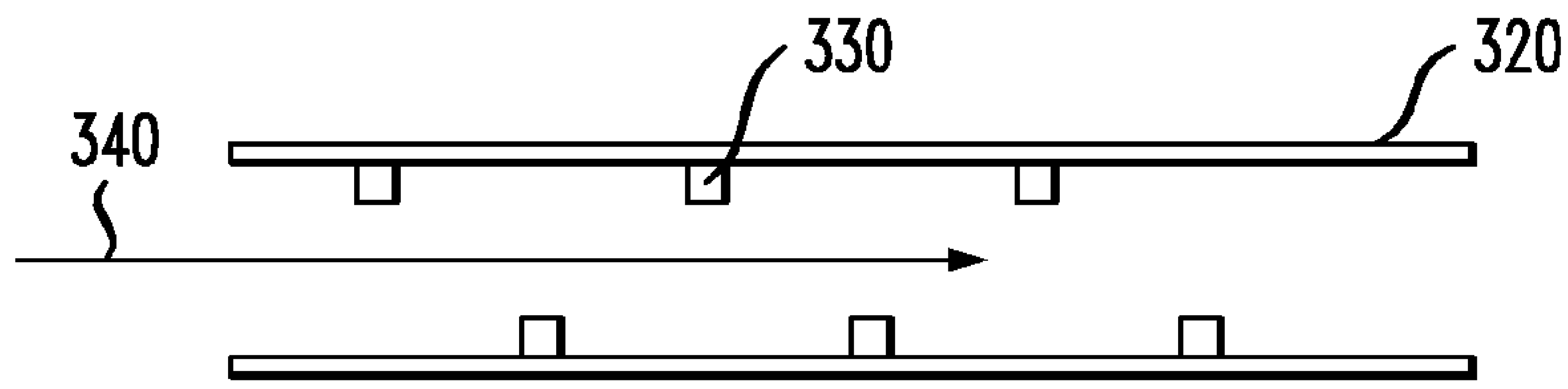


FIG. 4A

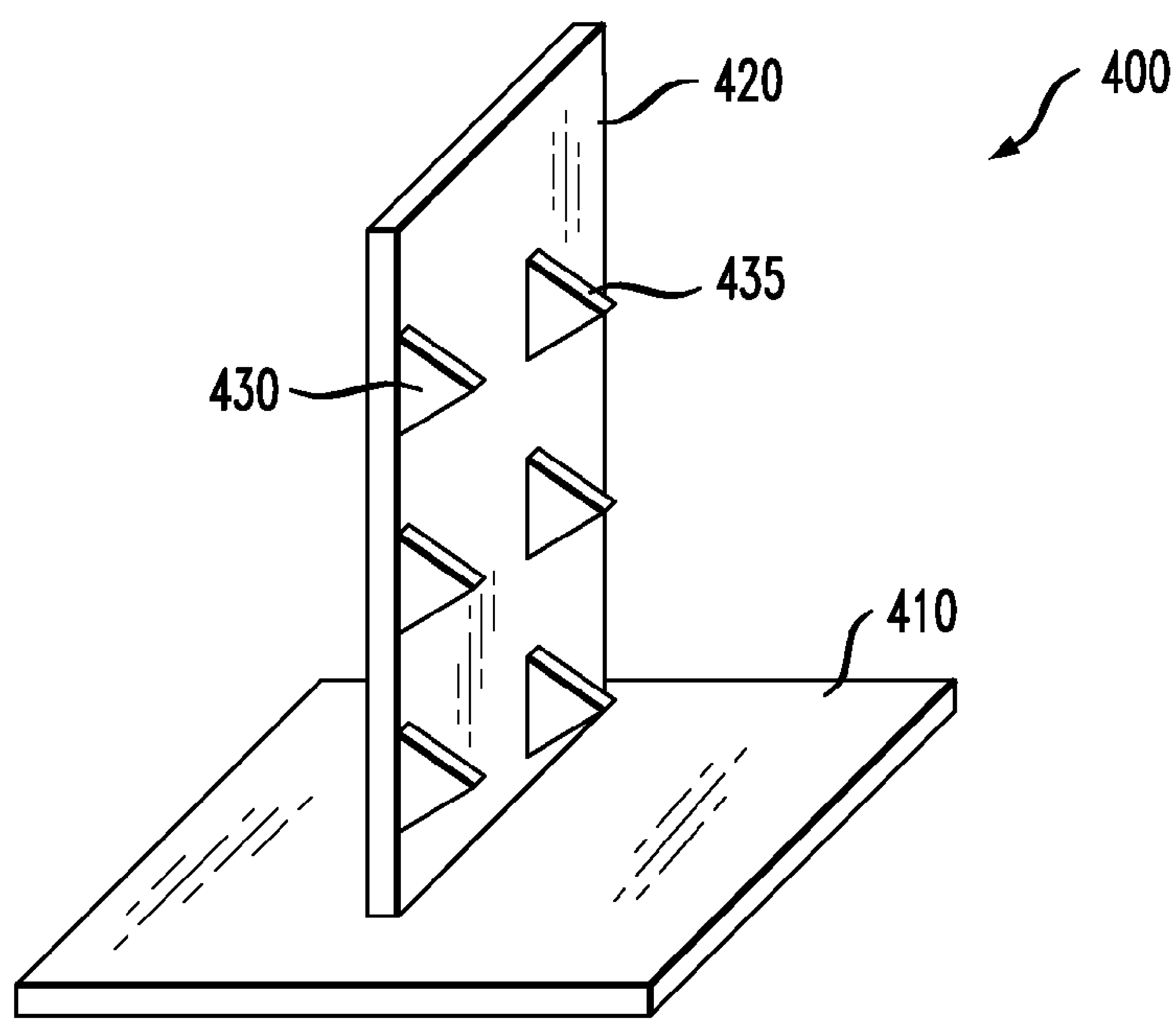


FIG. 4B

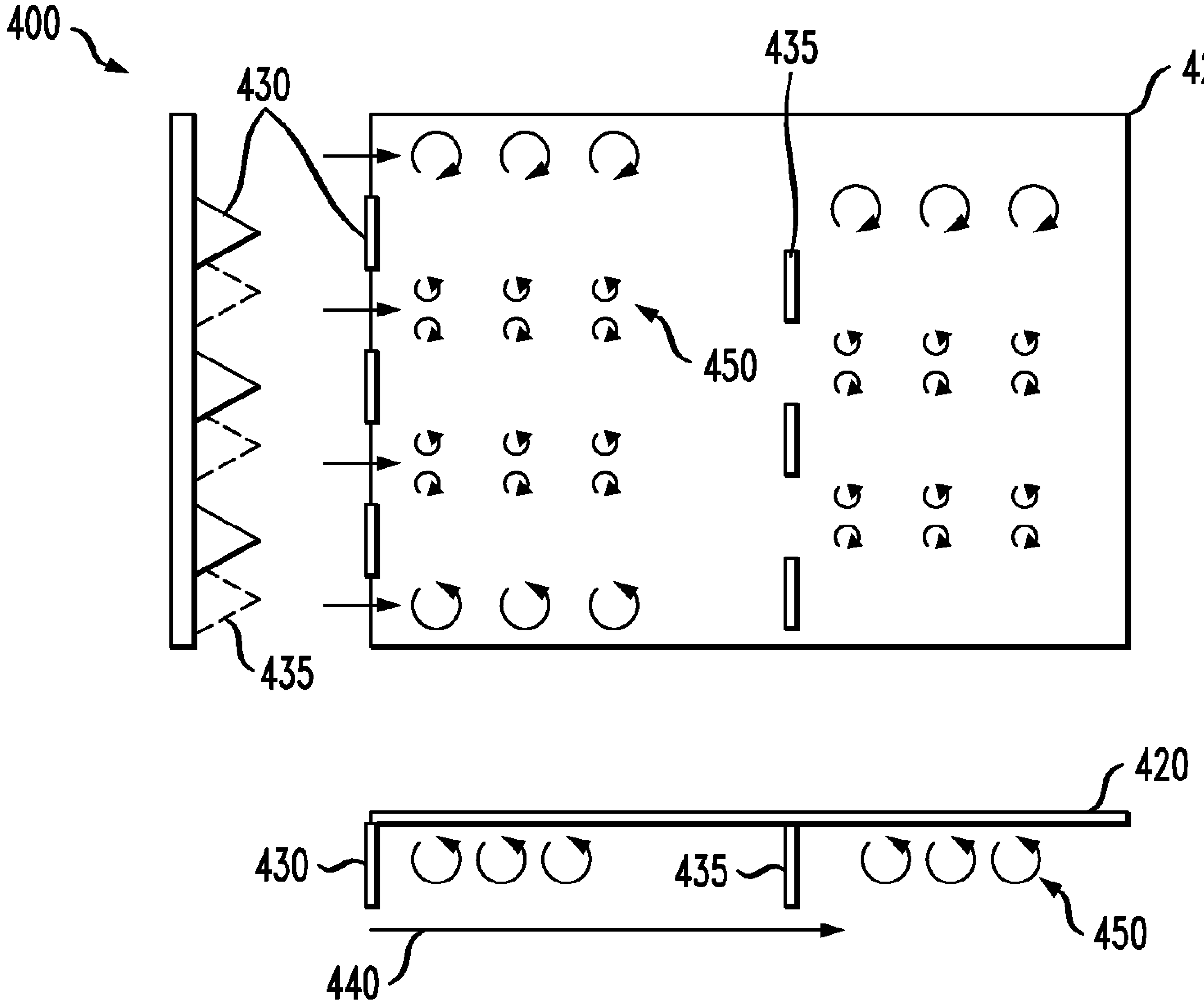


FIG. 5A

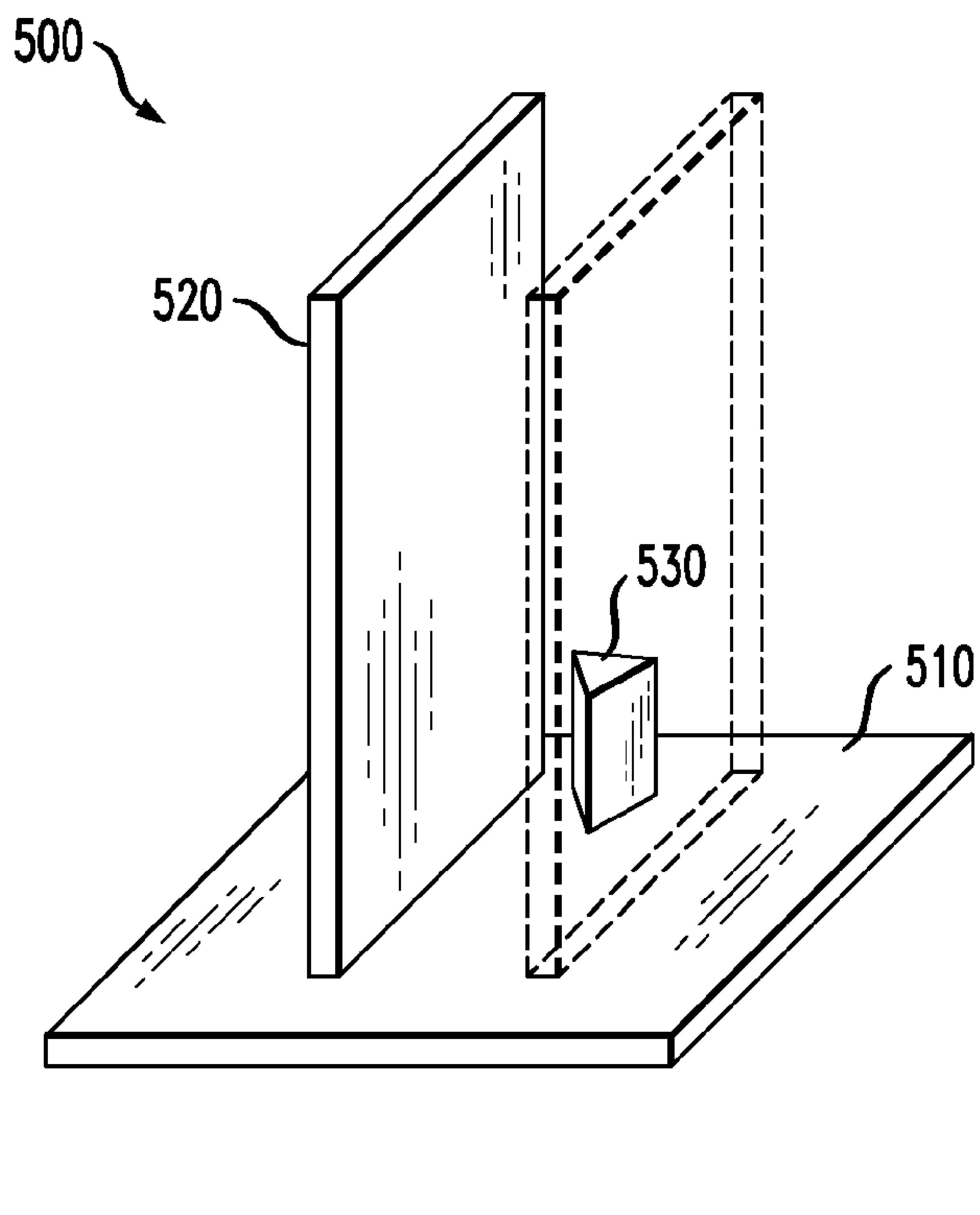


FIG. 5B

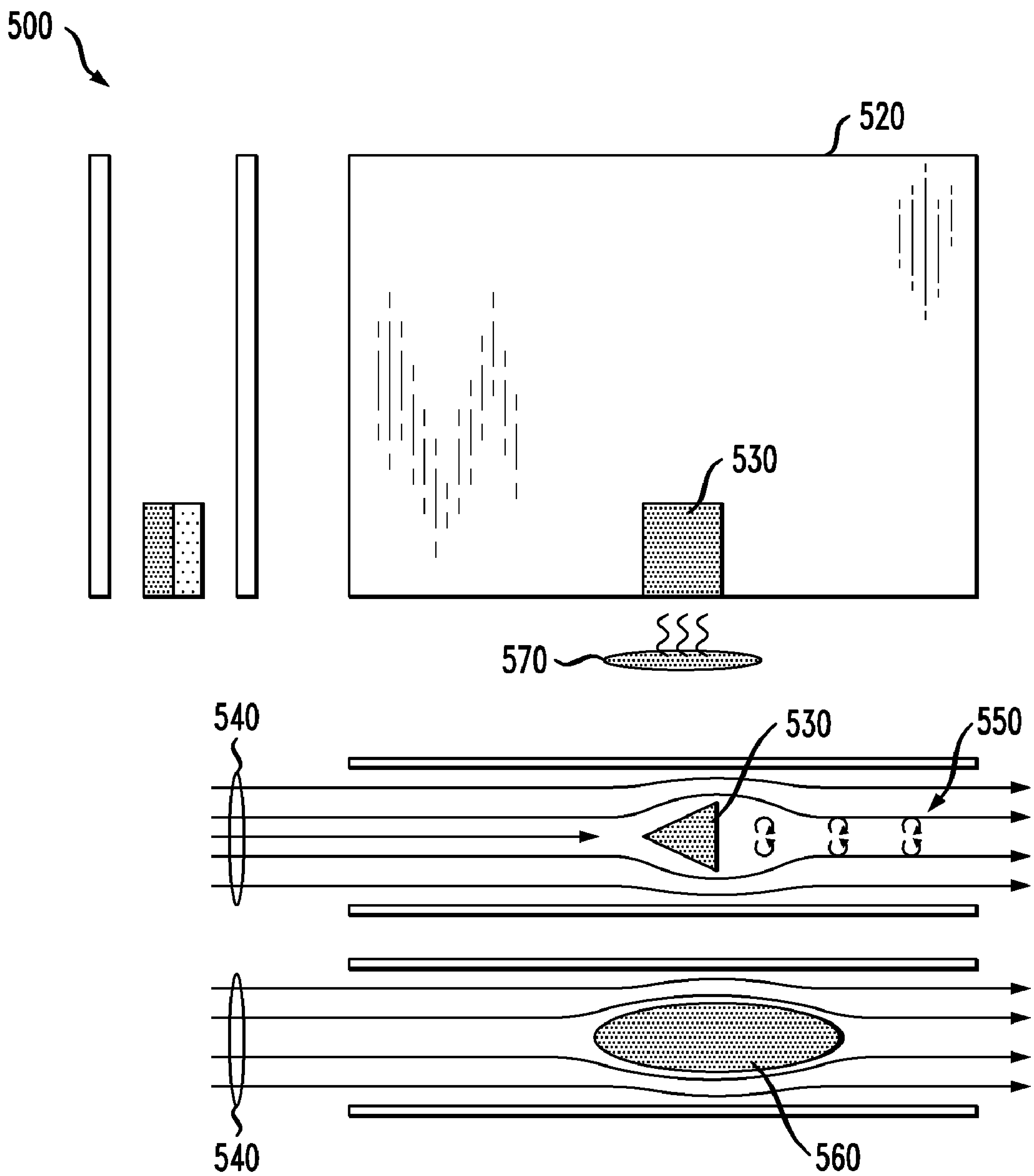


FIG. 5C

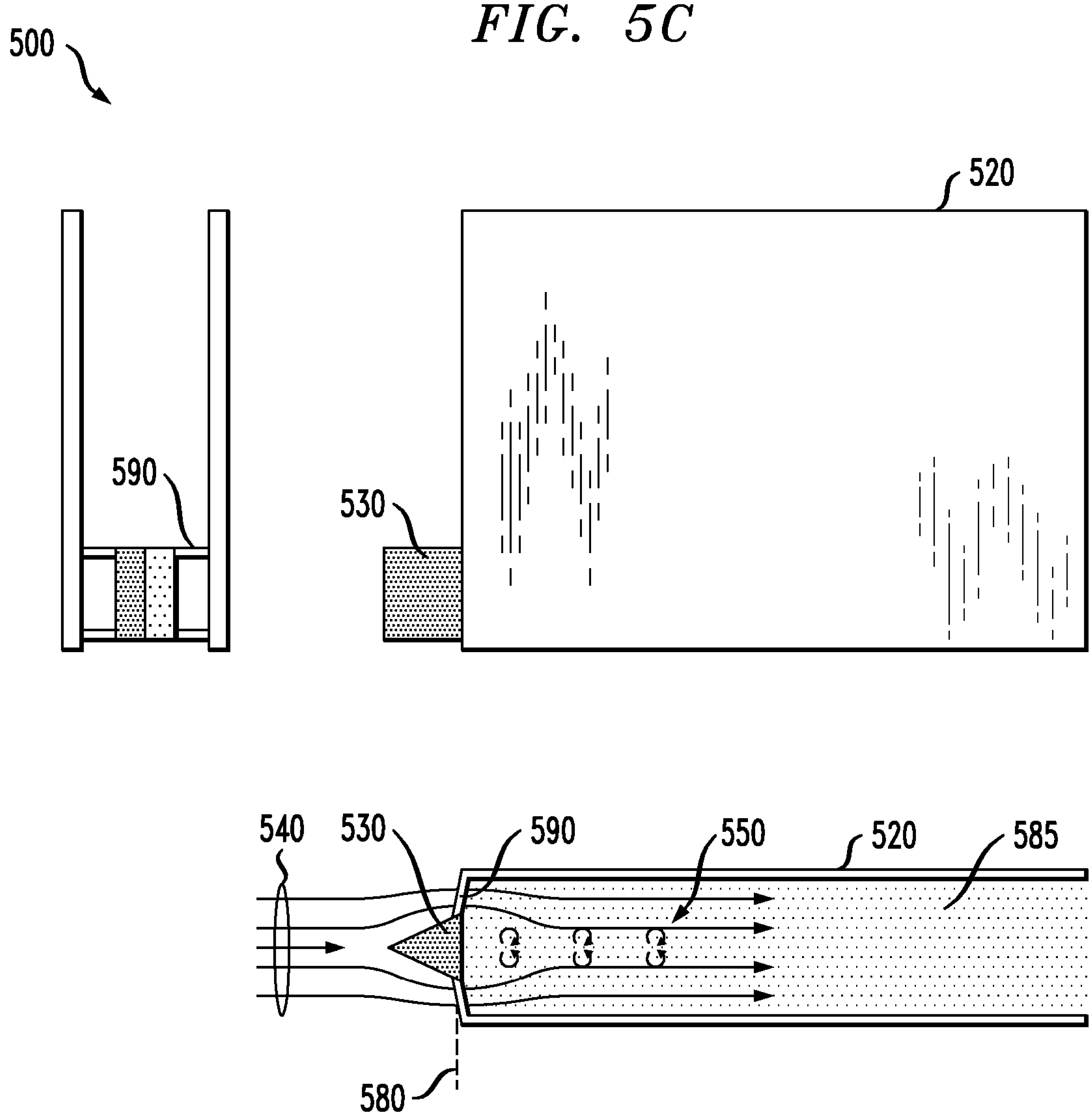


FIG. 6A

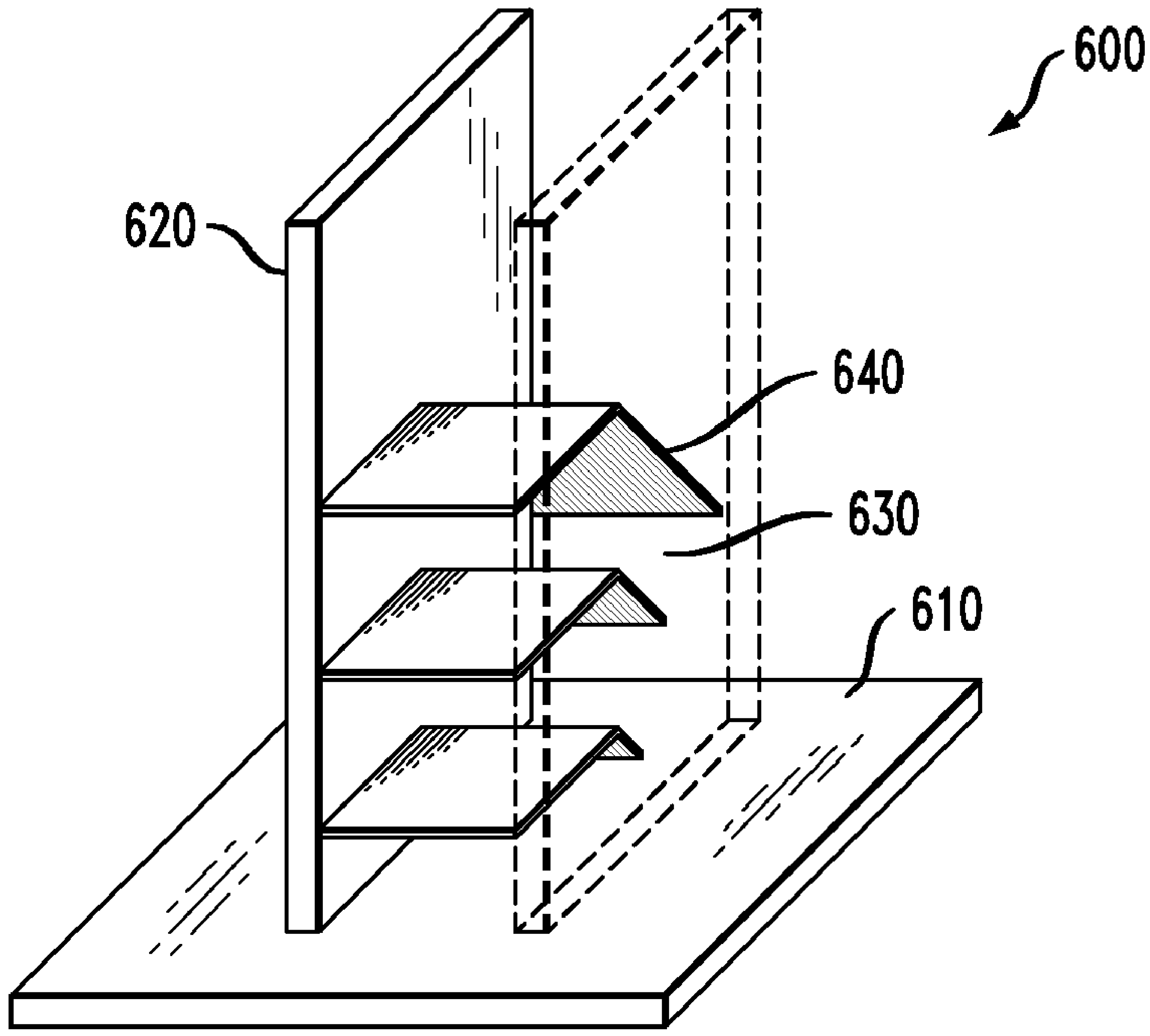


FIG. 6B

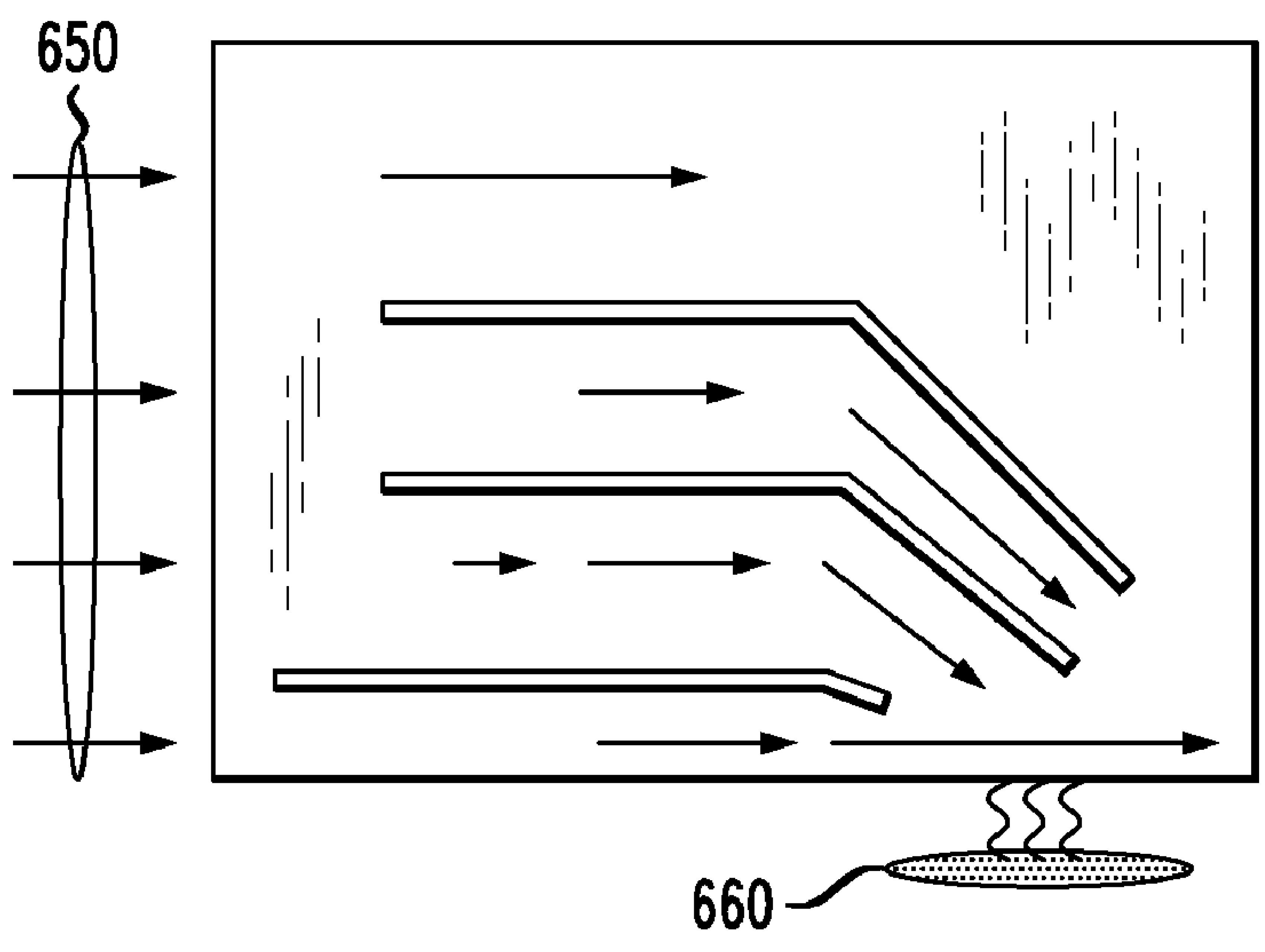


FIG. 6C

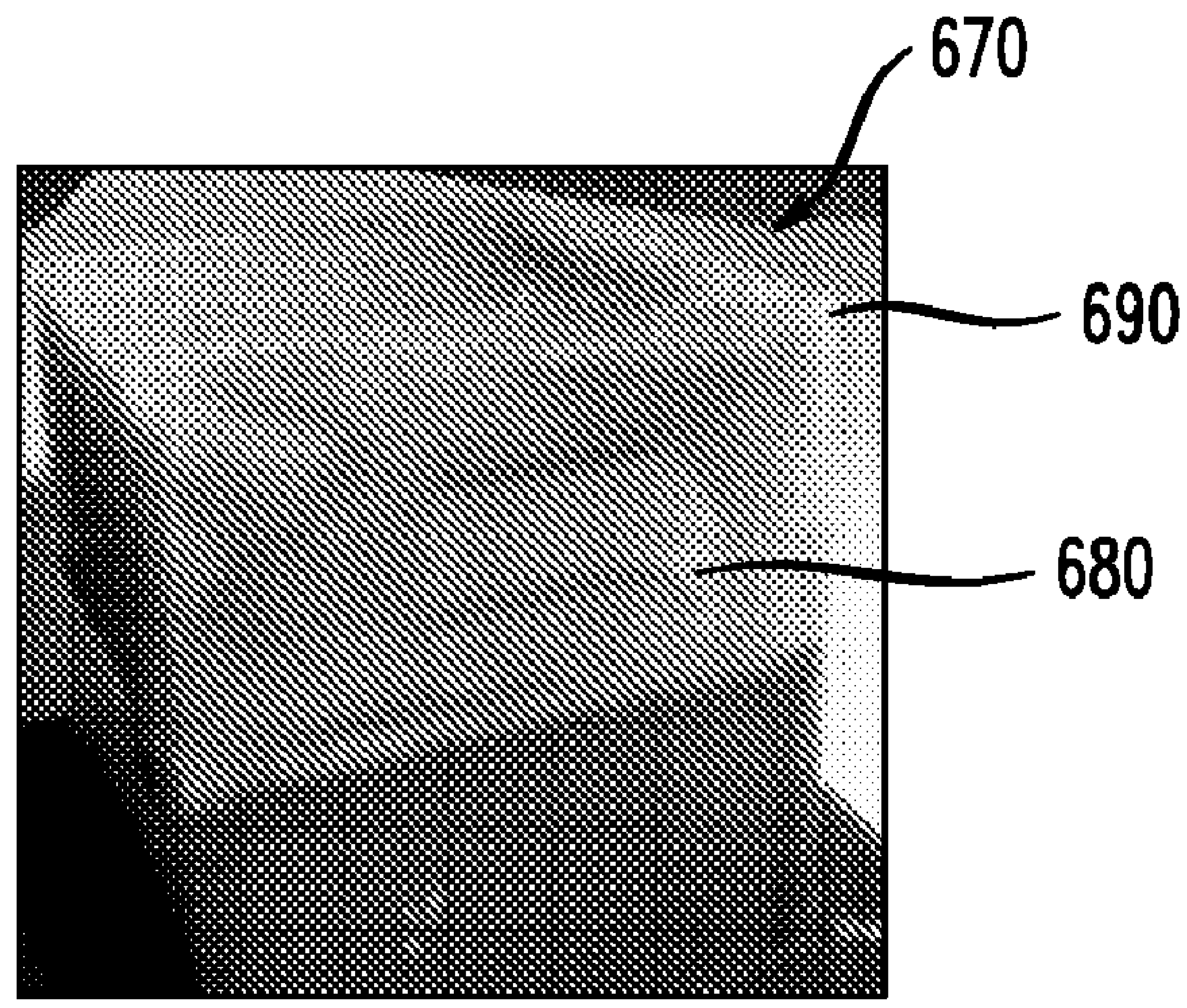
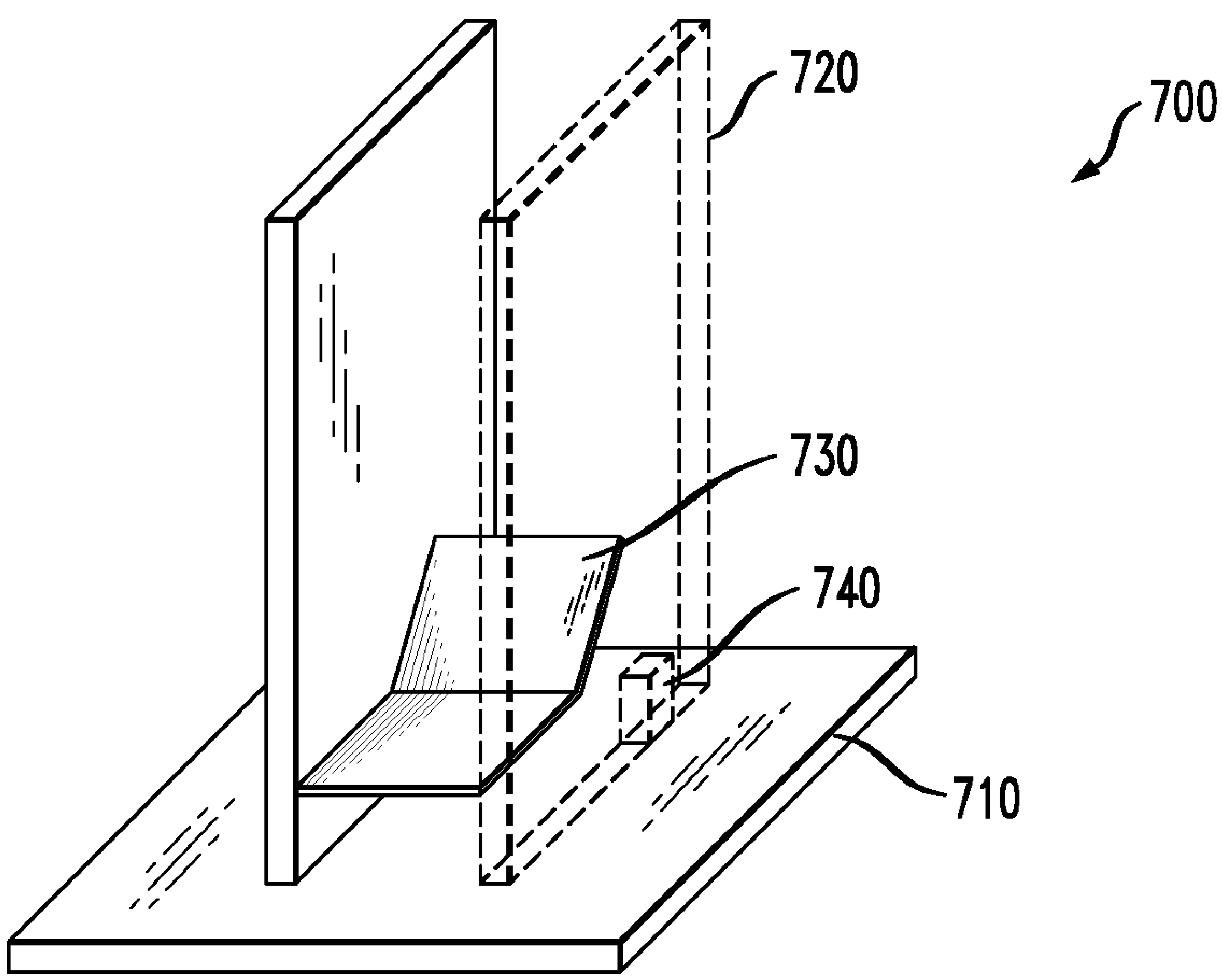


FIG. 7



FLOW DIVERTERS TO ENHANCE HEAT SINK PERFORMANCE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is related to U.S. patent application Ser. No. ______ to Hernon, et al., entitled "Active Heat Sink Designs", and which is commonly assigned with the present application, and U.S. patent application Ser. No. ______ to Hernon, et al., entitled "Monolithic Structurally Complex Heat Sink Designs," both of which are hereby incorporated by reference as if reproduced herein in their entirety.

TECHNICAL FIELD OF THE INVENTION

[0002] The present invention is directed, in general, to heat sinks.

BACKGROUND OF THE INVENTION

[0003] Heat sinks are commonly used to increase the convective surface area of an electronic device to decrease the thermal resistance between the device and cooling medium, e.g., air. Such heat sinks generally employ fins or pins to exchange heat with a fluid (air or liquid) flowing thereover. Some electronic components dissipate enough power that air-cooled heat sinks are becoming inadequate to sufficiently cool these devices. Liquid cooling adds significant costs and reliability concerns to system designs, and is thus undesirable in many cases. Methods of improving the heat transfer efficiency of air-cooled heat sinks are needed to extend their use to higher power components.

SUMMARY OF THE INVENTION

[0004] One embodiment is a heat sink that includes a base and fins attached to the base. A flow diverter is in contact with the base or at least one fin and is configured to disturb a laminar flow region of a fluid flowing adjacent to at least one of the fins or the base.

[0005] Another embodiment is a method that includes providing a heat sink having a base and fins attached thereto. A flow diverter is placed in contact with said fin or said base. The flow diverter is configured to disturb a laminar flow region of a fluid flowing adjacent to at least one of said fins or said base.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various embodiments are understood from the following detailed description, when read with the accompanying figures. Various features may not be drawn to scale and may be arbitrarily increased or reduced in size for clarity of discussion. Various features in figures may be described as "vertical" or "horizontal" for convenience in referring to those features. Such descriptions do not limit the orientation of such features with respect to the natural horizon or gravity. The term "surface" unless otherwise qualified applies to the combined surface of the heat sink, that is, the surface of the base, fins and any projections therefrom. Reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0007] FIG. **1** illustrates a prior art heat sink;

[0008] FIG. **2** illustrates air flow regions between two fins of a heat sink;

[0009] FIGS. **3-5** illustrate embodiments of a heat sink with various configurations of a flow diverter; and

[0010] FIGS. **6** and **7** illustrate embodiments of a heat sink where air flow is diverted vertically with respect to a base.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0011] Embodiments described herein reflect the recognition that structural features may be used in heat sinks that decrease thermal resistance between the heat sink and a fluid e.g., air. In some embodiments, these structural features may be used to produce unsteady flow of air, e.g., in selected portions of the heat sink to disturb laminar flow near surfaces of the heat sink. In other embodiments, features are formed that direct cooler, faster moving air from one region of a heat sink to a region having hotter, slower flow to increase the rate of heat transfer from the hotter regions. In some embodiments, three dimensional (3-D) rendering and investment casting may be employed to form such structural features in a cost-effective manner.

[0012] FIG. **1** illustrates a prior art heat sink **100**. Features of the heat sink **100** include a base **110** and fins **120**. The fins **120** of such heat sinks are typically structurally uniform, e.g., there are no projections or depressions in the surface of the fins **120** other than surface roughness typical of the particular manufacturing method.

[0013] An air stream **130** passes between the fins **120** with little obstruction. It is thought that as air enters the space between two fins, a boundary layer forms near the surfaces of the fins **120** and the base **110**. The boundary layer is a region of airflow adjacent to a surface that contains a velocity gradient. The gradient arises due to the fact that the velocity at the surface is about zero. Outside the boundary layer, in the so-called "free-stream" region, the velocity gradients are small or negligible. Therefore, the flow must go from nearly zero velocity at the wall to the free-stream velocity away from the wall within the boundary layer. The boundary layer acts as a thermal insulator. Thus, in general, the thinner the boundary layer, the lower the thermal resistance between the flowing air and a heat sink element such as a fin **120**.

[0014] FIG. **2** illustrates a schematic view of a nonlimiting model of a fluid **210** flowing between two conventional fins **220** with an opening **230** between them. By convention, the direction of flow of the air stream **210** is downstream, and the opposite direction is upstream. Within a region **240**, the air stream **210** flows with free-stream characteristics. Within a region **250** the air stream **210** flows with boundary layer characteristics. A transition region **260** marks a transition from free-stream characteristics to boundary layer characteristics. The boundary layers begin at the opening **230**. The thickness of the boundary layer region **250** increases with increasing distance from the opening **230** to a point **270**. The boundary layer generally includes a laminar flow region **280** adjacent to the surface of the fin **220** that includes a region of flow parallel to the surface. The laminar flow region may include regions of non-ideal flow, e.g., not exactly parallel to the adjacent surface. Such minor departures from ideal laminar flow are considered laminar flow in the present discussion. The laminar flow region **280** and may include a region of non-parallel flow. At the point **270**, the boundary layer region **250** is fully developed, meaning that essentially all of the air flows in a region of smoothly decreasing velocity gradient with increasing distance from the fins **220**. It is thought that the resistance of heat transfer between the air stream **210** and the fins **220** decreases with increasing boundary layer thickness, and more particularly with increasing thickness of the laminar flow region **280**. At the point **270**, the heat transfer rate is thought to reach a minimum. Thus, the thermal resistance is expected to increase from the opening **230** to a maximum at about the point **270**.

[0015] Embodiments described herein reflect the recognition that a laminar flow region adjacent a heat sink surface, e.g., a surface of a fin or a base, may be disturbed using structural elements, referred to herein as flow diverters. "Disturbed" as applied to a laminar flow region means that the laminar flow region has flow characteristics it would not have in the absence of the flow diverter. Examples of disturbed laminar flow region include, e.g., thinning, flow separation, and flow non-parallel to the adjacent surface.

[0016] Without limitation by theory, the flow diverters are thought to produce vortexes or unsteady flow at the downstream side of the flow diverters. Unsteady flow may include, e.g., vortices and eddies, and transitional, turbulent, unstable, chaotic and resonant airflow. In some cases, a low pressure region is thought to form on the downstream side of a flow diverter. The low-pressure region is thought to cause the fluid to flow in a manner that impinges on the laminar flow region adjacent the surface, e.g., the laminar flow region **280**. Such diversion of, e.g., a fluid stream causes diverts the fluid from a greater distance above the surface to a lesser distance above the surface. Because the thermal resistance of the heat sink is in part a function of the thickness of the laminar flow region, the impinging may have the effect of increasing the rate of heat transfer between the fluid and the heat sink. The flow diverters may be configured to reduce thermal resistance of a portion of a heat sink or the entire heat sink. For example, it may be desirable to reduce thermal resistance of only a portion of a heat sink located proximate a region of an electronic device that generates more heat than other regions of the device.

[0017] FIG. **3**A illustrates one embodiment of a heat sink **300** having a base **310** and a fin **320** formed thereon. Flow diverters **330** are attached to the fin **320**. FIG. **3**B illustrates the fin **320** in plan view and sectional view. An fluid stream **340** flows past the flow diverters **330**. The fluid stream **340** may a gas or a liquid, and may be used to transfer heat to or from a heat sink, depending on the application. For simplicity of discussion a fluid stream is referred to herein after as an air stream, while recognizing that other gases or liquids may be used as a heat exchange medium. Furthermore, heat is referred to as being extracted from the heat sink, while recognizing heat could be extracted by the heat sink from the fluid stream.

[0018] In this embodiment of FIG. **3**A, the flow diverters **330** are square cylindrical elements having a length equal to or less than the height of the fin **320** above the base **310**. The flow diverters **330** may have any desired cross-sectional profile, e.g., circular, square or triangular. Any shape that has the effect of causing a portion of the air stream **340** to impinge on a laminar flow region proximate the surface of the base **310** or the fin **320** is within the scope of this discussion. The flow diverters **330** are also stationary with respect to the fin **320**. In other embodiments, the flow diverters **330** may be an active element as described in U.S. patent application Ser. No. ______. (Hernon 1) There may be one or a plurality of flow diverters **330** on a fin **320**, and a particular heat sink may have flow diverters **330** formed on one or a plurality of fins **320**. Flow diverters **330** may be spaced at regular or uneven intervals on the fin **320**, and when present on adjacent fins and projecting into the same inter-fin space, may be aligned as illustrated in FIG. **3**C or staggered as illustrated in FIG. **3**D.

[0019] The flow regime of air or other cooling fluid through a heat sink may be characterized by a Reynolds number associated with the heat sink and the flowing fluid. As known by those skilled in the pertinent art, a Reynolds number describes the relationship between inertial forces and viscous forces in a fluid system. Laminar flow occurs when a fluid flows in parallel layers with little or no disruption between the layers. This flow regime is associated with a low Reynolds number. Turbulent flow is characterized by random eddies, vortices and other flow fluctuations, and is associated with a high Reynolds number. A transition regime between laminar and turbulent flow may be characterized by more predictable but non-uniform flow, such as vortices and eddies that are fairly stable over time. Thus, providing a heat sink with flow diverters may be viewed as increasing the Reynolds numbers associated with flow of the cooling fluid through the heat sink.

[0020] Turbulent flow is generally associated with greater resistance to flow of fluid. In the context of heat sinks, greater flow resistance translates to a greater pressure drop across the heat sink. In some cases, a greater pressure drop is undesirable. In such cases, the flow diverters **330** may be configured to produce non-uniform flow, but not turbulent flow. In general, such a configuration must be determined experimentally for a combination of cooling fluid, velocity of the fluid, and the configuration of the heat sink.

[0021] FIG. **3**B illustrates unsteady flow of an air stream **340** over the flow diverters **330**. The flow diverters **330** are thought to form a low-pressure region **350** downstream of the flow diverters **330** due to, e.g., flow separation. The low pressure region **350** may produce a standing wave or vortexes **360** at the downstream side of the flow diverters **330** depending on, e.g., the Reynolds number associated with the geometry of the heat sink **300** and the velocity of the air stream **340**. The standing wave or vortexes **360** include a flow direction component normal the surface of the fin **320**. This normal flow may have the effect of compressing the laminar flow region proximate the surface of the fin **320**, thus reducing the thermal resistance between the fin **320** and the air stream **340**.

[0022] FIG. **3**C illustrates an embodiment in which the flow diverters **330** are configured to cause air flow through the heat sink **300** to be resonant. In this nonlimiting example, the flow diverters **330** cause a standing pressure wave resulting in regions of differing pressure, e.g., low pressure regions **370** and high pressure regions **380**. The formation of the standing wave is expected to occur at a range of velocity of the air stream **340** that is dependent on the geometry of the fins **320** and the flow diverters **330**. The flow diverters **330** may be configured to form the low pressure regions **370** and the high pressure regions **380** at positions that result in reduction of the thermal resistance between the fins **320** and the air stream **340** near a portion of the heat sink **300** at which lower thermal resistance between the heat sink **300** and the air stream **340** is desired.

[0023] FIG. **3**D illustrates an embodiment in which the flow diverters **330** are placed on opposing faces of fins **320** in a staggered configuration. In some cases, it is thought that staggering the flow diverters **330** may aid the formation of a desired air flow characteristic, e.g., unsteady or resonant air flow, at a particular flow velocity of the air stream **340**. Configurations of the flow diverters **330** may be combined in any desired manner within a heat sink to result in the desired flow characteristics. A configuration may be determined, e.g., by wind-tunnel analysis or numerical modeling.

[0024] Turning to FIG. **4**A, illustrated is an embodiment of a heat sink **400** including a base **410** and a fin **420** thereon. A number of flow diverters **430** are placed at the leading edge of the fin **420**. These flow diverters **430** present a 2-D profile to an air stream (in the plane of the fin **420**), in contrast to the flow diverters **330**, which present a 1-D profile. In some cases, the length of the flow diverters **430** in the plane of the fin **420** is less than about 2 the height of the fin **420**. Thus, multiple flow diverters **430** may be placed in a line with space between them, as illustrated in FIG. **4**A. In some cases, flow diverters **435** may be placed on the fin **420** downstream of the leading edge of the fin **420** instead of or in addition to the flow diverters **430**.

[0025] FIG. **4**B illustrates the fin **420** in plan view and sectional view. An air stream **440** flows past the flow diverters **430**. The flow diverters **430** cause unsteady flow on the downstream side, illustrated without limitation as vortexes **450**. In this case, the vortexes **450** have a more complex motion due to the fact that the flow diverters **430** present a two-dimensional cross-section to the air stream **440**. The vortexes **450** are thought to have a direction component parallel and a direction component normal to the surface of the fin **420**. It is believed that in some flow regimes this motion is particularly effective at reducing thermal resistance between the fin **420** and the air stream **440**.

[0026] As mentioned above, flow diverters **435** may be placed downstream of the leading edge of the fin **420** in addition to the flow diverters **430**. These downstream flow diverters **435** may be aligned with upstream flow diverters **430** or they may be staggered, as illustrated, causing air to take a more tortuous path between the fins **430**.

[0027] Turning to FIG. **5**A, illustrated is a heat sink **500** having a base **510** and two fins **520**. A flow diverter **530** is attached to the base **510** between the fins **520**. The flow diverter **530** has, e.g., a triangular cross section in the plane of the base, but could have any other desired cross section, such as circular, elliptical, square, or a more complex cross section. The flow diverter **530** may have any height above the base **510**, though typically the height will be less than or equal to the height of the fin **520**. One flow diverter **530** is illustrated, but other embodiments include multiple flow diverters **530** between the fins **520**. Multiple flow diverters **530** may be the same or different heights, or have the same or different cross sectional profiles.

[0028] FIG. **5**B illustrates plan and sectional views of the fins **520**. The embodiment **500** has a single triangular flow diverter **530** with an air stream **540** impinging thereon. Air is forced to flow between the flow diverter **530** and the fin **520**, thereby increasing its velocity. The greater air speed parallel to the fin **520** is thought to cause the laminar flow region proximate the fin **520** to thin, thus reducing the thermal resistance between the air stream **540** and the fin **520**.

[0029] When a flow diverter **530** has an abrupt transition downstream of the leading edge, such as for the illustrated triangular flow diverter **530**, vortexes **550** may be formed. In some cases, such vortexes may be undesirable, such as when induced drag associated with the vortexes **550** increases the pressure drop across the heat sink.

[0030] An alternate embodiment is illustrated in FIG. **5**B in which a flow diverter **560** has an elliptical or streamlined cross section. In one embodiment, the flow diverter is configured as an elliptical airfoil. In each of these embodiments, the air stream **540** is forced to flow faster between the flow diverter and the fins **520** as before. However, the streamlined profile of the flow diverter **560** reduces the formation of vortexes at the downstream side, resulting in lower drag. This lower drag is expected to reduce the pressure drop across the heat sink **500**, improving heat transfer relative to the heat sink **500** using the triangular flow diverter **530**.

[0031] FIG. **5**C illustrates an embodiment in which the flow diverter **530** is positioned at a location **580** upstream of the fins **520** and outside a volume **585** bounded by the fins **520**. The volume **585** is that volume between the fins **520** that does not extend beyond the terminus of the fins **520**. The flow diverter **530** is attached to the fins **520** by, e.g., supports **590**. The flow diverter **530** may be any shape and may be placed in any position relative to the fins **520** that disturbs laminar flow of the air stream **540** adjacent to the fins **520**. In another embodiment, not shown, the flow diverter **530** is attached to a portion of the base, e.g., the base **510**, that extends beyond the terminus of the fins **520**.

[0032] In each of the embodiments illustrated in FIG. **3**, FIG. **4**, and FIG. **5**, the flow diverters may optionally be placed at a position downstream of the leading edge of the fin (e.g., fin **320**, **420**, **520**) to reduce thermal resistance between the fin and the air stream in the vicinity of a hot spot. A hot spot is a region of relatively greater heat flux from an integrated circuit, e.g., relative to the surrounding areas of the circuit. By so placing the flow diverter, thermal resistance may be reduced in a portion of the heat sink where the lower resistance is particularly beneficial, while minimizing the number of flow diverters to reduce resulting pressure drop.

[0033] Returning briefly to FIG. **5**B, an embodiment is illustrated in which the flow diverter **530** is placed over a hot spot **570**. It is expected that the heat flux from the hot spot **570** will be partially localized to the portion of the fins **520** immediately above the hot spot **570**. Therefore, reducing the thermal resistance between the fins **520** and the air stream **540** by decreasing the thickness of the laminar flow region in the vicinity of the hot spot **570** is expected to be particularly beneficial.

[0034] In some cases, the flow diverter (e.g., flow diverter **330**, **430** or **530**) may be placed near the point where the boundary layers between fins become fully developed. Referring to FIG. **2**, this point would be, e.g., about at the point **270**. Placement of the flow diverter near this point is thought to be particularly beneficial in some cases in that the number of flow diverters in an air path may be reduced. The effect of drag caused by the flow diverter may be balanced against the benefit of disrupting laminar flow regions by only placing the flow diverters at points of convergence of the boundary layers. Depending on factors such as fin spacing and the length of the path between the fins, two or more points of boundary layer convergence may possible in the path of air flow between the fins. In an embodiment, a flow diverter is placed at each convergence point in an air path.

[0035] In each of the illustrated embodiments, the flow diverters may or may not be integral to the structure of the heat sink. When a flow diverter is not integral, it may be, e.g., a metal or plastic portion affixed to the remaining portion of the heat sink. The flow diverter may be affixed by adhesive, welding, or brazing, e.g., or in some cases may simply be held in place by friction. In some cases, it may be desirable to use a heat transfer agent such as thermal grease to increase thermal coupling between the flow diverter and the remaining portion of the heat sink.

[0036] When the flow diverter is integral to the heat sink, the heat sink and the flow diverter may be formed as a monolithic structure, e.g., by the method of three dimensional (3-D) printing and investment casting. Such a method is disclosed in U.S. patent application Ser. No. ______ (Hernon 3). Briefly described, the method provides for using a 3-D printer to produce a sacrificial form of a heat sink. The form is used to fashion a mold, and is then melted or vaporized out of the mold. The mold is then used to form the final heat sink. This method provides the ability to form detailed 3-D patterns that might not be manufacturable by conventional methods, such as machining, die casting, folding or skiving. Moreover, the structural features are extensions of a single physical entity, e.g., a polycrystalline metallic casting. In addition to forming structural details not amendable to other methods, a monolithic structure is expected to reduce thermal resistance within the heat sink, making a greater surface area available to transfer heat to the air stream.

[0037] Turning to FIG. **6**A, illustrated is an embodiment of a ducted heat sink **600** in a projection view. The heat sink **600** includes a base **610** and fins **620** thereon. Air flow is diverted by one or more ducts **630** between the fins **620**. The ducts **630** may be formed by planar segments **640**, as illustrated, or any other desired shape, such as smoothly curved surfaces.

[0038] As illustrated in FIG. **6**B, in plan view, the ducts **630** divert an air stream **650** from a direction generally parallel to the base **610** to a direction having a component normal to the base **610**. Thus, cooler, faster air from a portion of the heat sink **600** further from the base **610** may be diverted to a region of warmer, slower air nearer to the base **610** at a hot spot **660**. Moreover, because the air diverted by the one or more ducts **630** joins the flow of air near the base **610**, a greater volume of air per unit time may be caused to flow over the hot spot **660** than may otherwise occur absent the ducts **630**.

[0039] FIG. **6**C illustrates a sacrificial form **670** of the heat sink **600** formed by **3**-D printing. Ducts **680** may be seen through the semi-transparent fins **690** of the form **670**. As described previously, the form **670** may be used to render the heat sink **600** in, e.g., a metal to produce a monolithic heat sink with the ducts **680** in a practical and efficient manner.

[0040] FIG. **7** illustrates an embodiment of a heat sink **700** having a base **710** and fins **720** thereon. A flow diverter **730** directs air flow from a lower level of the heat sink **700** to a higher level. The fin **720** also includes an optional opening **740** formed therein. The flow diverter **730** and the opening **740** may be positioned to allow cooler air from one portion of the heat sink **700** to flow through the fin **720** due to a pressure differential formed on the downstream side of the flow diverter **730**. The cooler air can then displace or mix with warmer air in the vicinity of a hot spot, e.g., thereby increasing the rate of heat removal from the hot spot. Optionally, another flow diverter may be positioned on the side of the fin **720** opposite the flow diverter **730** to direct air into the opening **740**. Without limitation, the investment casting method described above is well-suited to economically forming such features at the scale of heat sinks used to cool electronic components.

[0041] The various embodiments described herein may be combined in any desired manner to result in a desired air flow characteristic from a heat sink. Moreover, while the embodiments are described with respect to parallel-fin heat sinks, the embodiments may be practiced with heat sinks of other geometries where thermal resistance may be reduced by disturbing laminar flow regimes near a surface of the heat sink. Although the present invention has been described in detail, those skilled in the art should understand that they can make various changes, substitutions and alterations herein without departing from the spirit and scope of the invention in its broadest form.

What is claimed is:

1. A heat sink comprising:
a base;
fins attached to said base; and
a flow diverter in contact with said base or at least one of said fins and configured to disturb a laminar flow region of a fluid flowing adjacent to at least one of said fins or said base.

2. The heat sink as recited in claim **1**, wherein said flow diverter is configured to divert said fluid from a greater distance above a surface of said heat sink to a lesser distance above said surface.

3. The heat sink as recited in claim **1**, wherein said heat sink is in thermal contact with a device configured to dissipate heat, and said flow diverter is configured to direct said fluid from a region of relatively lower power dissipation by said device to a region of relatively greater power dissipation by said device.

4. The heat sink as recited in claim **1**, wherein said flow diverter comprises a duct between two of said fins.

5. The heat sink as recited in claim **1**, wherein said flow diverter is configured to produce unsteady flow in said fluid.

6. The heat sink as recited in claim **1**, wherein said flow diverter is located on said base between two of said fins.

7. The heat sink as recited in claim **6**, wherein a height of said flow diverter is less than a height of said fins.

8. The heat sink as recited in claim **6**, wherein said flow diverter has a streamlined profile.

9. The heat sink as recited in claim **1**, wherein said flow diverter is attached to said base or said fin and positioned upstream of said fin and outside a space bounded by said fins.

10. The heat sink as recited in claim **1**, wherein said flow diverter is a monolithic feature of said heat sink.

11. The heat sink as recited in claim **1**, further comprising an opening in said surface, wherein said flow diverter is configured to direct said fluid through said opening.

12. The heat sink as recited in claim **1**, wherein said flow diverter is an active element.

13. A method, comprising:
providing a heat sink having a base and fins attached thereto;
placing a flow diverter in contact with said fin or said base; and
configuring said flow diverter to disturb a laminar flow region of a fluid flowing adjacent to at least one of said fins or said base.

14. The method as recited in claim **13**, wherein said flow diverter is configured to divert said fluid from a greater distance above said base to a lesser distance above said base.

15. The method as recited in claim **13**, further comprising placing said heat sink in thermal contact with a device configured to dissipate heat, wherein said flow diverter is configured to divert said fluid from a region of relatively lower power dissipation by said device to a region of relatively greater power dissipation by said device

16. The method as recited in claim **13**, further comprising configuring a duct between two of said fins to divert said fluid.

17. The method as recited in claim **13**, further comprising configuring said flow diverter to produce unsteady flow in said fluid.

18. The method as recited in claim **13**, further comprising locating said flow diverter on said base between said fins and configuring said flow diverter to have a height less than a height of fins.

19. The method as recited in claim **13**, further comprising forming said flow diverter, said base and said fins as a monolithic structure.

20. The method as recited in claim **13**, wherein said flow diverter is an active element.

21. The method as recited in claim **13**, wherein said fluid is air.

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