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(71) Applicant *(for all designated States except US)*: **MEMPILE INC.** [US/US]; C/O PHS Corporate Services, Inc., Suite 5100, 1313 N. Market Street, Wilmington, Delaware 19801 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **LIVSHITS, David** [IL/IL]; 17/13 Hatsionut Street, 77452 Ashdod (IL). **ALPERT, Ortal** [IL/IL]; 16 Ha'arazim Street, 96182 Jerusalem (IL). **SALOMON, Yair** [IL/IL]; 33/1 Bitsur, 96400 Jerusalem (IL).

(74) Agent: **REINHOLD COHN AND PARTNERS**; P.O.B. 4060, 61040 Tel-Aviv (IL).

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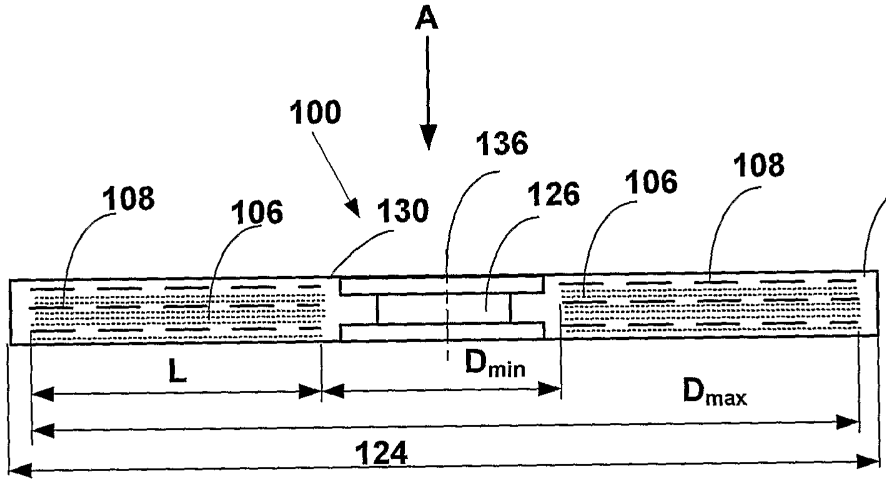
(54) Title: A THREE DIMENSIONAL OPTICAL INFORMATION CARRIER AND A METHOD OF MANUFACTURING THEREOF



(57) Abstract: A three dimensional optical information carrier is presented. The information carrier comprises formatting marks disposed on the nodes of a predefined three dimensional grid in the body of the carrier.

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A THREE DIMENSIONAL OPTICAL INFORMATION CARRIER AND A METHOD OF MANUFACTURING THEREOF

FIELD OF THE INVENTION

The present invention is generally in the field of optical memory devices, and relates to a three dimensional carrier for recording, reading and erasing of information and a method of manufacturing the carrier.

BACKGROUND OF THE INVENTION

Optical storage is one of the most popular information storage methods. The information is recorded, stored, read and erased on the three-dimensional storage media usually having the form of a disc. Carriers may be monolithic disc-like bodies made of a transparent or translucent polymer material or laminated of a number of plates made of the same material. The information is recorded on a carrier as series of three-dimensional (3D) regular marks or oblong and tilted data marks such as ones disclosed in WO 2005/015552, to the same assignee as the present application. Each record of the 3D mark or voxel represents information, which may be a discrete 0 or 1.

Three-dimensional storage media has capacity of hundreds of Gigabytes, far exceeding the capacity of conventional discs. High recording and reading speeds are imperative for proper utilization of such media. However, high rotation speed introduces tracking difficulties associated among others with mechanical deformations caused by centrifugal forces.

Some optical discs have, in addition to information marks written on them, so called servo or formatting marks. Servo marks are embossed or optically recorded marks or symbols having a certain pattern that indicates the coordinates of the optical pick-up head relative to a nominal track. Knowledge of the coordinates allows synchronized or guided information recording, reading and erasing.

In a non-linear media and particularly two-photon media, laser beams of different wavelengths and power perform three dimensional storage media recording, reading and erasing processes. The guiding or servo beam may have a similar to the reading beam wavelength or a different wavelength. Proper information recording, reading and erasing require accurate determination of the laser beam location and appropriate laser power settings.

Known techniques of the kind specified are disclosed for example in U. S. patents Nos. 5,408,453 and 6,873,586. Additional reference may be the ECMA 317 standard.

SUMMARY OF THE INVENTION

The present invention, in its one broad aspect, provides a three dimensional optical information carrier, comprising formatting marks and symbols disposed in the body of the carrier in the vicinity of the nodes of a predefined three dimensional grid.

The grid may be formed by the intersection of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes.

According to another broad aspect of the invention, there is provided a three dimensional optical information carrier having a body made of polymeric material, and comprising a reinforcing carcass supporting the body of the carrier, said carcass being made of material different from the body of the carrier and being an integral part of the carrier.

According to yet another broad aspect of the invention, there is provided a three dimensional optical information carrier having a body made of polymeric material, and comprising: a reinforcing carcass supporting the body of the carrier, said carcass being made of material different from the body of the carrier; and formatting marks made in the body of the carrier and being disposed on the nodes of a three dimensional grid formed by the intersection of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes. Generally speaking, formatting marks are located in the vicinity of nodes, such that the arrangement of formatting marks corresponds to the arrangement of nodes, e.g. above or below the respective node. Each node may be associated with more than one (a few) formatting marks. The lattice structure of the grid of nodes is equivalently evident in the lattice structure of the formatting marks. The lattice structure is kept in a locality whose size is proportional to the formatting accuracy.

According to yet another broad aspect of the invention, there is provided a three dimensional optical information carrier having a body made of polymeric material, and comprising: a central hub, which is made of material different from the body of the carrier, is an integral part of the carrier, and serves as the carrier mounting facility; and formatting marks made in the body of the carrier and being disposed about the nodes of a three dimensional grid formed by the intersection of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes.

In yet further broad aspect of the invention, there is provided a three dimensional multilayer optical information carrier comprising an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates.

According to yet further aspect of the invention, there is provided a three dimensional multilayer optical information carrier comprising an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates, and comprising a central hub made of material different from the body of the carrier and serving as the carrier mounting facility.

According to yet another aspect of the invention, there is provided a three dimensional multilayer optical information carrier comprising an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates, and comprising formatting marks made in the body of the carrier and being disposed on the nodes of a three dimensional lattice formed by the intersections of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes.

According to yet another aspect of the invention, there is provided a three dimensional multilayer optical information carrier comprising: a body formed by an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates; and comprising a reinforcing carcass supporting the plates and being made of material different from the plates; and formatting marks made in the body of the carrier and being disposed on the nodes of a three dimensional grid formed by the intersection of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes.

The present invention, in its yet another broad aspect, provides a three dimensional optical information carrier, comprising a rotational axis and a polymeric body with bound to it active moiety, and comprising an enforcement carcass at least partially supporting the body, the body and the carcass being centered around said rotational axis.

According to yet further aspect of the invention, there is provided a three dimensional information carrier for information recording, comprising oblong and tilted, optically recorded formatting marks of controlled size and shape disposed on a three dimensional grid nodes, the nodes being an intersection between equidistantly spaced spiral tracks, equiangular spaced radial planes and a plurality of recording planes, the recording planes being orthogonal to the radial planes.

Yet another broad aspect of the invention provides a three dimensional information carrier for information recording, comprising at least one embossed layer and a plurality of optically recorded layers forming a three dimensional lattice, the embossed layer being an integral part of the lattice.

Yet further aspect of the invention provides a three-dimensional carrier made of polymeric material having an embossed or optically recorded marks, wherein the carrier comprises a reinforcing carcass with a coating having coded data or servo data marks.

The invention also provides a method of casting a three-dimensional optical information carrier. The method comprises carrying out the casting with an reinforcement carcass inserted in a casting form and polymer layers cast on both sides of the carcass being connected through holes in the carcass and converting the disc-like carrier into a truss-like structure, thereby significantly increasing the carrier resistance to bend and wobble.

According to yet another aspect of the invention, a method of assembly of a three dimensional information carrier is provided, the method comprising providing a carcass or a hub as an integral part of the carrier, said carcass or hub serving as assembly tools.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, preferred embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1A and 1B are illustrations of the first exemplary embodiment of a three-dimensional information carrier.

Fig. 2 exemplifies three dimensional grid defining nodes, in the vicinity of which formatting marks and symbols are located.

Fig. 3 is a schematic illustration of the second exemplary embodiment of a three-dimensional information carrier.

Figs. 4A and 4B are schematic illustrations of two examples of the third exemplary embodiment of a three-dimensional information carrier having a body including a plurality of monolithic plates.

Figs. 5A – 5L are illustrations of additional exemplary embodiments of a three-dimensional information carrier having a carcass.

Figs. 6A – 6C are schematic illustration of one of carcasses with through holes and the truss-like three-dimensional carrier structure produced by utilizing such a carcass.

Fig. 7 is a schematic illustration of a further embodiment of carrier with a reinforcing carcass.

Fig. 8 is a three dimensional illustration of the carcass of Figure 7.

Figs. 9A – 9F are schematic illustrations of the fifth exemplary embodiment of a three-dimensional information carrier having a carcass.

Figs. 10A – 10I are schematic illustrations of the sixth exemplary embodiment of a three-dimensional information carrier.

Fig. 11 is a schematic illustration of a jig for assembly of a three-dimensional information carrier;

Fig. 12 is a schematic illustration of an improved gripper for non contact handling of plates of the three-dimensional information carrier;

Fig. 13 is a schematic illustration of the handling process of three-dimensional information carrier plates by the improved gripper;

DETAILED DESCRIPTION OF THE INVENTION

The structure and principles of the carrier and the assembly method described thereby may be understood with reference to the drawings, wherein like reference numerals denote like elements through the several views and the accompanying description of non-limiting, exemplary embodiments. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the method.

Three-Dimensional Information Carrier

Figs. 1A and 1B illustrate a first exemplary embodiment of a three-dimensional optical information carrier of the present invention. Carrier **100** may be a monolithic disc body made of a transparent or translucent material **102**, for example **a** polymer material, such as Polymethylmethacrylate (PMMA) and compositions including acrylate and methacrylate monomers. An active moiety, capable of changing its state from one isomeric form to another upon interaction with electromagnetic energy, such as laser radiation, is bound to polymer **102**. The active moiety exhibits two-photon absorption. Such an active moiety as disclosed for example in WO 03/070689 to the same assignee, could be used as a three-dimensional optical information carrier. The information is recorded in carrier **100** as series of three dimensional (3D) regular or oblong or oblong and tilted data marks such as ones disclosed in WO 2005/015552 to the same assignee. Each record of the 3D mark or voxel may represent information, which may be a discrete 0 or 1.

The information is optically recorded in carrier **100** in practically any location, although it is convenient to record it on a plurality of "virtual" layers **106**. The distance between layers **106** may be 10 – 15 micron. Thickness *t* of carrier **100** may vary between 1 and 6 mm. In addition to optically recorded regular or oblong or oblong and tilted data marks representing the information, a pattern of servo or formatting marks is optically recorded in carrier **100**. Formatting marks are recorded on a plurality of layers **108** that may be located at different depths of carrier **100**, and the formatting marks may be similar or sometimes identical to data marks, although the structure of formatting marks containing layers **108** may be different from the structure of data marks containing layers **106**. One formatting or servo layer may be sufficient to provide coordinate information to a number of data containing layers **106**. Accordingly, each formatting or servo layer **108** is interspaced by at least one data-containing layer **106**.

Carrier **100** further features an external diameter **124**; a peripheral annular section **128**, and an inner annular section **130**. Typically, sections **128** and **130** are not utilized for recording data or servo marks, but may be used to record auxiliary information. A mounting bore **126** is provided for mounting carrier **100** on a spindle of an optical recording/reading apparatus.

According to most of the standards, formatting marks are located on spiral tracks directed outwards or inwards, depending on the carrier rotation direction, beginning at the largest recordable dimension of an optical information carrier and ending at the smallest recordable dimension or *vise versa*.

Adjacent tracks **120** are arranged with a certain track pitch $\mathbf{T_1}$, which is the distance between the centerlines of a pair of adjacent tracks measured in a radial direction, and may be about 800 nm. In the present example, formatting marks **114** are arranged in spaced-apart locations in the vicinity of the intersections between spiral tracks **120** and equidistantly angularly spaced radiuses **122**. A distance **T** between two successive formatting marks **114** may be about 600 micron on the outer tracks and smaller on the inner tracks.

Tracks **120** begin at annular peripheral section **128** and end at inner annular section **130**. Spiral tracks **120** represent a 360 degrees turn of a spiral materialized by a succession of pre-written marks recorded about the nominal center of spiral line. Carrier **100**, mounting bore **126**, and spiral tracks **120** have an essentially common axis **136**, which is the geometrical center of disc like information carrier body **100** and a rotational axis of the carrier. The central intersection point of the equidistantly angularly spaced radiuses **122** coincides with the geometrical and rotation axes **136**.

Analysis show that the number of formatting marks **114**, which may be regular or oblong or oblong and tilted marks, on each of spiral tracks **120** (Fig. 1B) of optical information carrier **100** would be equal to $n_1=\pi D/T$, where **D** is the track diameter and **T** is the distance between two successive marks. Marks **114** are recorded on the active area of optical information carrier **100**, which is bound by largest spiral track diameter D_{max} on which spiral track **120** begins (for example at point **140**) and smallest spiral track diameter D_{min} on which spiral track **120** ends (for example at point **146**). The width **L** of the active area would be $L = (D_{max} - D_{min})/2$. The number of spiral tracks for such a carrier would be $n=L/T_1$, where T_1 is the average pitch of the spiral tracks (being about 1 micron). For a 120 millimeter external diameter carrier, D_{max} would be about 117 mm and D_{min} would be about 44 mm, which results in about 40,000 spiral tracks and about $25x10^6$ formatting marks.

If a radius **122** is traced from point **136**, which is the rotation and geometric axis of carrier **100**, to the largest diameter D_{max} of the spiral track it will intersect all spiral tracks existing on carrier **100**. The number of intersections of a radius with the spiral tracks is equal to the number of tracks and would be $n = L/T_1$. A plurality of radiuses **122** exiting from point **136** may be traced and spaced such as to intersect each of formatting marks **114** residing on D_{max}, The angular increments ω of radiuses **122** may be selected such as to ensure that formatting marks **114** form a constant angular velocity servo pattern. The number of nodes or intersections points between the radiuses and spiral tracks is equal to the number of formatting marks present on carrier **100**. The intersection points or nodes generated by the equidistantly spaced spiral tracks **120** and equiangular spaced radiuses **122** form a well-defined grid pattern. Accordingly, formatting marks **114** may be recorded about the nominal position of each of the nodes to form a constant angular velocity servo pattern. Other grid pattern, meeting the requirements of constant linear velocity or constant zonal velocity servo pattern may be provided.

Generally, use of arcs, instead of radiuses, that do not pass through the central intersection point is possible, although the positional error would be greater than for radiuses or radial arcs and the pattern of marks is more complicate.

Indeed as shown, in **Fig. 1B**, formatting marks **114** are disposed on a grid, the nodes **116** of which are generated by an intersection between equidistantly spaced spiral tracks **120** and equiangular spaced radiuses **122** or radial planes. As it was noticed, the regular or oblong or oblong and tilted formatting marks of controlled size and shape may be optically recorded on carrier **100** in any location, although it is convenient to record it on a plurality of layers **108**. On each of layers **108**, formatting marks **114** are disposed on a grid the nodes **116** of which are generated by an intersection between equidistantly spaced spiral tracks **120** and equiangular spaced radiuses **122**. It should be understood that the formatting marks may not be located exactly at the intersection points (nodes), but in the vicinity thereof, e.g. above and/or below such intersection point.

Recorded formatting marks **114** form on carrier **100** a three dimensional lattice with axes being the radial mark position, angular mark position and position of the mark in the depth or what is called axial direction of carrier **100**. **Fig. 2** illustrates a three dimensional lattice with nodes **116**. Formatting marks **114** are located about the nominal position of nodes **116**. Thus, in this embodiment of the invention information carrier **100** of the present invention contains formatting marks disposed in the vicinity of a three dimensional lattice nodes, namely the arrangement of formatting marks corresponds to the arrangement of lattice nodes, where nodes **116** of the lattice are intersections between equidistantly spaced (cylindrical) spiral tracks **120**, equiangular spaced radial planes (radiuses) **122** and a plurality of recording planes **106** or **108** (virtual layers) orthogonal to the radial planes. The extent in which the grid (either nodes or formatting marks) preserves a lattice structure correlation depends on the formatting quality.

There is a well-known practice in the industry of providing a "blank" optical information carrier with one formatted layer. **Fig. 3** is a schematic illustration of the second exemplary embodiment of a three-dimensional information carrier. Carrier **160** has an embossed servo pattern **164**. Typically, such layer/pattern **164** is embossed or printed by any known in the art method on one of the carrier sides. This embossed servo pattern becomes a part or a reference, or basic layer of the three-dimensional lattice about nodes **168** of which optically recorded marks **172** will be located. The form of the embossed pattern and the distance between two adjacent marks define the form of the spiral tracks and the distance between two adjacent optically recorded marks.

Reference is made to **Figs. 4A and 4B** illustrating some other exemplary embodiments of a three-dimensional information carrier. In a carrier **180** of **Fig. 4A**, a monolithic body of the above-described carrier **100** is replaced by a plurality of attached to each other recordable, essentially monolithic plates **182** made of a transparent or translucent polymer material (**102** in Fig. 1A). Plates **182** are produced separately as blocks of about 200 micron thickness or any other thickness convenient for processing, or as an assembly of thinner layers adhered to each other to form a group of suitable thickness. Each of plates **182** could as explained supra, bear at least one servo pattern **114** of formatting or servo marks. Alternatively, each of plates **182** may bear an embossed or printed servo pattern produced by any known in the art method. The method of the invention for assembling the plates will be explained below.

Transparent adhesive **184** that contains an active moiety may attach plates **182** to each other. Adhesive **184** fills-in the embossed marks of servo pattern (**164** in Fig. 3). The active moiety is responsible to electro-magnetic or laser radiation and it changes its state from one isomeric form to another upon interaction with electromagnetic (laser) energy. Since the proportion of the active moiety in adhesive **184** may be different from the one in the material of plates **182**, marks of pattern **164** respond to the appropriate laser radiation in a different way than information marks recorded in the volume of plates **182**. This allows easy discrimination between the servo marks and recorded information marks. The servo marks may be of any form and size mentioned above.

In an example of **Fig. 4B**, disc like plates **182** may have a micro relief **194** impressed on one of the flat surfaces **186** or **188**. Micro relief **194** contains guiding or formatting symbols **200** that may serve as servo symbols or marks. The micro relief may also serve as a guiding and fixing feature for the assembly of plates **182**. When plates **182** are assembled into a carrier body, the micro relief symbols become disposed on a three-dimensional lattice, and each of symbols has defined coordinates in the lattice and each symbol has defined coordinates in a two dimensional plane, which may be a recording plane. Transparent adhesive **184** that attaches plates **182** to each other fills-in the micro relief, and accordingly symbols **200**, and allow easy discrimination between the servo symbols and recorded information marks. Symbols **200** that typically are servo marks may be of a size different from that of regular data or formatting marks.

It should be noted that polymer material (**102** in Fig. 1A) of the carrier body defines the physical support and durability to the optical information carrier. Polymer **102** might not possess proper mechanical strength required for high rotational speed. High rotational speed might cause irreparable mechanical damage to optical discs. Increase of rotational speed is however imperative for high capacity information carriers.

Figs. 5A – 5L illustrate yet other examples of a three-dimensional optical information carrier of the present invention. These carriers have a reinforcing carcass. In the examples of Figs. 5A-5F, carcasses **210a-210f** are symmetric internal carcasses; in the examples of Figs. 5G-5L, these are asymmetric external carcasses **220g-220l**. Metal, plastic or composite materials are different, stronger than polymer **102** materials, of which reinforcing carcasses **210a-210f** and **220g-220l** may be produced. For example, the carcasses may be made of beryllium, which has superior stiffness and does not distort even at such high rotational speeds as 45,000 rpm.

Use of any type of reinforcing carcasses made of materials having higher strength than polymer of which the recordable layers are made, supports rotation of the information carrier at a speed substantially higher than carriers that do not have such reinforcing carcass. Reinforcing carcass reduces or eliminates carrier mechanical deformations caused by centrifugal forces that act on the rotating carrier. Rotational speeds exceeding 10,000 rpm are obtained.

Thus, **Figs 5A-5F** exemplify three-dimensional information carriers with symmetric carcasses having recordable medium **102** disposed on both sides of carcass (denoted **210a-210f**, respectively). In the examples, both sides **212** and **214** of carcass are in contact with monolithic polymeric bodies **216** and **218**, or with bodies assembled of disc like plates **182** (Figs. 5D-5F). Carcasses **210a** – **210c** of **Figs. 5A** – **5C** have a plurality of through holes **230**, disposed on the surface of carcass as illustrated more specifically in **Figs. 6A-6C**. Monolithic polymeric material **102** forming the carrier body or at least one of plates **182** is cast simultaneously into a form containing carcass. Polymeric material **102** penetrates through holes **230** and connects plates disposed on both sides of the carcass. This method of production, as illustrated in **Figs 6B and 6C**, converts the disc-like carrier into a truss-like structure and significantly increases the three-dimensional carrier resistance to bend, wobble and fracture. For the simplicity of explanation, the truss-like structure in **Figs 6B and 6C** is shown without carcass.

Embossed or printed formatting layers may be also used in cases where plates **182** are cast or pressed separately and transparent adhesive or adhesive material **184** is used to attach them to the carcass.

Carcasses **210a** – **210e** may have embossed servo marks or test and guiding symbols on their flat surfaces **212** and **214**, that are in contact with polymeric bodies **216** and **218** (**Figs. 5A-5C**) or with plates **182** (**Figs. 5D-5E**). These embossed servo marks or test and guiding symbols are similar to symbols **200** (Fig. 4B) that may serve as servo symbols or marks. Symbols similar to symbols **200** represent a micro relief impressed on surfaces of carcasses **210a** – **210e**. The micro relief may serve as a guiding and position-fixing feature for the assembly of plates **182**. Transparent adhesive (**184** in Fig. 4A) that contains an active moiety in a proportion different from the one of polymeric bodies **216** and **218** may fill-in the micro relief and adhere polymeric bodies **216** – **218** to carcasses **210a** – **210e**. The principles of operation of these symbols are similar to the described above embodiments. Symbols **200** may indicate axial and radial position of the guiding or servo laser beam. This provides at least one reference servo layer that may be utilized for optically writing additional servo layers located in different layers disposed within the 3D carrier.

Similar to the previously described embodiment, the embossed servo pattern becomes a part or the first or basic layer of three-dimensional lattice about nodes **168** of which optically recorded marks **172** (Fig. 3) will be located. The embossed pattern defines the form of the spiral tracks and the pitch between two adjacent marks. In a similar manner, the marks of the embossed pattern of carrier **210e-210f** may be filled in by transparent adhesive **184** that contains an active moiety having a proportion of active ingredient different from the proportion of active moiety in material **102** of the monolithic body.

Figs. 5G – 5L illustrate three-dimensional carriers with asymmetric carcasses, denoted respectively **220g-220l**, to which a monolithic polymeric body is attached by different means. In the examples of **Figs. 5I, 5J and 5L**, a polymeric body assembled of disc like plates **182** is attached to the respective asymmetric carcasses. Carcasses **220j – 220l** have a rim with conical inner surfaces **240** and **246**. Different symbols embossed or engraved on these surfaces may be used for determination of the axial location of the laser beam.

Carcasses **210d – 210f** and **220i – 220l** have hub like inner parts with outer conical surfaces **246**. These conical surfaces may serve as a centering feature for the assembly of disc like plates **182**. Carcasses **210a – 210f** and **220i - 220l** serve as a base for assembly of monolithic polymeric bodies or disc like plates **182**. All described above properties of the carriers, like location of the marks about the nodes of a three dimensional grid, transparent adhesive **184** and others are *mutatis mutandis* applicable to all the embodiments described herein.

Outer diameter surfaces **224** and **226** of carcasses **210a-210f** and **220g-220l** of three-dimensional information carriers may be used for placement on them marks, symbols or alphanumeric characters identifying for example manufacturer, batch number etc. Alternatively or additionally, the marks may be used for reading angular rotation speed, coordinates of a specific location on the information carrier, etc.

The reinforcing carcass may be produced of a composite material that consists of metal nanospheres having a magnetic nucleus, for example those commercially available from MPI Metal Powder Industries Ltd., Beer-Sheba, Israel. Such a carcass provides a convenient way of making a magnetic coded servo combined with optical recording means. Alternatively, a magnetically recordable coating may be deposited on the relevant side of the carcass or on the polymer material of which optical information carrier is made. Encoding marks on the carcass can be used for additional data encoding purposes besides servo.

Fig. 7 illustrates a carrier **270** that has a carcass **274** with a step like surface **278.** Accordingly, a contact surface **280** of either a monolithic material **282** or a body assembled from disc-like plates (not shown) has a matching contact surface. Use of a step like surface enables easier coarse laser beam location determination.

Fig. 8 is a three dimensional illustration of the carcass of Fig. 7. Symbols **282** impressed on each of the steps of step like surface **278** may have different pitch and may be shifted with respect to the previous surface symbols. This simplifies determination of the position of any of the participating in the guiding, recording, reading or erasing laser beams. All of the properties and features of symbols **200** described above are *mutatis mutandis* applicable to symbols **282.**

All carcasses described above have their central part implemented in a hub-like form. Hubs provide convenient and highly accurate carrier mounting means. Three-dimensional carriers are planed for multiple and long term use. Hubs, being made of material stronger than the carrier body material, improve the durability of the mounting elements of the carrier. The conical surfaces of the hubs may be used as assembly jigs or tools for assembly of plates of which the carrier is produced. The external diameters of the carcasses **210a-210f** and **220g-220l**, inner diameter of mounting bores **236**, and spiral tracks have a common rotation axis **240**, which is the geometrical center of disc like information carriers.

Figs. 9A to 9F illustrate some exemplary embodiments of a three-dimensional information carrier of the present invention with an external symmetric reinforcing carcass. Carcasses **300**, **302** **(Figs. 9A-9E)** and carcass **306** **(Fig. 9F)** are of a disc like shape and made of a transparent material, for example polycarbonate, that is stronger than a polymeric material of monolithic body, designated here **310**, **400**, **314**. A micro relief, similar to the one disclosed above, is impressed/embossed on one of the sides of carcasses **300**, **302** and **306**. Carriers of **Figs 9A – 9C** are produced by casting with carcasses **300** and **302** inserted in the casting form. Alternatively, a regular adhesive or such as adhesive **184** attaches carcasses **300** and **302** to carriers of **Figs. 9D – 9F**. Use of a symmetric carcass creates a strong truss-like bending and wobble resisting structure of the three-dimensional information carrier and supports conducting of guiding, recording, reading and erasing processes from both sides of the carrier.

All properties and features of symbols **200** filled in by adhesive **184** are *mutatis mutandis* applicable to micro relief/symbols impressed on surfaces of carcasses **300**, **302** and **306**. Symbols **200** may serve as a reference layer for optically recorded formatting layers with formatting marks being disposed about (in the vicinity of) the nodes of a three dimensional lattice/grid similar to the earlier disclosed lattice.

Fig. 9F illustrates an embodiment where one transparent carcass **306** is used. Carcass **306** may be attached to a monolithic body **314** directly or with the help of an intermediate disc like plate **320**. A micro relief bearing formatting symbols may be embossed on carcass **306** or on disc like plate **320**. Adhesive **184** facilitates carcass to monolithic body attachment. All carcasses and associated with them polymeric bodies of **Figs. 9A – 9F** are centered on a rotational axis **334** of the three-dimensional carrier.

Figs. 10A – 10I are schematic illustrations of further exemplary embodiments of a three-dimensional information carrier of the present invention. In the examples of **Figs. 10A-10C**, plates **350** are assembled on hubs **360a – 360c**, respectively. Conical surfaces **364** of hubs **360a-360c** engage a matching surface of inner circumference and centers disc like plates on common axis **370**, which is the rotational axis of three-dimensional carriers **330**. Hubs **360a – 360c** serve as assembly jigs/tools. In addition to this, conical surface **364** may be used, as explained before for rough laser beam position feedback and orientation.

Disc like plates **350** may have at least on one of their surfaces a micro relief that contains test and guiding symbols **200** that may serve as servo symbols or marks. The micro relief may serve as a guiding and disc position-fixing feature for the assembly of plates **350**. When plates **350** are assembled into a carrier body, micro relief symbols **200** become disposed on a three dimensional lattice/grid, and each of symbols **200** has defined coordinates in the lattice and defined coordinates in a two dimensional plane, which may be a recording plane.

A transparent adhesive (like above-described adhesive **184**) that attaches plates **350** fills-in the micro relief and accordingly in symbols **200**. Symbols **220** may indicate axial and radial position of the guiding or servo laser beam. Guiding symbols **200** may be substantially larger than the optically recorded information marks. Although being on the same three-dimensional lattice, the number of symbols **200** in each of the layers may be different, and missing symbols may indicate on particular layer axial location. All hubs **360a-360i**, their mounting bores **368** and associated with them polymeric bodies of **Figs. 10A – 10I** are centered on the three-dimensional carrier rotational axis **370**.

Carriers of **Figs. 10H – 10I** may be cast with hubs **360h – 360i** inserted in the casting form. Hubs made of material more stable (metal for example) than the polymeric material, improve the casting accuracy and produce a carrier with reduced wobble and outer surfaces run-out. All hubs **360** have on both of their sides conical troughs **374** or **376**. These troughs simplify the casting form assembly/disassembly and facilitate use of hubs **360** in the casting process.

Method of Handling and Assembly of Plates of Recordable Material

As mentioned above, plates **182** made of polymer material **102** are produced separately. Carcasses **210a-210l**, as shown in **Figs. 5A – 5L**, and hubs **360a-360i** (**Figs. 10A – 10I**) may serve as a jig and facilitate the assembly process. Proper facilities for IR curable material and IR curing sources should be provided.

Assembly of plates **182** or the like into a carrier requires special jigs such as the one shown in **Fig. 11**. Jig **400** for assembly of plates **182** includes a base plate **402** on which a post **404**, having an accurate outside diameter matching the mounting bore **126** inner diameter, is mounted. A dispenser **406** dispenses a regular IR curable adhesive (or adhesive **184**) such that it covers by an even layer the surface of the preceding plate **182**. Next plate **182** is overlaid and cured by thermal radiation provided by a source of IR radiation **408** or a ceramic heater. The flux provided by IR source **408** is appropriately controlled to illuminate the curable surfaces by an evenly distributed radiation. The IR flux may be provided from one or both sides of the assembly.

Polymer material (previously referred to as **102**) is a delicate one and contact handling of plates **182** of material **102** might leave on it scratches, pits and other symbols that might complicate recording or reading processes. Use of pick-up heads or grippers for non-contact objects handling is known in the art. One example of such pick-up head or gripper are disclosed in U.S. Pat. No. 5,871,814 to Livshits. The gripper is however not adapted for handling of parts having a bore in their central region. Reference is made to **Figs. 12 and 13** illustrating construction and operation of an improved version of the above gripper suitable to be used in the present invention. A fluid flow **430**, for example air, introduced into a passageway **434** creates a pressure below atmospheric at the output part **440** (Fig. 13) of gripper **444**. The improved version includes improved conical fluid shaping means **450** disposed in the passageway in fluid communication with the inlet for changing the shape of the fluid flow into a planar fluid flow flowing radial outwardly from a central point, and an improved disk **452** having flow homogenizing dissectors **454**. These improvements create a better vacuum adjacent to the disk surface, and hold in a more reliable manner objects having a central bore.

Fig. 13 illustrates plate **182** or a similar item handling by grippers **444**. When fluid flow **430** is activated, gripper **444** develops a pressure below atmospheric at the output part **434** thereof. Gripper **444** picks up plate **182** from a plate production line and delivers it to the assembly station which may be a station such as jig **400** (Fig. 11) or carcass **210a-210f** or hub **360a-360i**. If necessary, the orientation of plate **182** may be changed with the help of a second gripper **444-I**. Regulating the fluid flow through each of grippers **444** and **444-I** regulates the vacuum they develop and accordingly the force that holds plate **182**.

While the exemplary embodiment of the present method have been illustrated and described, it will be appreciated that various changes can be made therein without affecting the spirit and scope of the method. The scope of the method, therefore, is defined by reference to the following claims.

CLAIMS:

1. A three dimensional optical information carrier, comprising formatting marks and symbols made in the body of the carrier and being disposed in the vicinity of nodes of a three dimensional grid.

2. The carrier of Claim 1, wherein the formatting marks include at least one of the following types: regular, oblong, oblong and tilted marks of controlled size and shape forming a servo pattern.

3. The carrier of Claim 1, formed said nodes of grid in the body of the carrier are intersection of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes.

4. The carrier of Claim 1, wherein the body of the carrier includes at least one of a monolithic body and an assembly of monolithic plates.

5. The carrier of Claim 1, wherein the body of the carrier contains an active moiety that is responsive to electromagnetic radiation.

6. The carrier of Claim 1, wherein the formatting marks are responsive to electromagnetic radiation.

7. The carrier of Claim 2, wherein the body of the carrier includes an assembly of monolithic plates, at least one layer of formatting marks and symbols being in the form of a micro relief impressed on at least one flat side of the plates.

8. The carrier of Claim 1, wherein each of the marks and symbols has defined coordinates in the grid, and each mark and symbol has defined coordinates in the two dimensional recording plane.

9. The carrier of Claim 7, wherein the micro relief is configured to serve as guiding and position fixing feature for the assembly of the plates.

10. The carrier of Claim 1, wherein the formatting marks and symbols are substantially larger than information marks.

11. The carrier of Claim 1, wherein the body of the carrier includes an assembly of monolithic plates, the plates being attached to each other by an adhesive containing a proportion of the active moiety different from the one contained in the plates.

12. The carrier of Claim 1, having a body made of polymeric material, and comprising a reinforcing carcass supporting said body, said carcass being made of material different from the body material and being an integral part of the carrier.

13. The carrier of Claim 12, wherein the reinforcing carcass is made of at least one of the following materials: metal, plastic, composite material and metal-coated plastic.

14. The carrier of Claim 12, wherein said reinforcing carcass has a coating having magnetic coded servo marks.

15. The carrier of Claim 12, wherein the body of the carrier includes an assembly of monolithic plates, at least one layer of formatting marks and symbols being in the form of a micro relief impressed on at least one flat side of the plates.

16. The carrier of Claim 1, having a body made of polymeric material, and comprising a central hub, which is made of material different from the body of the carrier, is an integral part of the carrier, and serves as the carrier mounting facility.

17. The carrier of Claim 16, wherein the hub is made of at least one of the following materials: metal, plastic and composite material.

18. A three dimensional optical information carrier, comprising formatting marks and symbols made in the body of the carrier and being disposed in the vicinity of nodes of a three dimensional grid, the formatting marks and symbols including at least one of the following types: regular, oblong, oblong and tilted marks of controlled size and shape forming a servo pattern.

19. A three dimensional optical information carrier having a body made of polymeric material, and comprising a reinforcing carcass supporting the body of the carrier, said carcass being made of material different from the body of the carrier and being an integral part of the carrier.

20. The carrier of Claim 19, comprising a micro relief impressed on at least one flat side of the carcass, said micro relief generating a reference layer of formatting marks and symbols.

21. The carrier of Claim 19, wherein said carcass comprises a coating having magnetic coded marks.

22. The carrier of claim 19, wherein the body of the carrier includes at least one of a monolithic body and an assembly of monolithic plates.

23. The carrier of claim 19, wherein the body of the carrier contains an active moiety that is responsive to electromagnetic radiation.

24. The carrier of claim 19, wherein formatting marks formed in the carrier are disposed in the vicinity of nodes of a three dimensional grid in the body of the carrier.

25. The carrier of Claim 24, wherein said nodes of the grid are formed by intersection of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes.

26. The carrier of claim 19, wherein the marks include at least one of the following types: regular, oblong and oblong and tilted marks of controlled size and shape.

27. The carrier of claim 19, wherein the marks are responsive to electromagnetic radiation.

28. The marks of claim 19, wherein the formatting marks are substantially larger than information marks.

29. The carrier of claim 19, wherein the reinforcing carcass is made of at least one of the following materials: metal, plastic, composite material and metal-coated plastic.

30. The carrier of claim 20, wherein the micro relief serves as guiding and position fixing feature for assembly of the plates.

31. A three dimensional optical information carrier having a body made of polymeric material, and comprising a reinforcing carcass supporting the body of the carrier, said carcass being made of material different from the body of the carrier and being an integral part of the carrier, the carcass being formed with a micro relief impressed on at least one flat side of the carcass, said micro relief generating a reference layer of formatting marks and symbols.

32. A three dimensional optical information carrier having a body made of polymeric material, and comprising a reinforcing carcass supporting the body of the carrier, said carcass being made of material different from the body of the carrier, and comprising formatting marks made in the body of the carrier and being disposed in the vicinity of nodes of a predefined three dimensional grid.

33. The carrier of claim 32, wherein the body of the carrier includes at least one of a monolithic body and an assembly of monolithic plates.

34. The carrier of claim 32, wherein the body of the carrier contains an active moiety that is responsive to laser radiation.

35. The carrier of claim 32, wherein the marks include at least one of the following types: regular, oblong, oblong and tilted marks.

36. The carrier of claim 32, wherein the marks are responsive to electromagnetic radiation.

37. The marks of claim 32, wherein the formatting marks are substantially larger than information marks.

38. The carrier of claim 32, wherein the reinforcing carcass is made of at least one of the following materials: metal, plastic, composite material and metal-coated plastic.

39. The carrier of claim 32, comprising a micro relief impressed on at least one flat side of the carcass, said micro relief generating a reference layer of formatting marks and symbols.

40. The carrier of claim 39, wherein the micro relief serves as guiding and position fixing feature for assembly of the plates.

41. A three dimensional optical information carrier having a body made of polymeric material, and comprising a central hub, which is made of material different from the body of the carrier, is an integral part of the carrier, and serves as the carrier mounting facility.

42. The carrier of Claim 41, comprising formatting marks made in the body of the carrier and being disposed in the vicinity of nodes of a predefined three dimensional grid.

43. The carrier of Claim 42, wherein said nodes of the grid are formed by intersection of equiangular spaced radial planes, equidistantly spaced cylindrical spiral tracks and virtual recording planes.

44. The carrier of claim 41, wherein the hub is made of at least one of the following materials: metal, plastic and composite material.

45. A three dimensional multilayer optical information carrier comprising an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates.

46. The carrier of claim 45, wherein the plates have a micro relief on at list one of the surfaces.

47. The carrier of claim 45, wherein the adhesive containing a proportion of active moiety different from the one contained in the plates fills-in the micro relief.

48. The carrier of claim 45, wherein the micro relief includes marks and symbols serving as formatting marks.

49. The carrier of claim 48, wherein the marks and symbols include at least one of the following: regular, oblong and oblong and tilted marks of controlled size and shape serving a constant servo pattern.

50. The carrier of claim 48, wherein the formatting marks are substantially larger than information marks.

51. The carrier of claim 45, comprising a micro relief impressed on at least one flat side of the carcass, the micro relief generating a reference layer of formatting marks and symbols.

52. A three dimensional multilayer optical information carrier comprising an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates, and comprising a central hub made of material different from the body of the carrier and serving as the carrier mounting facility.

53. The carrier of claim 52, wherein the hub is made of at least one of the following materials: metal, plastic and composite material.

54. The carrier of claim 52, wherein the plates have a micro relief on at list one of their surfaces.

55. The carrier of claim 54, wherein the adhesive containing a proportion of active moiety different from the one contained in the plates that fills-in the micro relief.

56. The carrier of claim 54, wherein the micro relief includes marks and symbols serving as formatting marks.

57. The carrier of claim 56, wherein the marks include at least one of the following types: regular, oblong and oblong, and tilted marks of controlled size and shape.

58. The carrier of claim 57, wherein the formatting marks are substantially larger than information marks.

59. The carrier of claim 54, wherein the micro relief impressed on at least one flat side of the carcass generates a reference layer of formatting marks and symbols.

60. A three dimensional multilayer optical information carrier comprising an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates, and comprising formatting marks made in the body of the carrier and being disposed in the vicinity of nodes of a three dimensional grid.

61. The carrier of claim 60, wherein the plates have a micro relief on at list one of the surfaces.

62. The carrier of claim 61, wherein the adhesive containing a proportion of active moiety different from the one contained in the plates fills-in the micro relief.

63. The carrier of claim 61, wherein the micro relief includes marks and symbols serving as formatting marks.

64. The carrier of claim 63, wherein the marks include at least one of the following types: regular, oblong, oblong and tilted marks.

65. The carrier of claim 63, wherein the formatting marks are substantially larger than information marks.

66. A three dimensional multilayer optical information carrier comprising: a body formed by an assembly of plates containing an active moiety, the plates being attached to each other by an adhesive containing a proportion of active moiety different from the one contained in the plates; and comprising a reinforcing carcass supporting the plates and being made of material different from the plates; and formatting marks made in the body of the carrier and being disposed in the vicinity of nodes of a three dimensional grid.

67. A three dimensional optical information carrier, comprising a rotational axis and a polymeric body with bound to it active moiety, and comprising an enforcement carcass at least partially supporting the body, the body and the carcass being centered around said rotational axis.

68. The carrier of claim 67, wherein the body further comprises a micro relief that includes test and guiding symbols and the symbols serve as a reference formatting layer for optically recorded formatting marks, and further characterized in that all marks and symbols are disposed on a three dimensional lattice, and each of the symbols has defined coordinates in the lattice and each symbol has defined coordinates in a two dimensional recording plane.

69. The carrier of claim 67, wherein said body is formed by plates adhered to each other by a transparent adhesive containing an active moiety having a proportion of active material different from the one the body has.

70. The carrier of claim 69, wherein the symbols are filled-in by the adhesive.

71. A three dimensional information carrier for information recording, comprising at least one embossed layer and a plurality of optically recorded layers forming a three dimensional grid, the embossed layer being an integral part of the lattice.

72. A three-dimensional carrier made of polymeric material having an embossed or optically recorded marks, and comprising a reinforcing carcass with a coating having magnetic coded marks.

73. A method of casting a three-dimensional optical information carrier, that the method comprising: carrying out the casting with an reinforcement carcass inserted in a casting form and polymer layers cast on both sides of the carcass being connected through holes in the carcass and converting the disc-like carrier into a truss-like structure, thereby significantly increasing the carrier resistance to bend and wobble.

74. A method of assembly of a three dimensional information carrier, the method comprising providing a carcass or a hub as an integral part of the carrier, said carcass or hub serving as assembly tools.

75. The method of assembly of claim 74, wherein a micro relief is impressed on at least one surface of plates, forming the body of the carrier, and serves as guiding and position fixing feature.

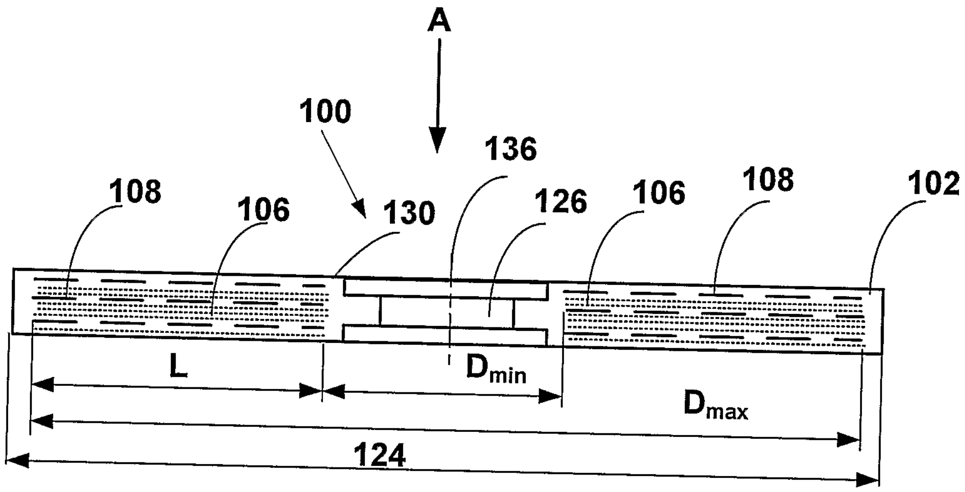


FIG. 1A

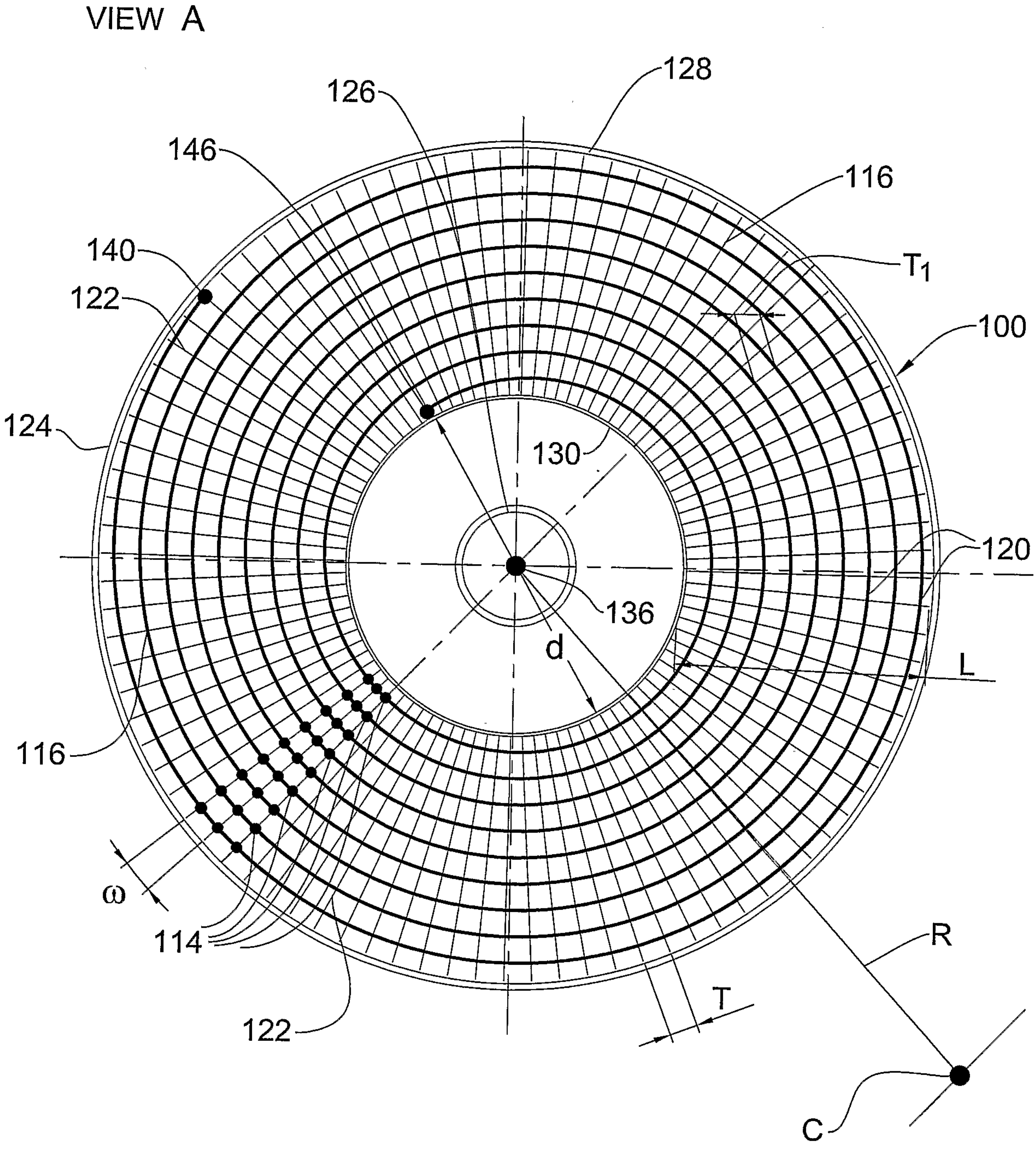

VIEW A
128
126
146
116
140
T_1
122
100
124
130
120
136
d
L
116
ω
114
R
122
T
C

FIG. 1B

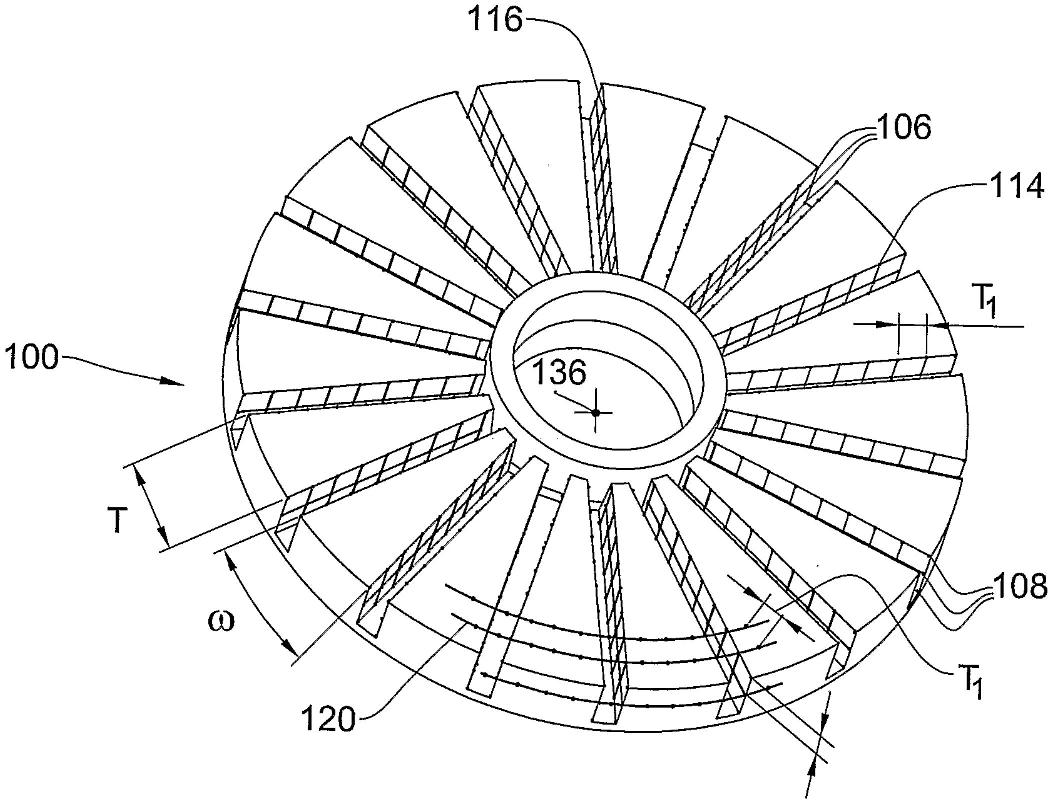


FIG. 2

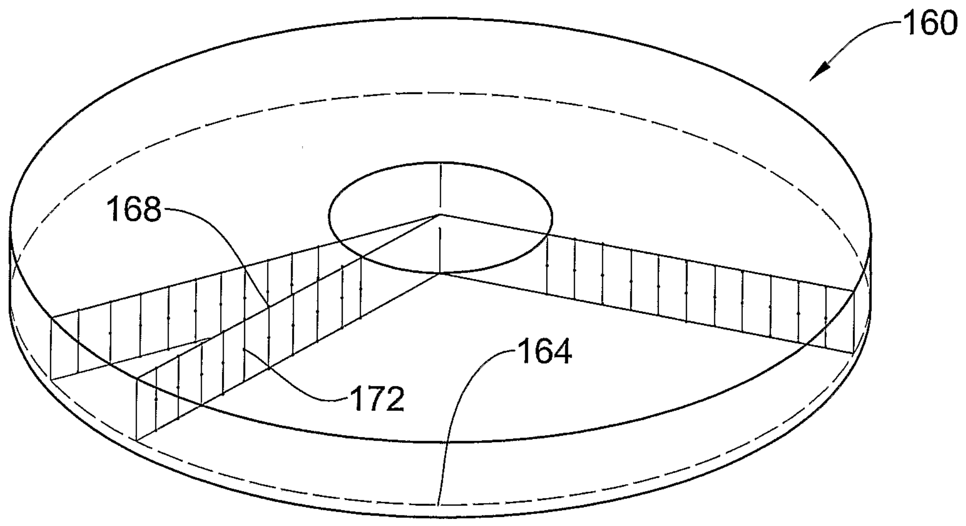


FIG. 3

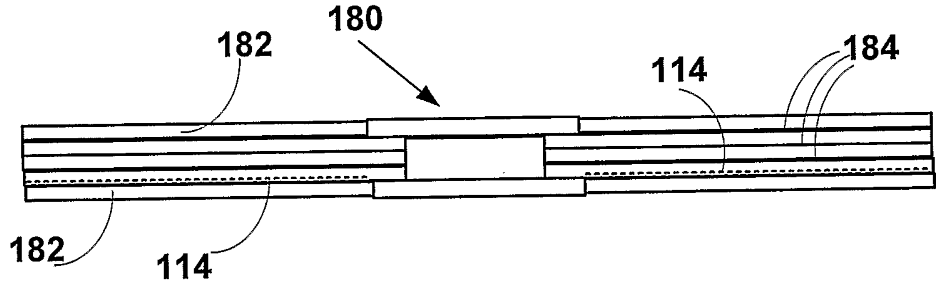


FIG. 4A

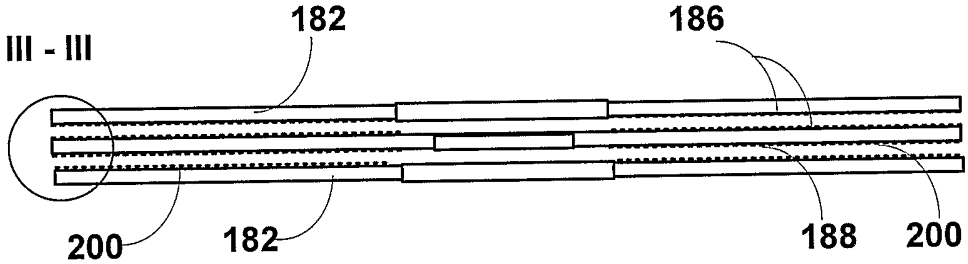
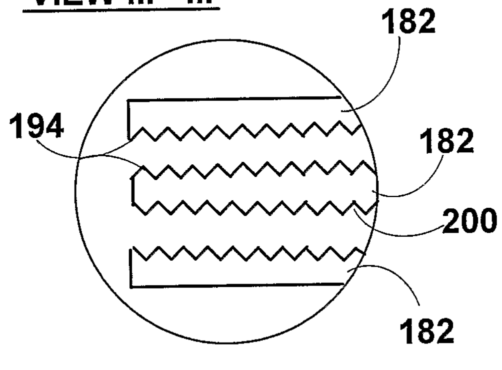


FIG. 4B

VIEW III - III



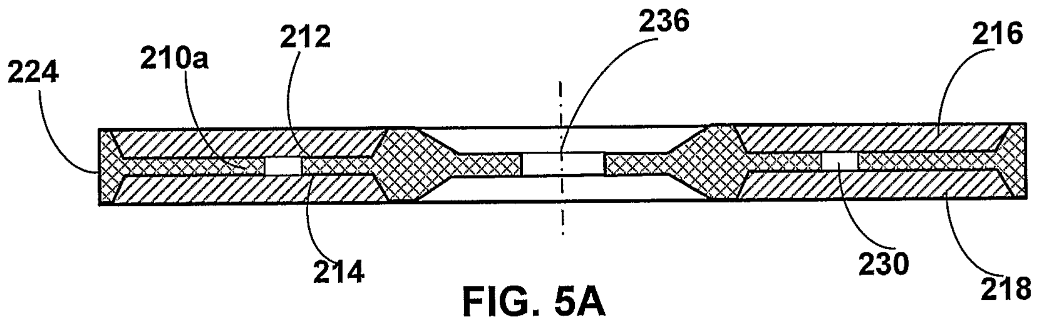


FIG. 5A

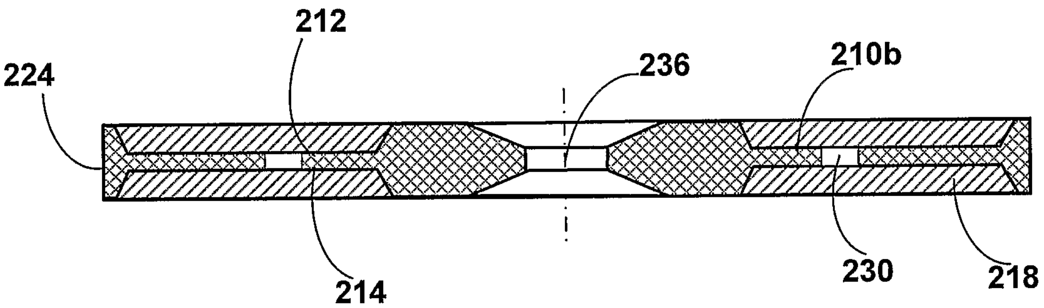


FIG. 5B

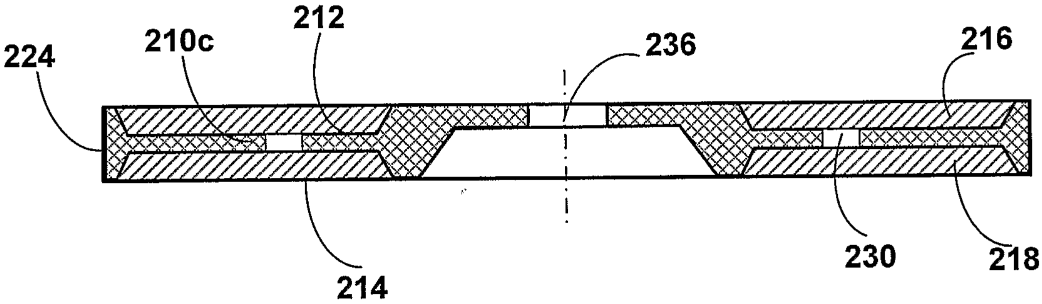


FIG. 5C

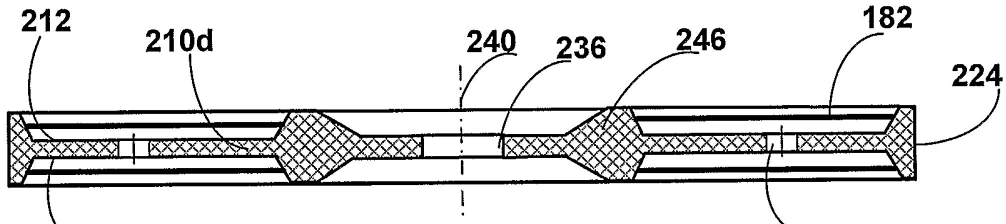


FIG. 5D

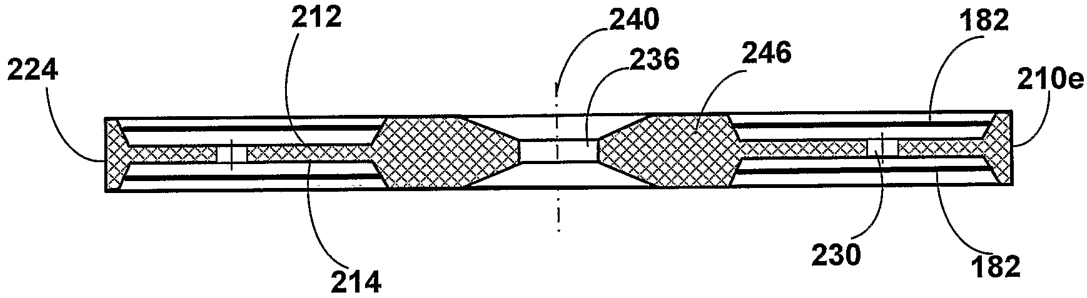


FIG. 5E

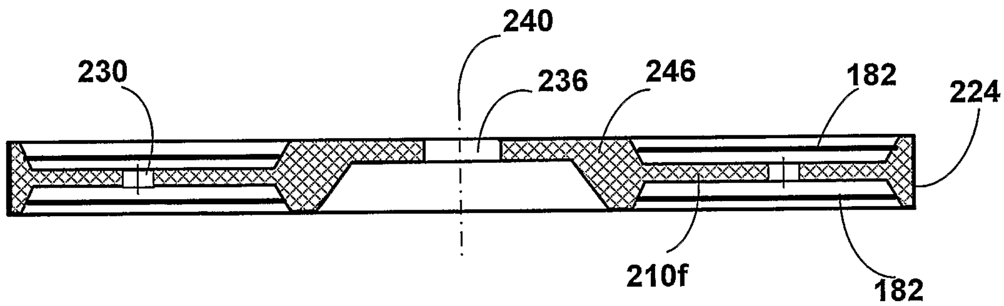


FIG. 5F

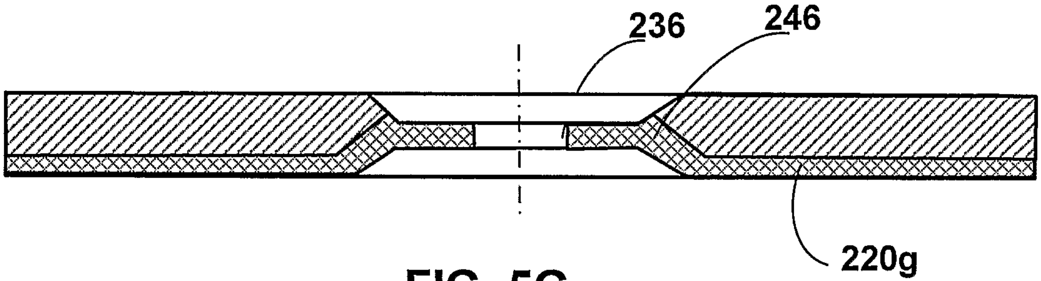


FIG. 5G

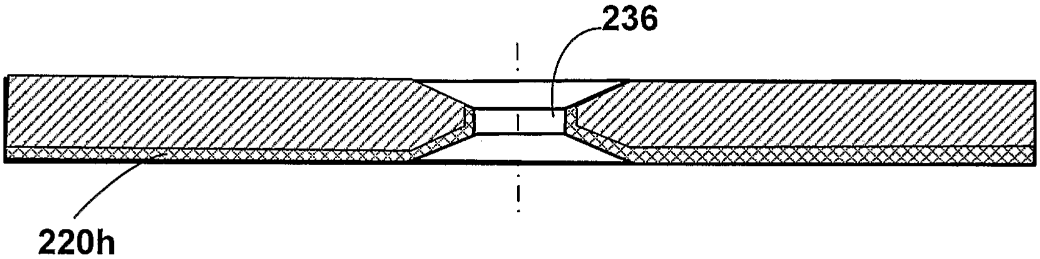


FIG. 5H

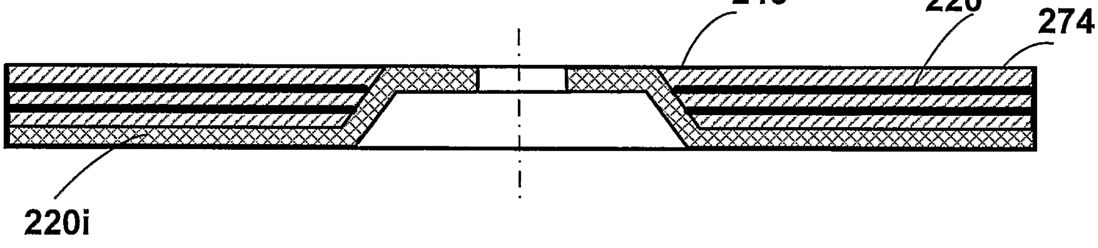


FIG. 5I

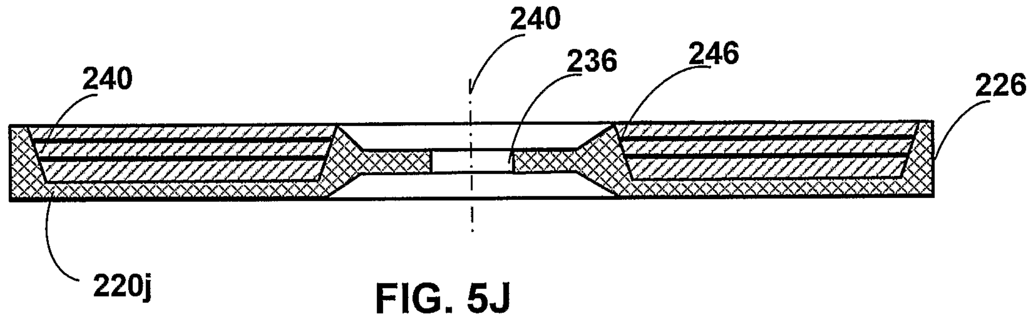


FIG. 5J

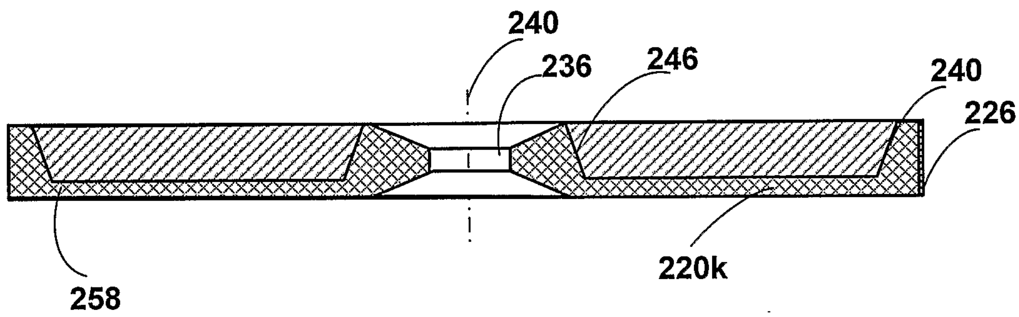


FIG. 5K

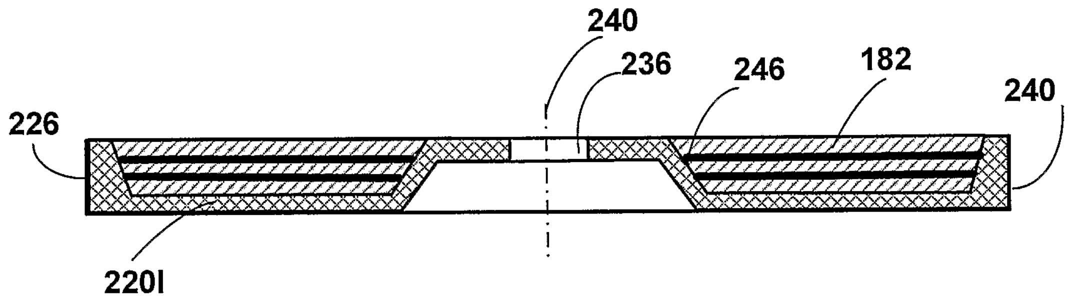


FIG. 5L

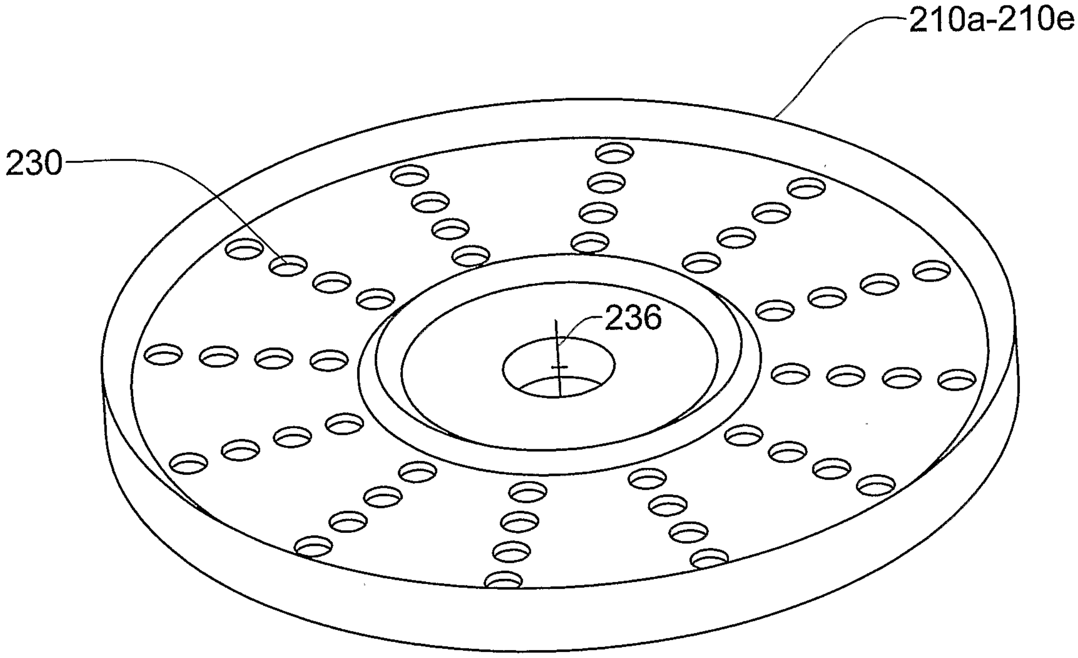


FIG. 6A

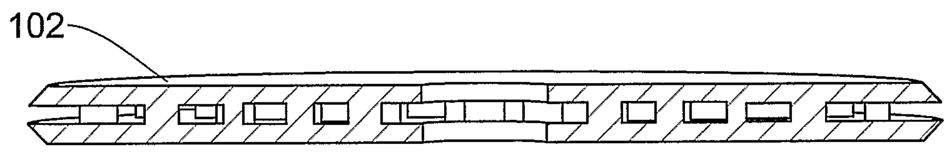


FIG. 6B

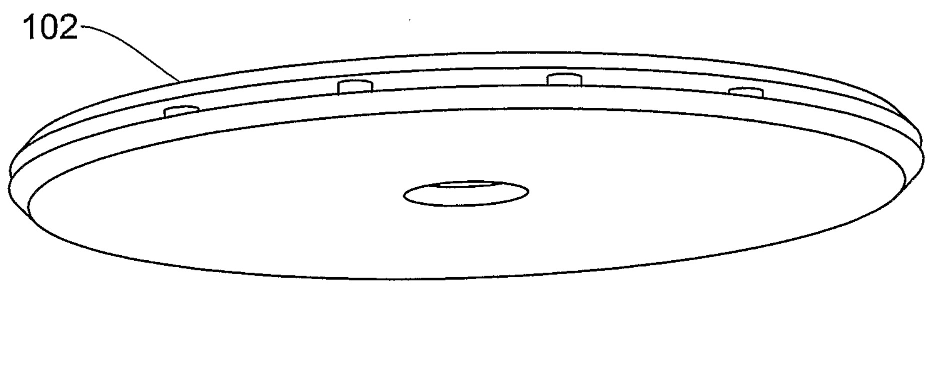


FIG. 6C

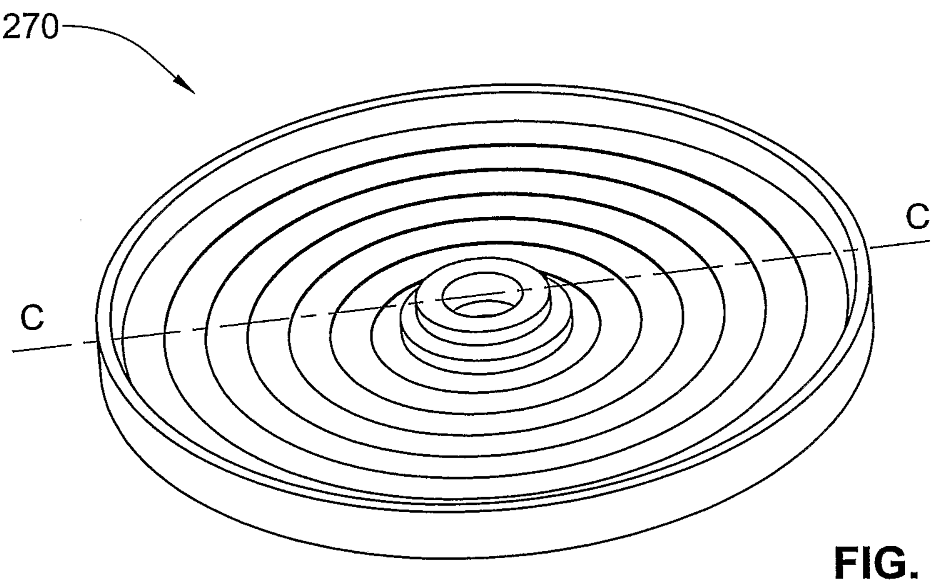


FIG. 7A

Section C-C

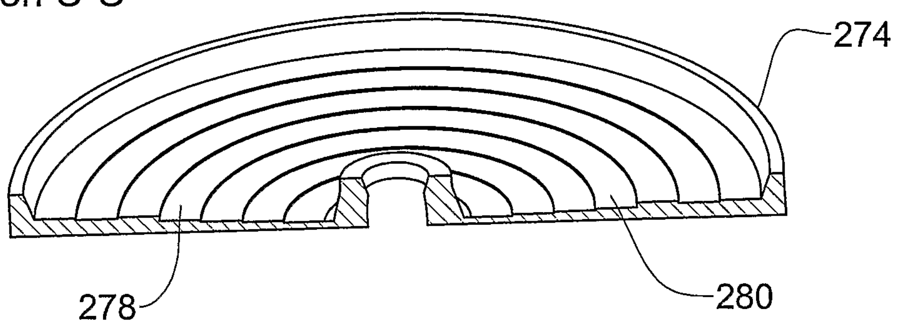


FIG. 7B

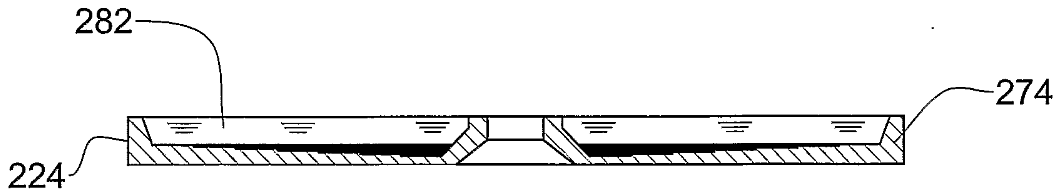


FIG. 7C

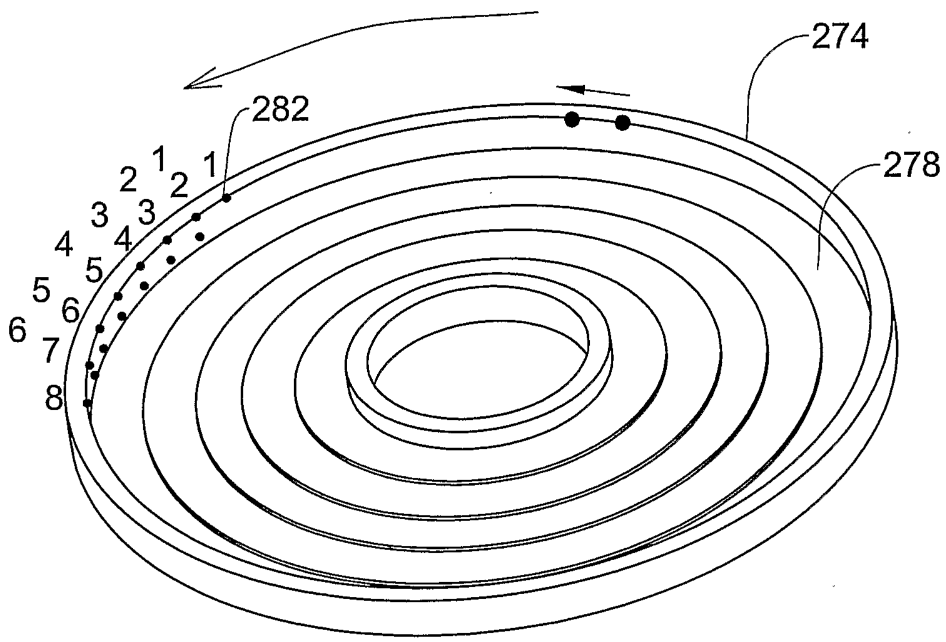


FIG. 8

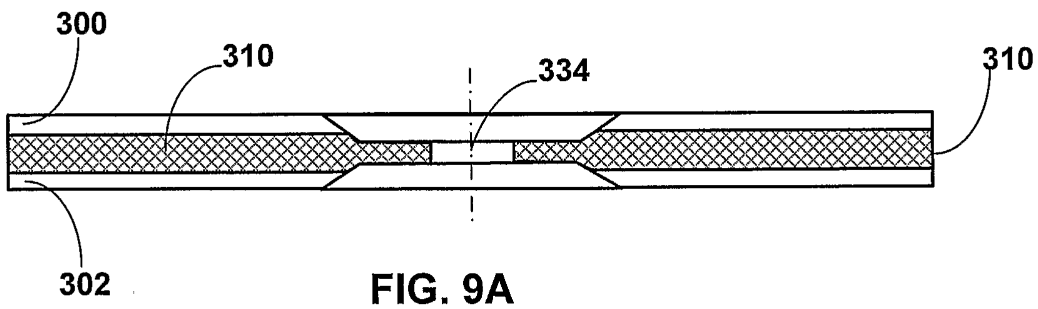


FIG. 9A

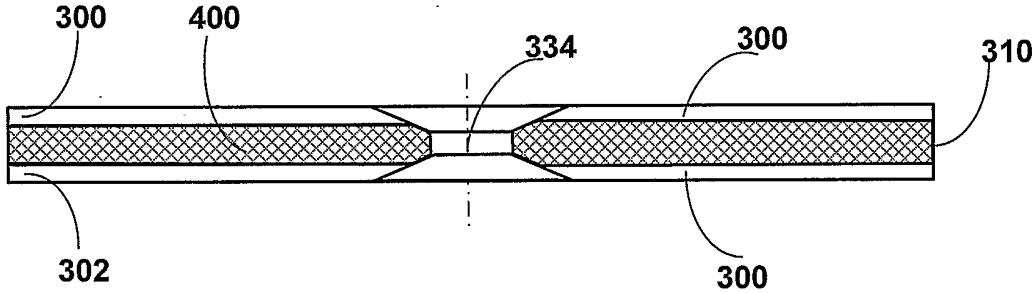


FIG. 9B

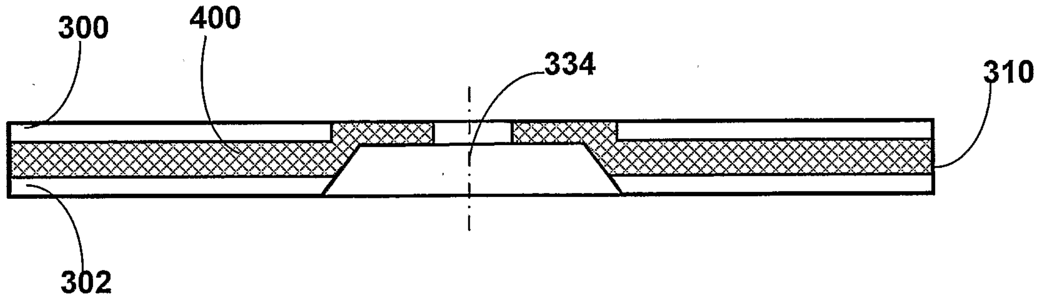


FIG. 9C

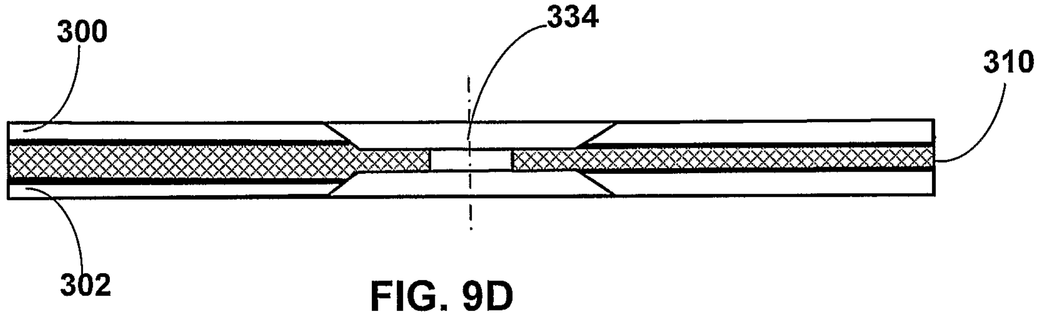


FIG. 9D

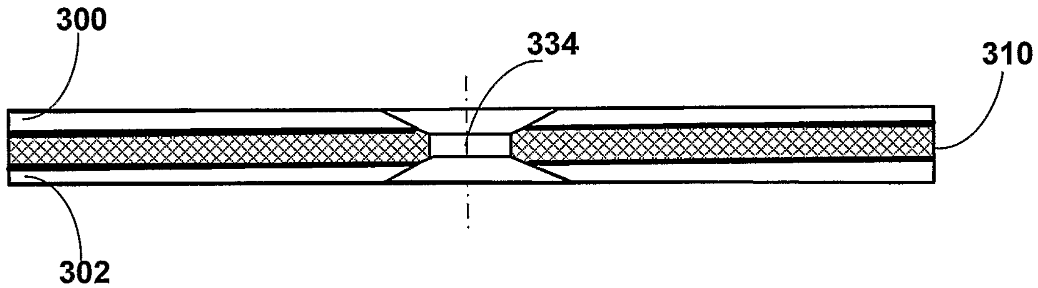


FIG. 9E

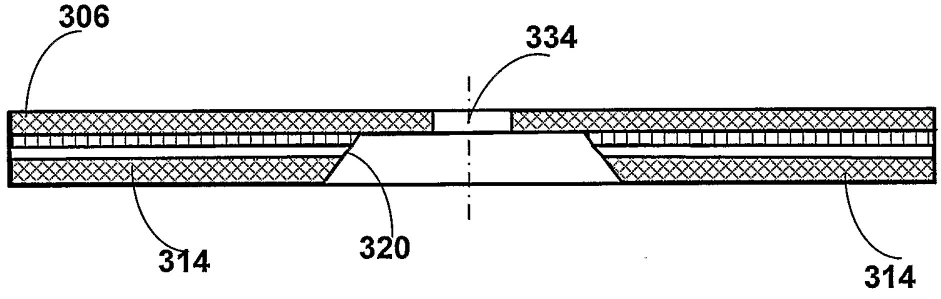


FIG. 9F

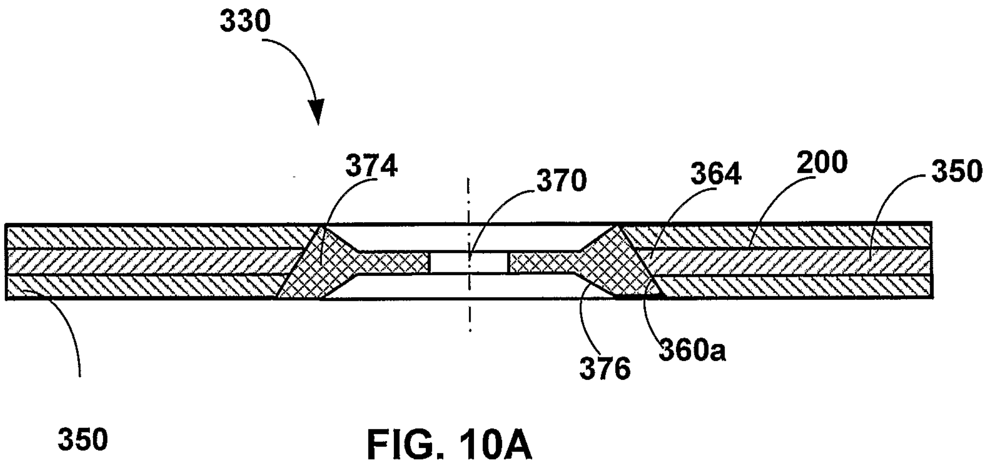


FIG. 10A

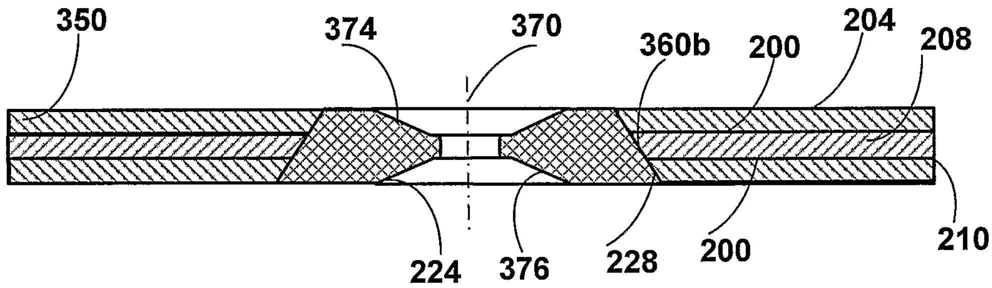


FIG. 10B

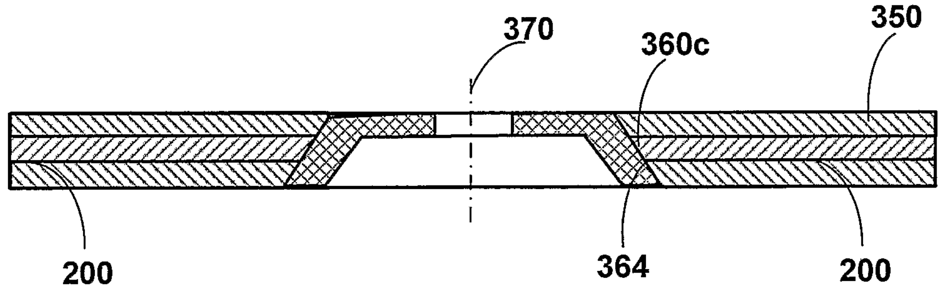


FIG. 10C

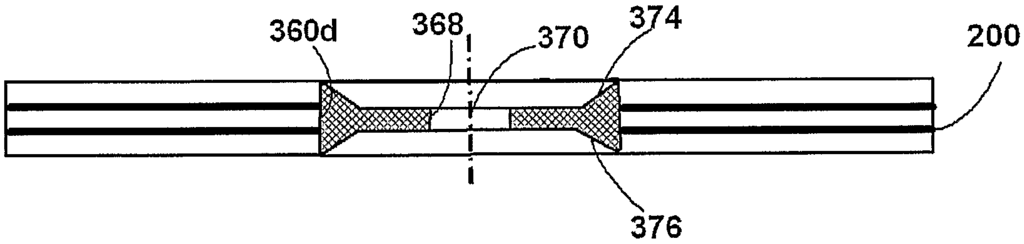


FIG. 10D

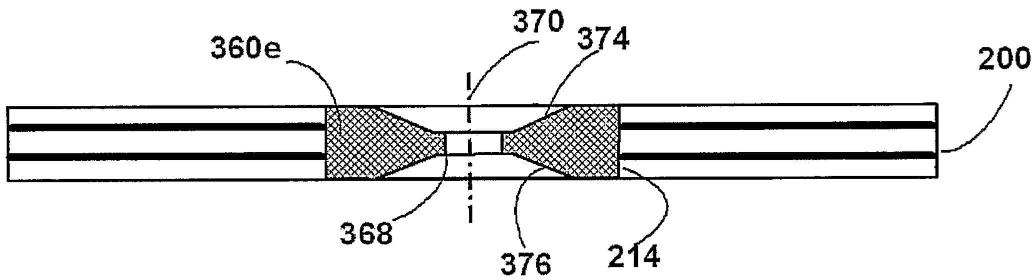


FIG. 10E

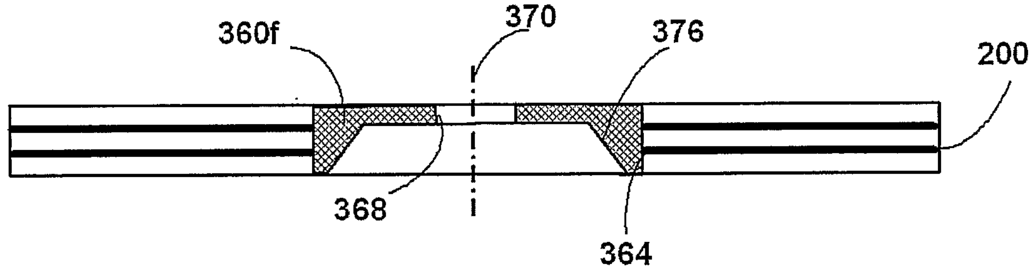


FIG. 10F

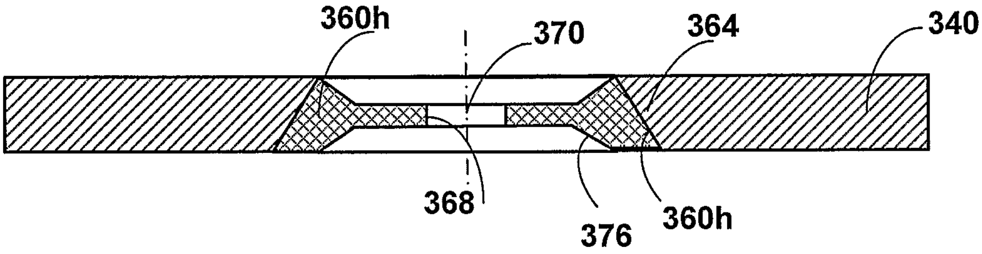


FIG. 10H

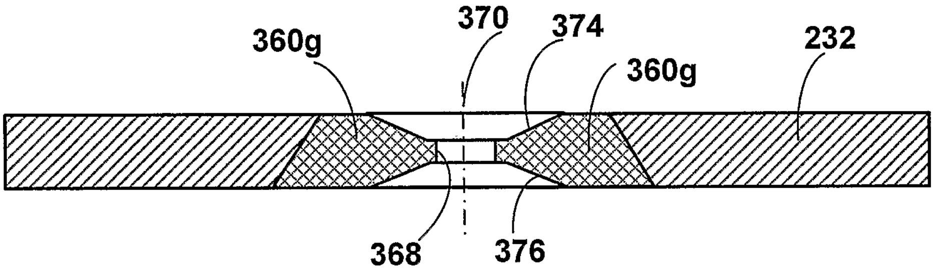


FIG. 10G

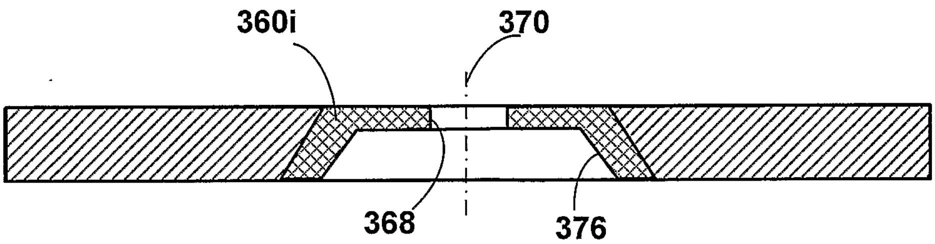


FIG. 10I

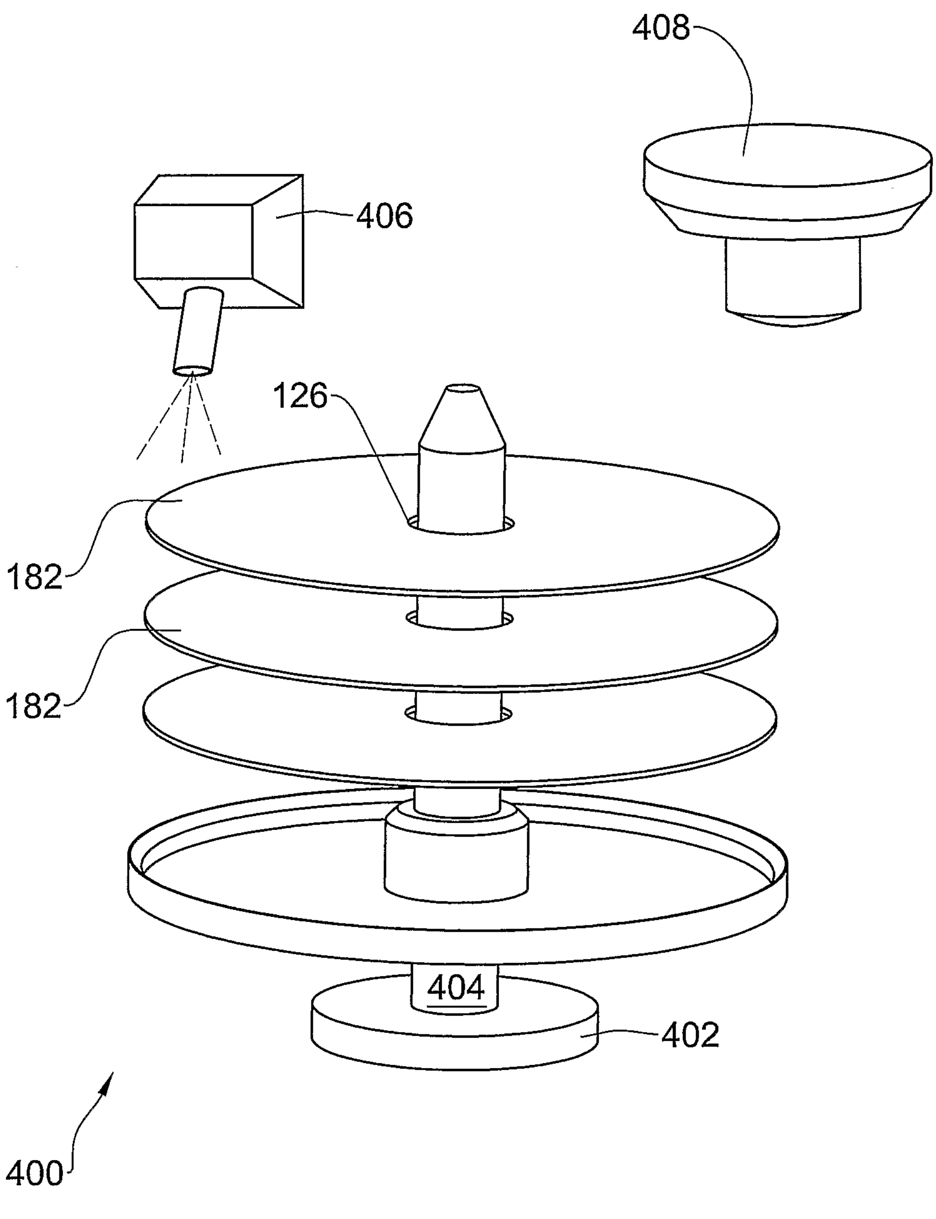


FIG. 11

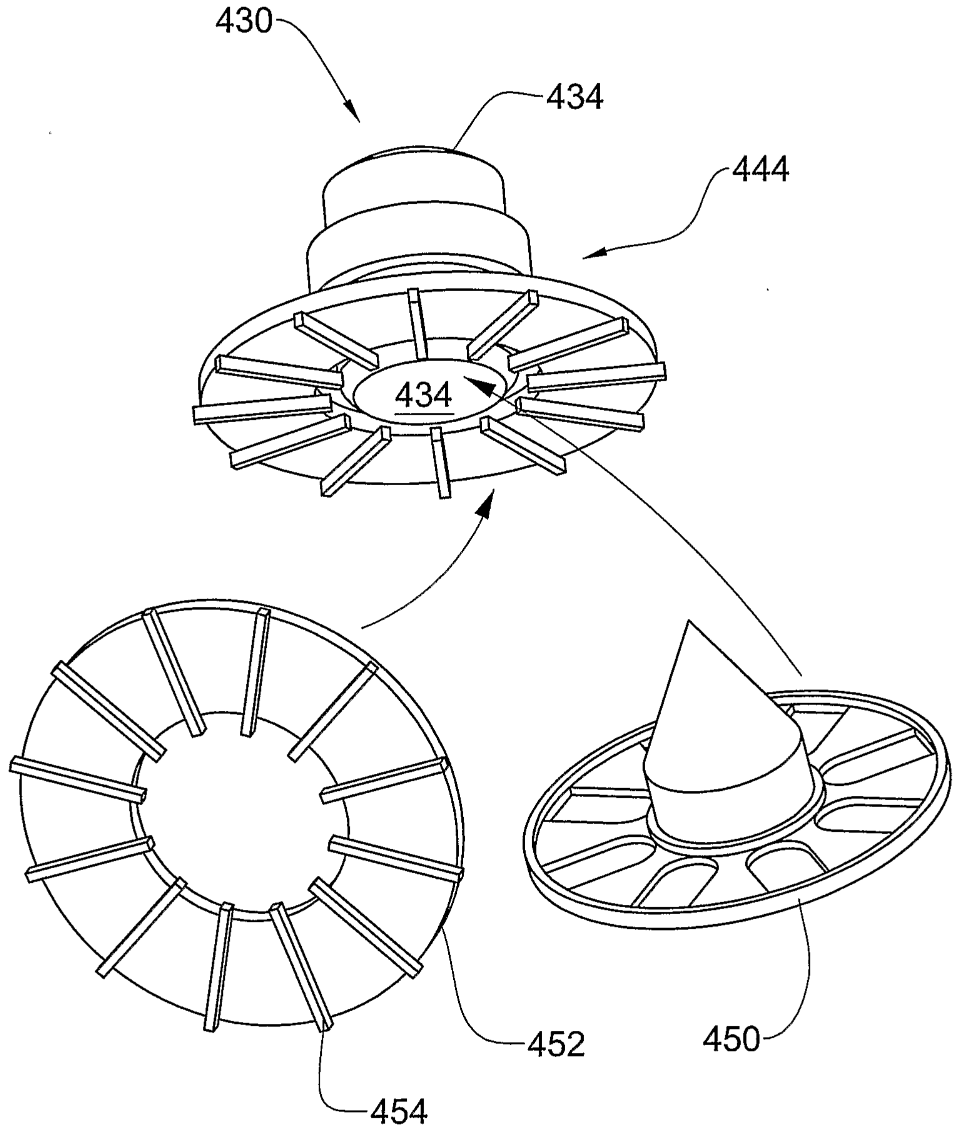


FIG. 12

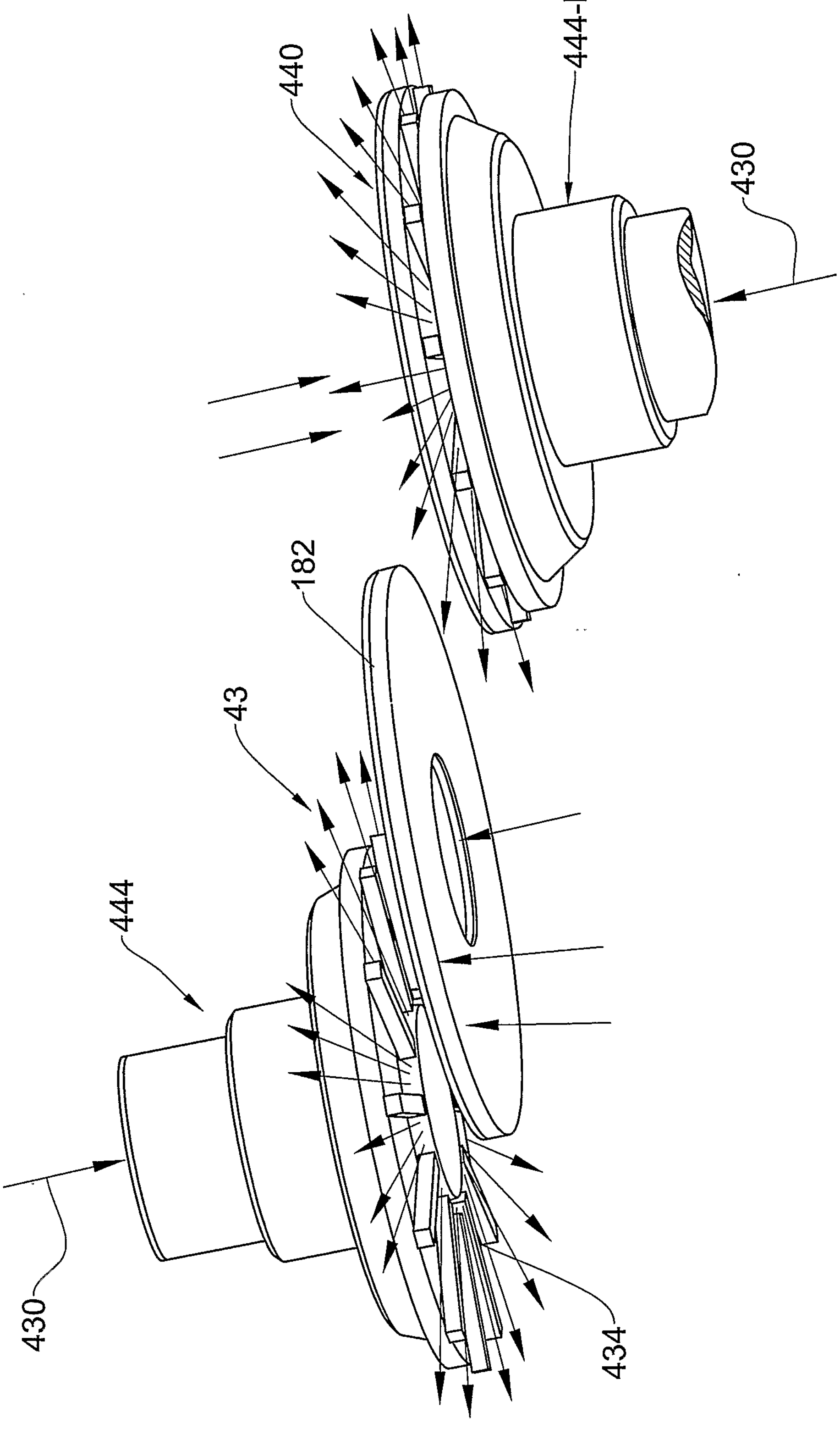


FIG. 13