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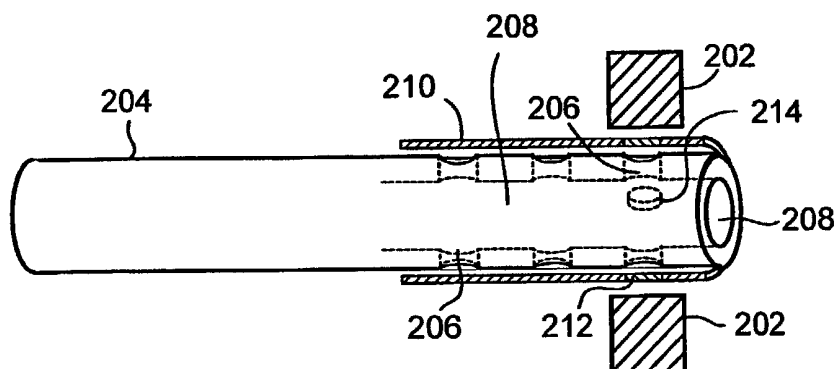
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(54) Title: METHOD AND APPARATUS FOR MANUFACTURING MEDICAL SUPPORT DEVICES



(57) Abstract: Method for producing a medical support device from an object, using an electromagnetic field generator, whereby the method comprises of the steps of placing a formation mandrel against the object, close to a predetermined formation area, and applying the electromagnetic field to the formation area, thereby forming the object. The produced object can be made from a tubular segment, a folded sheet of material or a plurality of wires joined together.

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METHOD AND APPARATUS FOR MANUFACTURING MEDICAL SUPPORT DEVICES

FIELD OF THE INVENTION

5 The present invention relates to a method and apparatus for manufacturing medical devices, in general and to a method and apparatus for manufacturing medical support devices, in particular.

BACKGROUND OF THE INVENTION

10

Medical support devices are known in the art. An artery support device is also called a stent. Methods for manufacturing stents are known in the art. US patent No. 5,767,480, to Anglin et al, is directed to a hole generation and lead forming for integrated circuit lead frames using laser machining.

15

US patent No. 5,073,694 to Tessier et al, is directed to a method and apparatus for laser cutting a hollow metal workpiece. The method provides for the cutting of the hollow metal workpiece while minimizing or eliminating residue adherence to the inner circumference of the workpiece. Coolant is pumped through the apparatus to contact the inner portion of the workpiece before and during laser cutting.

20

US patent No. 5,345,057 to Muller, is directed to a method of cutting an aperture in a device by means of a laser beam.

25

US patent No. 5,780,807 to Saunders, is directed to a method and apparatus for direct laser cutting of metal stents. The expandable stent is made from a single length of tubing and utilizes direct laser cutting from a single metal tube using a finely focused laser beam. The stent may be made in a variety of ways, but the preferred method provides for cutting a thin-walled tubular member of materials such as stainless steel in order

to remove portions of the tubing and give a desired pattern. This is done by utilizing a laser beam.

US patent No. 5,707,385 to Williams, is directed to a drug loaded elastic membrane comprising an expandable sheath for delivering
5 a therapeutic drug in a body lumen. The expandable membrane has a first layer and a second layer, which are joined along their edges to form a fluid-tight seal. Before joining the layers, a plurality of apertures are formed in the first layer by known methods such as using a laser.

US patent No. 5,843,117 to Alt et al., is directed to an implantable vascular
10 and endoluminal stent and the process of fabricating the same. Tube-type stent is fabricated from tubing with longitudinally oriented struts interconnected by bars or bridges, which define a plurality of through-holes in the wall of the tube. This multiplicity of through-holes is cut by a laser beam.

US patent No. 5,531,741 to Barbacci, is directed to illuminated
15 stents which are designed as an improved light emitting device. The stent is formed by extruding a length of tubing and then followed by molding and shaping. Drainage openings are formed in one step of the process. These holes may be made by piercing the wall of the tubing by utilizing a sharpened cutter or by use of a laser.
20

Electromagnetic forming (EMF) is known in the art. In general, this method is used to form, cut, pierce, and join metals having relatively high electrical conductivity, such as copper, mild alloy, aluminum, low-carbon steel, brass, and molybdenum. The EMF process uses a
25 capacitor bank, a forming coil, a field shaper (mandrel), and an electrically conductive workpiece to create intense magnetic fields that are used to do useful work. This intense magnetic field, produced by the discharge of a bank of capacitors into a forming coil, lasts only a few microseconds. The resulting eddy currents that are induced in a conductive workpiece that is
30 placed close to the coil, then interact with the magnetic field to cause mutual repulsion between the workpiece and the forming coil. The force of

this repulsion is sufficient to stress the work metal beyond its yield strength, resulting in a permanent deformation. The magnetic field rapidly accelerates the workpiece against the mandrel, thus forming it to the desired shape. Because the actual forming takes place in a matter of a few microseconds, the high strain rate forming does not affect the material properties in an adverse way. The pressure induced on the workpiece, is comparable to that encountered in mechanical forming of similar parts.

EMF can be usually applied to five forming methods: compression, expansion, contour forming, punching and joining. It is used to expand, compress, or form tubular shapes, to form a flat sheet, and to combine several forming and assembly operations into a single step. It is used in single-step assembly of metal parts to each other or to other components, such as in electrical cables, and joining of aluminum and copper. Highly resistant metals such as titanium, need special EMF equipment, which operate at higher frequencies in the range of 20 to 100kHz.

Because the material is loaded into its plastic region, the springback often associated with mechanical forming, is virtually absent in electroformed parts. Joints made by EMF process are typically stronger than the parent material, and compared to other joining methods, such as laser welding. Assemblies using metal parts formed onto plastics, composites, rubber, and ceramics are also common.

More information regarding EMF can be found in the following references: V. S. Balanethiram, Xiaoyu Hu, Marina Altynova and Glenn S. Daehn, "High Velocity forming: Is it Time to Rediscover This Technology", *Engineering Research Center Report ERC/NSM-S-94-15*, The Ohio State University, Columbus, OH, 1994, PP. 36-37, V. S. Balanethiram, Xiaoyu Hu, Marina Altynova and Glenn S. Daehn, "Hyperplasticity: Enhanced Formability at High Rates", *Journal of Materials Processing Technology*, Vol. 45, 1994, pp. 595-600, G. S. Daehn, M. Altynova, V. S. Balanethiram, G. Fenton, M. Padmanabhan, A. Tamhane, and E. Winnard,

"High-Velocity Metal Forming—An Old Technology Addresses New Problems", *JOM*, Vol. 7, July 1995, pp. 42-45, and Metals Handbook, 9th Edition, Volume 14, Forming & Forging, ASM Electromagnetic Forming International, Metals Park, OH, pp. 644-653.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide a novel method for manufacturing medical support devices, which overcomes the disadvantages of the prior art.

5 Another object of the present invention is to provide a novel method for manufacturing metal medical devices, while maintaining their original characteristics, which overcomes the disadvantages of the prior art.

 In accordance with the present invention, there is thus provided
10 a method for producing a medical support device from at least one object, using an electromagnetic field generator. The method includes the steps of placing a forming mandrel against the at least one object in the vicinity of a predetermined formation area, and applying at least one electromagnetic field on the formation area, thereby forming the shape of
15 the at least one object.

 The method can further include the steps of determining the formation area on the object and repeating from the step of determining, so that additional formation areas define a final shape for the object, the final shape being generally cylindrical.

20 According to one aspect of the present invention, the object has a tubular shape. In this case, the forming mandrel includes at least one opening, wherein the step of determining includes positioning a selected one of the openings underneath a selected one of the formation areas. Hence, the result of the step of applying an electromagnetic field is
25 punching of material within the selected formation area.

 According to another aspect of the invention, the tubular object is made of a material, which can be selected from families of shape memory materials, super elastic materials, stainless steel, alloys, polymeric materials, biocompatible materials, and the like. Accordingly, the
30 method can further include a preliminary step of applying shape memory characteristics to the tubular object. Alternatively, the method can also

include a final step of applying shape memory characteristics to the tubular object.

In accordance with another preferred embodiment of the present invention, there is thus provided a method for producing a medical support
5 device from a hollow tubular object. The method includes the steps of placing a predetermined mandrel against each of a plurality of formation areas, and applying at least one electromagnetic field on each of the formation areas, thereby forming the tubular object at each of the formation areas.

10 The method can further include a step of determining the formation area on the object. The mandrel can include at least one opening, in which case, the step of placing, includes positioning of a selected one of the openings underneath a selected one of the formation areas. Hence, the step of applying the electromagnetic field causes
15 punching of material within the selected formation area.

The tubular object can be made of shape memory material. The method can further include a preliminary step of applying shape memory characteristics to the tubular object. Alternatively, the method can further include a final step of applying shape memory characteristics to the tubular
20 object.

According to a further aspect of the invention, the above object can include a plurality of wires. Thus, the formation area is defined by an overlap intersection of at least two wires. For example, the method can further include a step of placing the wires in a crosswise structure.

25 It is noted that selected ones of the wires can be straight or curved. These wires can be made of any of the above list of materials, and treated accordingly, before or after formation.

In accordance with a further preferred embodiment of the present invention, there is provided a medical support device, which
30 includes a tubular object. The tubular object includes a plurality of openings, wherein selected ones of the openings were electromagnetically

formed. This tubular object can be made of any of the above list of materials.

In accordance with a further preferred embodiment of the present invention, there is provided a medical support device, which includes a sheet of conductive material. The sheet of conductive material is folded so as to provide a tubular object, where one edge of the sheet of conductive material overlaps the other, thereby defining an overlapping section. The overlapping edges are joined by means of electromagnetic forming. This medical support device can further include a plurality of openings, where at least some of them were formed according to EMF or according to conventional forming techniques such as drilling, laser cutting, chemical etching, fluid punching, electrical discharge machining, chemical machining, photochemical blanking, abrasive material flow machining, ultrasonic machining, hydrodynamic machining, stamping, and the like.

The sheet of conductive material can be made of any of the above listed materials. The method can have a preliminary or a final step of applying shape memory characteristics to the sheet of conductive material.

In accordance with another preferred embodiment of the present invention, there is provided a medical support device, which includes a sheet of conductive material. The sheet of conductive material includes a plurality of openings, which are formed by electromagnetic forming. The sheet of conductive material is folded so as to provide a tubular object, where one edge of the sheet of conductive material overlaps the other, thereby defining an overlapping section.

The joining of the overlapping edges within the overlapping section can be made using EMF or by conventional techniques such as arc welding, gas welding, resistance welding, soldering, brazing, electron beam welding, laser beam welding, friction welding, diffusion bonding, explosive welding, adhesive bonding, and the like.

In accordance with a further preferred embodiment of the present invention, there is provided a method for producing a medical support device from a sheet of formable material. The method includes the steps of placing a predetermined mandrel against a plurality of formation areas, and applying at least one electromagnetic field on each of the formation areas, thereby forming the sheet at each of the formation areas. The method can further include a step of determining the formation area on the object.

The mandrel can include at least one opening. In this case the step of placing includes positioning a selected one of the openings underneath a selected one of the formation areas. Hence, the step of applying the electromagnetic fields causes shearing of material within the selected formation area.

The sheet of formable material is made of any of the above materials.

The method can further include a step of folding the sheet of formable material, thereby producing a tubular object.

According to one aspect of the invention, at least selected ones of the formation areas are located in overlapping sections of the sheet of formable material, the overlapping sections being defined in the step of folding.

Depending on various considerations, which arise from the physical organ to be treated, the formable material can either be electrically conductive or not electrically conductive.

In accordance with a further preferred embodiment of the present invention, there is provided a method for producing a medical support device including the steps of placing a plurality of wires wherein at least a section of each of the wires overlaps a section of at least another of the wires, each of the overlapping section defining an intersection area, and applying at least one electromagnetic field on the overlapping wires of

each of the intersection area, thereby joining each of the wires at the intersection area.

The method can further include a step of repeating the step of applying, thereby forming a mesh-like structure of the wires. The method
5 can also include a step of folding the mesh, thereby forming a cylinder.

The wires can be generally straight or curved. The arrangement of the wires can be crosswise. At least selected ones of the wires can be made of shape memory alloy, or any of the above listed materials.

In accordance with a further preferred embodiment of the
10 present invention, there is provided a medical support device, which includes a plurality of wires. Each of the wires intersects with at least another of the wires, thereby defining a plurality of intersection points, thereby forming a mesh, where the mesh is folded to the shape of a cylinder. At least selected ones of the intersecting wires are joined to the
15 wires intersecting therewith, by means of electromagnetic forming process.

BRIEF DESCRIPTION OF THE DRAWINGS CORRECT DRAWING LIST

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

5 Figure 1 is a schematic illustration of a system for manufacturing metal medical support elements, constructed and operative in accordance with a preferred embodiment of the present invention;

 Figure 2 is an illustration of two wires to be joined together and a forming coil, constructed and operative in accordance with another
10 preferred embodiment of the invention;

 Figure 3A is a cross sectional illustration of a stent manufacturing device, constructed and operative in accordance with a further preferred embodiment of the present invention;

 Figure 3B is a cross sectional view of the stent manufacturing
15 device and the work-piece of Figure 3A, constructed and operative in accordance with another preferred embodiment of the present invention;

 Figure 4A is a side view illustration of a work-piece, constructed and operative in accordance with a further preferred embodiment of the present invention;

20 Figure 4B is an illustration in perspective of the coil of the device of Figure 4A, constructed and operative in accordance with another preferred embodiment of the present invention;

 Figure 4C is an illustration in perspective of the mandrel of the device of Figure 4A, constructed and operative in accordance with a
25 further preferred embodiment of the present invention;

 Figure 4D is an illustration in perspective of the work-piece of Figure 4A, constructed and operative in accordance with another preferred embodiment of the present invention;

 Figure 4E is an illustration in perspective of work-piece, after
30 being treated by the device of Figure 4A;

Figure 5 is an illustration in perspective of a forming device, constructed and operative in accordance with a further preferred embodiment of the present invention;

Figure 6 is a cross-sectional illustration of a forming device,
5 constructed and operative in accordance with another preferred embodiment of the present invention;

Figure 7A is a cross-sectional illustration of a forming device, constructed and operative in accordance with a further preferred embodiment of the present invention;

10 Figure 7B is an illustration in perspective of a coil of the device of Figure 7A, constructed and operative in accordance with another preferred embodiment of the present invention;

Figure 7C is a cross-sectional illustration of a forming device, constructed and operative in accordance with a further preferred
15 embodiment of the present invention;

Figure 8 is a schematic illustration of a metal web, constructed in accordance with another preferred embodiment of the present invention;

Figure 9A is a schematic illustration of a plurality of wire elements, and a wire structure, constructed and operative in accordance
20 with a further preferred embodiment of the invention;

Figure 9B is an illustration of a wire, constructed in accordance with another preferred embodiment of the present invention;

Figure 9C is an illustration of a mesh structure, constructed in accordance with a further preferred embodiment of the present invention;

25 Figure 9D is an illustration of a medical support device, constructed and operative in accordance with another preferred embodiment of the invention;

Figure 10A is an illustration in perspective of a forming device, constructed and operative in accordance with a further preferred
30 embodiment of the present invention;

Figure 10B is an illustration in perspective of a mandrel, for use with the forming device of Figure 10A, constructed and operative in accordance with another preferred embodiment of the present invention; and

5 Figure 10C is a side view of forming device of Figure 10A, constructed and operative in accordance with a further preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention overcomes the disadvantages of the prior art by providing a novel method for manufacturing medical support devices and elements, using electromagnetic forming (EMF) techniques.

5 Reference is now made to Figure 1, which is a schematic illustration of a system for manufacturing metal medical support elements, generally referenced 100, constructed and operative in accordance with a preferred embodiment of the present invention.

 System 100 includes a forming coil 106 (electromagnetic
10 generator), energy storage capacitors 104 and a power supply 102. The energy storage capacitors 104 are connected to the power supply 102 and to the forming coil – the electromagnetic field generator 106. In the present example, the electromagnetic field generator includes a metal coil.

 The forming coil 106 is placed around a conductive metal object,
15 generally referenced 110 and produces pulses of electromagnetic field. A field shaper mandrel 112 is inserted between the work piece 110 and the coil 106. The electromagnetic generator (forming coil 106) produces pulses of electromagnetic field. This very intense electromagnetic field is produced by the discharge of a bank of capacitors 104 into the forming coil
20 106. The resulting eddy currents that are induced in the conductive metal object, then interact with the magnetic field to cause mutual repulsion between the conductive metal work-piece 110 and the forming coil 106. The force of this repulsion is sufficient to stress the metal work-piece beyond its yield strength, resulting in a permanent deformation. The field
25 shaper mandrel 112 is used to concentrate the magnetic field at the points at which the forming/cutting is desired. The magnetic pressure is localized in certain regions of the metal work-piece. This technique most efficiently uses stored energy to produce high local forming pressures in desired areas. In the present example, mandrel 112 includes a hole. Accordingly,
30 the apparatus 100 can Electro-Magnetically “punch” a hole in the

work-piece, by accelerating the metal work piece in the vicinity of the hole, toward it.

Reference is now made to Figure 2, which is an illustration of two wires to be joined together and a forming coil, constructed and operative in accordance with another preferred embodiment of the invention. Wires 162 and 160 are placed one over the other, whereby they cross each other at a crossing section 164. A support member 166 is placed underneath wire 160. An accelerator element 168 can be placed over the crossing section 164. Forming coil 152 is located around the crossing section 164 and the supporting member 166. At a predetermined moment, the forming coil 152 produces a magnetic field pulse. This electromagnetic field accelerates the two wires, toward the support member 166, thereby forcing them to join at the crossing section 164. At the same time, the magnetic field pulse also accelerates the accelerator element 168 towards the support member 166. Accelerator element 168 can be used in various cases where additional forces are required, such as, when the two joined pieces are characterized by poor conductivity or non at all.

It is noted that the material characteristics of the two wires 162 and 160 are not changed outside the crossing section 164. The strength of the welded joint is at least comparable to the strength of the parent material.

Reference is now made to Figure 3A, which is a cross sectional illustration of a stent manufacturing device, generally referenced 200, constructed and operative in accordance with a further preferred embodiment of the present invention. Device 200 includes a mandrel 204 and a coil 202. Mandrel 204 is a general hollow tube (defined by a shaft 208), which includes a plurality of holes 206, at the perimeter thereof. Mandrel 204 is concentrically placed within coil 202. A tubular work-piece 210 is concentrically placed between mandrel 204 and coil 202.

Reference is further made to Figure 3B, which is a cross sectional view of device 200 and work-piece 210 of Figure 3A. Coil 202 produces an electromagnetic pulse, when an electrical current pulse is conducted there through. This magnetic pulse causes a counter flow of electrical current within the work-piece 210. The vector combination of the electromagnetic field and the counter electric current, causes the generation of mechanical forces on the work-piece 210, which are directed toward the center of mandrel 204.

As a result, pieces (generally referenced 214) of material of the work-piece 210 are sheared against openings 206, thus producing holes 212. In accordance with one aspect of the present invention, the various portions of the work-piece 210 can be punched in a single cycle. Alternatively, the entire work-piece 210 can be punched in a single cycle. It is noted that the material characteristics of the work-piece 210 are substantially maintained throughout and after the punching process. The amount of heat, generated through the process of the present invention is significantly reduced in comparison with other methods for manufacturing stents from a single work-piece.

Reference is now made to Figures 4A, 4B, 4C and 4D. Figure 4A is a side view illustration of a work-piece, generally referenced 310, and a device, generally referenced 300, for executing a preliminary stage in the manufacturing of a tubular device, constructed and operative in accordance with another preferred embodiment of the present invention. Figure 4B is an illustration in perspective of the coil of the device of Figure 4A. Figure 4C is an illustration in perspective of the mandrel of the device of Figure 4A. Figure 4D is an illustration in perspective of the work-piece of Figure 4A.

Device 300 includes a coil 302 and a mandrel 304. Coil 302 is a flat coil, which is adapted to surround flat objects (Figure 4B). Mandrel 304 (Figure 4C) is a flat surface, which includes a plurality of holes, generally referenced 308. Mandrel 304 is placed within coil 302 (Figure 4A).

Work-piece 310 is placed within coil 302, adjacent to mandrel 304. When coil 302 conducts a strong electric pulse, it produces a respective magnetic field pulse, therein. The magnetic field induces electrical current in the work-piece 310, and in turn causes mechanical forces, which drive the work-piece 310 towards mandrel 304. These forces are significantly strong and press the work-piece 310 against mandrel 304. In the present example, these forces cause shearing of work-piece material, where the mandrel 304 exhibits a sharp edge, such as in holes 308.

Reference is further made to Figure 4E, which is an illustration in perspective of work-piece 310, after being treated by device 300. Now, work-piece 310 includes holes, generally referenced 312, in a pattern, which is respective of the hole pattern of mandrel 304. The above device and procedure, provide means for perforating a pattern of holes in a material sheet, which can be further folded, and formed to a shape of a perforated tube. The edges of the material sheet may be joined by metal joining methods known in the art, such as arc welding, gas welding, resistance welding, soldering, brazing, electron beam welding, laser beam welding, friction welding, diffusion bonding, explosive welding, ultrasonic welding, adhesive bonding, EMF forming, and the like.

Reference is now made to Figure 5, which is an illustration in perspective of a forming device, generally referenced 350, constructed and operative in accordance with a further preferred embodiment of the present invention. Device 350 includes a coil 352 and a mandrel 354. Mandrel 354 is a massive support device, which is fixed to its place. A work-piece 360 is made of a generally flat sheet of material, which is folded to form a tubular object. Device 350 is designed to firmly connect the overlapping edges 362 and 364 of work-piece 360, thereby producing a closed shape. Work-piece 360 is inserted in coil 352. Mandrel 354 is inserted inside work-piece 360, and placed in the vicinity of overlapping edges 362 and 364. As a strong pulse of electric current flows through the wire, which includes coil 352, the coil 352 produces a strong magnetic field

pulse. This magnetic pulse, causes a counter electric current pulse in work-piece 360. The vector combination of the magnetic pulse and the counter electric current pulse, produce a mechanical force, which accelerates overlapping edges 362 and 364 toward mandrel 354. The strong impact force, causes the two overlapping edges 362 and 364 to join together, thereby producing a closed cylinder. It is noted that this procedure can be performed on work-pieces, which were treated according to the procedure presented above, in conjunction with Figure 4A. Alternatively, this procedure can be used independently, for work-pieces, which were initially treated by any other forming technique known in the art. Such techniques include laser beam machining, electrical discharge machining, electrochemical machining, chemical machining, photochemical blanking, abrasive jet machining, abrasive flow machining, ultrasonic machining, hydrodynamic machining, electronic beam machining, stamping, fine blanking, drilling, and the like.

It is noted that the present invention can also be implemented for forming materials, which exhibit poor electrical conductivity or non at all, by utilizing an accelerator element. The accelerator element is made of a highly electrical conductive material, which provides high-induced currents.

Reference is now made to Figure 6, which is a cross-sectional illustration of a forming device, generally referenced 370, constructed and operative in accordance with another preferred embodiment of the present invention. Device 370 includes a coil 372, a mandrel 374 and an accelerating element 376. Two work-pieces 380 and 382 are inserted in coil 372, overlapping each other.

Reference is now made to Figures 7A and 7B. Figure 7A is a cross-sectional illustration of a forming device, generally referenced 400, constructed and operative in accordance with a further preferred embodiment of the present invention. Figure 7B is an illustration in perspective of a coil of the device of Figure 7A. Device 400 includes a pair

of coils 402A and 402B and a mandrel 404. Coils 402A and 402B each is designed and constructed in the form of a ring.

The coils 402A and 402B are positioned parallel to each other. Mandrel 404 is placed between the coils 402A and 402B. A work-piece
5 410 is placed between coil 402A and mandrel 404, in close vicinity to coil 402A. When wire 408 conducts an electric current pulse, it produces in turn, a magnetic field pulse, which is induced onto work-piece 410. Work-piece 410 produces a counter electric current. The vector combination of the magnetic field and the counter electric current pulse
10 produces a mechanical force, which accelerates work-piece 410 towards mandrel 404. Work-piece 410 is deformed depending on the shape (curves and openings) which characterizes mandrel 404.

Reference is further made to Figure 7C, which is a cross-sectional illustration of a forming device, generally referenced 420,
15 constructed and operative in accordance with another preferred embodiment of the present invention. The forming device includes a coil 422 similar to coil 402A as described with reference to Figure 7A, and a mandrel 426. A work-piece 424 is placed between the coil 422 and mandrel 426. Work-piece 424 is deformed depending on the shape
20 (curves and openings) which characterizes mandrel 426, in a process similar to that described with respect to Figure 7A.

Reference is now made to Figure 8, which is a schematic illustration of a metal web, generally referenced 450, constructed in accordance with a further preferred embodiment of the present invention.

25 Web 450 is formed of a plurality of wires, generally referenced 452 and 454. These wires are arranged in a crosswise structure, wherein the length portion of web 450 is made of wires 452, and the breadth portion is made of wires 454. An intersection between a selected length wire 452 and a selected breadth wire 454 is denoted 456. In the present
30 example, the upper right intersection 456 is further denoted by a circle. In

accordance with the present invention, each of these intersections, is joined using electromagnetic forming techniques.

It is noted that each of the wires 452 and 454 can be made using a different metal or conductive compound material.

5 For example, the length portion wires can be made of elastic alloys while the breadth portion wires are made of shape memory alloys. It is noted that the use of electromagnetic forming, simplifies the manufacturing process, while maintaining the original characteristics of the materials used, such as elasticity, plasticity, shape memory
10 characteristics, and the like.

Reference is now made to Figure 9A, which is a schematic illustration of a plurality of wire elements, generally referenced 470, and a wire structure, constructed and operative in accordance with another preferred embodiment of the invention.

15 Wire 470 is shaped, generally as a uniform sinus waveform. Wires 470A, 470B and 470C, being identical to wire 470, form a mesh structure, when placed side by side and joined at selected intersections (generally referenced 472) thereof, by means of electromagnetic forming techniques.

20 It is noted that similarly to the structure of Figure 8, various types of material can be used to form each of the wires 470. Hence, the structure can be made of many different materials. In the present example, wire 470A is made of shape memory material having a two-way action, at two different temperatures, wire 470B is made of shape memory alloy
25 having a one way action, at a predetermined temperature and wire 470C is made of a spring alloy. It is noted that alloys having plastic characteristics can also be used for such wires.

Reference is now made to Figures 9B and 9C. Figure 9B is an illustration of a wire, generally referenced 500, constructed in accordance
30 with a further preferred embodiment of the present invention. Figure 9C is

an illustration of a mesh structure, generally referenced 510, constructed in accordance with another preferred embodiment of the present invention.

Wire 500 is shaped as a non-uniform wave function, having “maximum” locations, generally referenced 502 and 504. It is noted that in accordance with further aspects of the invention, this wave function can include a combination of any known wave function, such as triangle, square, chainsaw, and the like. With reference to Figure 9C, a plurality of wires 500 are joined together by means of electromagnetic technique, to form mesh structure 510.

Reference is further made to Figure 9D, which is an illustration of a medical support device, generally referenced 520, constructed and operative in accordance with a further preferred embodiment of the invention. In general, each of the mesh or web structures presented above, can be used to form a medical support device such as a stent or a catheter tip. In the present example, mesh 510 is curved so that the left side meets the right side thereof, thereby forming the cylinder, which makes up support device 520. It is noted that the intersections between the left side wire 500A and the right side wire 500B can be fixed together by means of electromagnetic forming techniques, where one electromagnetic coil is placed around the tube mesh, or by any other joining technique, such as laser welding.

Reference is now made to Figures 10A, 10B, and 10C. Figure 10A is an illustration in perspective of a forming device, generally referenced 550, constructed and operative in accordance with another preferred embodiment of the present invention. Figure 10B is an illustration in perspective of a mandrel, generally referenced 554A, for use with the forming device 550 of Figure 10A, constructed in accordance with a further preferred embodiment of the present invention. Figure 10C is a side view of forming device 550 of Figure 10A.

Forming device 550 includes a forming coil 552, a mandrel 554 and a conductive layer 556. Mandrel 554 is adapted to receive a plurality

of wires, arrange them in a predetermined structure and hold them together during the forming procedure. With reference to Figure 10B, mandrel 554A includes a plurality of grooves, generally referenced 558A, which define a web-like structure. These grooves are then filled with wires and formed within device 550.

Referring both to Figures 10A and 10C, a plurality of wires, generally referenced 560 are placed in the grooves 558. Mandrel 554 and the inserted wires 560 are wrapped with conductive layer 556, which increases the conductivity of the wire structure. Similar to devices presented herein above, the coil 552 produces a magnetic field pulse as an electric current pulse flows there through. In turn, the combination of conductive layer 556 and wires 560 produce a counter electric current and the combination of the above produces a mechanical force, which bonds the wires together.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described here in above. Rather the scope of the present invention is defined only by the claims which follow.

CLAIMS

1. Method for producing a medical support device from at least one object, using an electromagnetic field generator, the method comprising the steps of:
5 placing a forming mandrel against said at least one object in the vicinity of a predetermined formation area; and
applying at least one electromagnetic field on said formation area, thereby forming the shape of said at least one object.
- 10 2. The method according to claim 1, further comprising the step of determining said formation area on said at least one object.
3. The method according to claim 2, further comprising the step of repeating from said step of determining, so that additional formation
15 areas define a final shape for said at least one object, said final shape being generally cylindrical.
4. The method according to claim 1, wherein said at least one object comprises a tubular object.
- 20 5. The method according to claim 4, further comprising the step of determining said formation area on said at least one object,
wherein said forming mandrel includes at least one opening,
wherein said step of determining includes positioning a selected one
25 of said at least one opening underneath a selected one of said formation areas, thereby causing punching of material within said selected formation area, as a result of said step of applying said at least one electromagnetic field.
- 30 6. The method according to claim 4, wherein said tubular object is made of a material, selected from the list consisting of:

- shape memory materials;
super elastic materials;
stainless steel;
alloys;
5 polymeric materials; and
 biocompatible materials.
7. The method according to claim 1, further comprising a preliminary
step of applying shape memory characteristics to said tubular object.
- 10 8. The method according to claim 1, further comprising a final step of
applying shape memory characteristics to said tubular object.
9. Method for producing a medical support device from a tubular object,
15 the tubular object being hollow, the method comprising the steps of:
 placing a forming mandrel against each of a plurality of formation
 areas; and
 applying at least one electromagnetic field on each said formation
 areas, thereby forming said tubular object at each said formation
20 areas.
10. The method according to claim 9, further comprising the step of
determining said formation areas on said tubular object.
- 25 11. The method according to claim 9, wherein said forming mandrel
includes at least one opening, wherein said step of placing includes
positioning a selected one of said at least one opening underneath a
selected one of said formation areas, thereby causing punching of
material within said selected formation area, as a result of said step
30 of applying said at least one electromagnetic field.

12. The method according to claim 9, wherein said tubular object is made of a material, selected from the list consisting of:
- shape memory materials;
 - super elastic materials;
 - 5 stainless steel;
 - alloys;
 - polymeric materials; and
 - biocompatible materials.
- 10 13. The method according to claim 9, further comprising a preliminary step of applying shape memory characteristics to said tubular object.
14. The method according to claim 9, further comprising a final step of applying shape memory characteristics to said tubular object.
- 15 15. Medical support device comprising a tubular object, said tubular object including a plurality of openings, wherein at least selected ones of said openings were electromagnetically formed.
- 20 16. The medical support device, according to claim 15, wherein said tubular object is made of a material, selected from the list consisting of:
- shape memory materials;
 - super elastic materials;
 - 25 stainless steel;
 - alloys;
 - polymeric materials; and
 - biocompatible materials.
- 30 17. Medical support device comprising a sheet of conductive material, said sheet of conductive material being folded so as to provide a

tubular object, where one edge of said sheet of conductive material overlaps another edge of said sheet of conductive material, thereby defining an overlapping section, wherein said overlapping edges are joined by means of electromagnetic forming.

5

18. The medical support device according to claim 17, further comprising a plurality of openings.

10

19. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by drilling.

20. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by laser cutting.

15

21. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by chemical etching.

22. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by fluid punching.

20

23. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by means of electromagnetic forming.

25

24. The medical support device according to claim 17, wherein said sheet of conductive material is made of a material, selected from the list consisting of:

shape memory materials;

super elastic materials;

30

stainless steel;

alloys;

polymeric materials; and
biocompatible materials.

- 5 25. The method according to claim 17, further comprising a preliminary step of applying shape memory characteristics to said sheet of conductive material.
- 10 26. The method according to claim 17, further comprising a final step of applying shape memory characteristics to said sheet of conductive material.
- 15 27. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by electrical discharge machining.
28. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by chemical machining.
- 20 29. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by photochemical blanking.
- 25 30. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by abrasive material flow machining.
31. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by ultrasonic machining.

32. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by hydrodynamic machining.
- 5 33. The medical support device according to claim 18, wherein at least a selected ones of said openings are formed by stamping.
34. Medical support device comprising a sheet of conductive material, said sheet of conductive material comprising a plurality of openings, said openings being formed by electromagnetic forming, said sheet of
10 conductive material being folded so as to provide a tubular object, where one edge of said sheet of conductive material overlaps another edge of said sheet of conductive material, thereby defining an overlapping section.
- 15 35. The medical support device according to claim 34, wherein said overlapping edges are joined by arc welding.
36. The medical support device according to claim 34, wherein said
20 overlapping edges are joined by gas welding.
37. The medical support device according to claim 34, wherein said overlapping edges are joined by resistance welding.
- 25 38. The medical support device according to claim 34, wherein said overlapping edges are joined by soldering.
39. The medical support device according to claim 34, wherein said overlapping edges are joined by brazing.
- 30

40. The medical support device according to claim 34, wherein said overlapping edges are joined by electron beam welding.
41. The medical support device according to claim 34, wherein said overlapping edges are joined by laser beam welding.
42. The medical support device according to claim 34, wherein said overlapping edges are joined by friction welding.
43. The medical support device according to claim 34, wherein said overlapping edges are joined by diffusion bonding.
44. The medical support device according to claim 34, wherein said overlapping edges are joined by explosive welding.
45. The medical support device according to claim 34, wherein said overlapping edges are joined by adhesive bonding.
46. The medical support device according to claim 34, further comprising a preliminary step of applying shape memory characteristics to said sheet of conductive material.
47. The medical support device according to claim 34, further comprising a final step of applying shape memory characteristics to said sheet of conductive material.
48. Method for producing a medical support device from a sheet of formable material, the method comprising the steps of:
placing a forming mandrel against a plurality of formation areas; and
applying at least one electromagnetic field on each said formation areas, thereby forming said sheet at each said formation areas.

49. The method according to claim 48, further comprising the step of determining said formation areas on said sheet.
- 5 50. The method according to claim 48, wherein said forming mandrel includes at least one opening, wherein said step of placing includes positioning a selected one of said at least one opening underneath a selected one of said formation areas, thereby causing shearing of material within said selected formation area, as a result of said step
10 of applying said at least one electromagnetic field.
51. The method according to claim 48, wherein said sheet of formable material is made of a material, selected from the list consisting of:
shape memory materials;
15 super elastic materials;
stainless steel;
alloys;
polymeric materials; and
biocompatible materials.
- 20 52. The method according to claim 48, further comprising a preliminary step of applying shape memory characteristics to said sheet of formable material.
- 25 53. The method according to claim 48, further comprising a final step of applying shape memory characteristics to said sheet of formable material.
- 30 54. The method according to claim 48, further comprising the step of folding said sheet of formable material, thereby producing a tubular object.

55. The method according to claim 54, wherein at least selected ones of said formation areas are located in overlapping sections of said sheet of formable material, said overlapping sections being defined in said
5 step of folding.
56. The method according to claim 48, wherein said formable material is electrically conductive.
- 10 57. The method according to claim 48, wherein said formable material is not electrically conductive.
58. Method for producing a medical support device comprising the steps of:
15 placing a plurality of wires wherein at least a section of each said wires overlaps a section of at least another of said wires, each said overlapping section defines an intersection area; and
applying at least one electromagnetic field on the overlapping wires of each said intersection area, thereby joining each said wires at
20 said intersection area.
59. The method according to claim 58, further comprising the step of repeating said step of applying, thereby forming a mesh-like structure of said wires.
25
60. The method according to claim 58, further comprising the step of folding said mesh, thereby forming a cylinder.
61. The method according to claim 58, wherein said wires are generally
30 straight.

62. The method according to claim 58, wherein said wires are generally curved.
63. The method according to claim 58, wherein said step of placing is
5 further characterized by a crosswise arrangement.
64. The method according to claim 58, wherein at least selected ones of
said wires are made of a material, selected from the list consisting of:
shape memory materials;
10 super elastic materials;
stainless steel;
alloys;
polymeric materials; and
biocompatible materials.
- 15 65. The method according to claim 58, further comprising a preliminary
step of applying shape memory characteristics to at least selected
ones of said wires.
- 20 66. The method according to claim 58, further comprising a final step of
applying shape memory characteristics to at least selected ones of
said wires.
- 25 67. Medical support device comprising a plurality of wires, each said
wires intersecting with at least another of said wires, thereby defining
a plurality of intersection points, thereby forming a mesh, said mesh
having the shape of a cylinder,
wherein at least selected ones of said wires are joined to other
selected ones of said wires intersecting therewith, by means of
30 electromagnetic forming process.

68. The medical support device according to claim 67, wherein at least one of said wires is made of a material, selected from the list consisting of:

shape memory materials;
super elastic materials;
stainless steel;
alloys;
polymeric materials; and
biocompatible materials.

69. The medical support device according to claim 67, further comprising a preliminary step of applying shape memory characteristics to at least selected ones of said wires.

70. The medical support device according to claim 67, further comprising a final step of applying shape memory characteristics to at least selected ones of said wires.

71. The medical support device according to claim 67, wherein at least one of said wires is generally shaped as a straight line.

72. The medical support device according to claim 67, wherein at least one of said wires is generally shaped as a curved line.

73. The medical support device according to claim 67, wherein said mesh defines a crosswise structure.

74. A method according to any of the claims 1-8 substantially as described herein above.

75. A method according to any of the claims 1-8 substantially as illustrated in any of the drawings.
- 5 76. A method according to any of the claims 9-14 substantially as described herein above.
77. A method according to any of the claims 9-14 substantially as illustrated in any of the drawings.
- 10 78. A device according to any of the claims 15-16 substantially as described herein above.
79. A device according to any of the claims 15-16 substantially as illustrated in any of the drawings.
- 15 80. A device according to any of the claims 17-33 substantially as described herein above.
81. A device according to any of the claims 17-33 substantially as illustrated in any of the drawings.
- 20 82. A device according to any of the claims 34-47 substantially as described herein above.
- 25 83. A device according to any of the claims 34-47 substantially as illustrated in any of the drawings.
84. A method according to any of the claims 48-57 substantially as described herein above.
- 30 85. A method according to any of the claims 48-57 substantially as illustrated in any of the drawings.

86. A method according to any of the claims 58-66 substantially as described in any of the drawings.

5 87. A method according to any of the claims 58-66 substantially as illustrated in any of the drawings.

88. A device according to any of the claims 67-73 substantially as described herein above.

10

89. A device according to any of the claims 67-73 substantially as illustrated in any of the drawings.

15

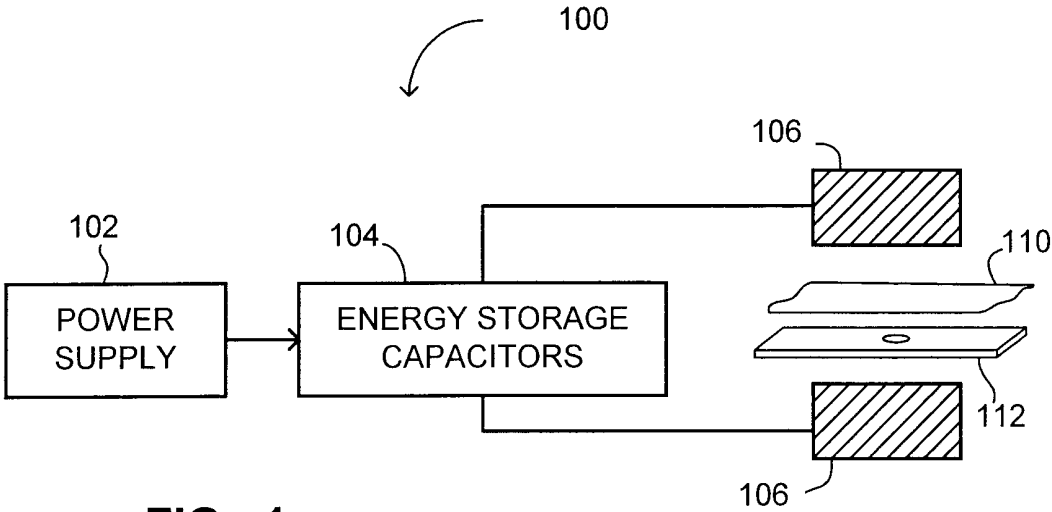


FIG. 1

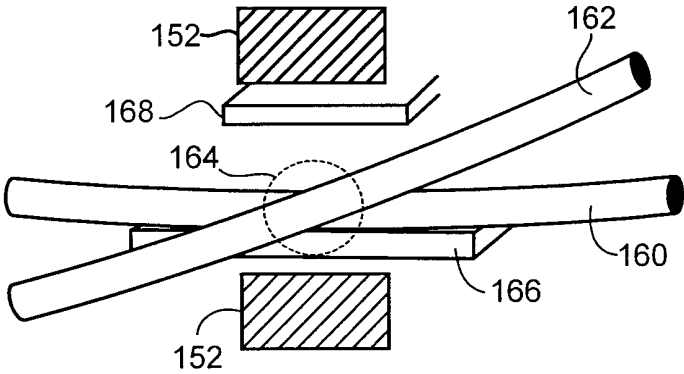


FIG. 2

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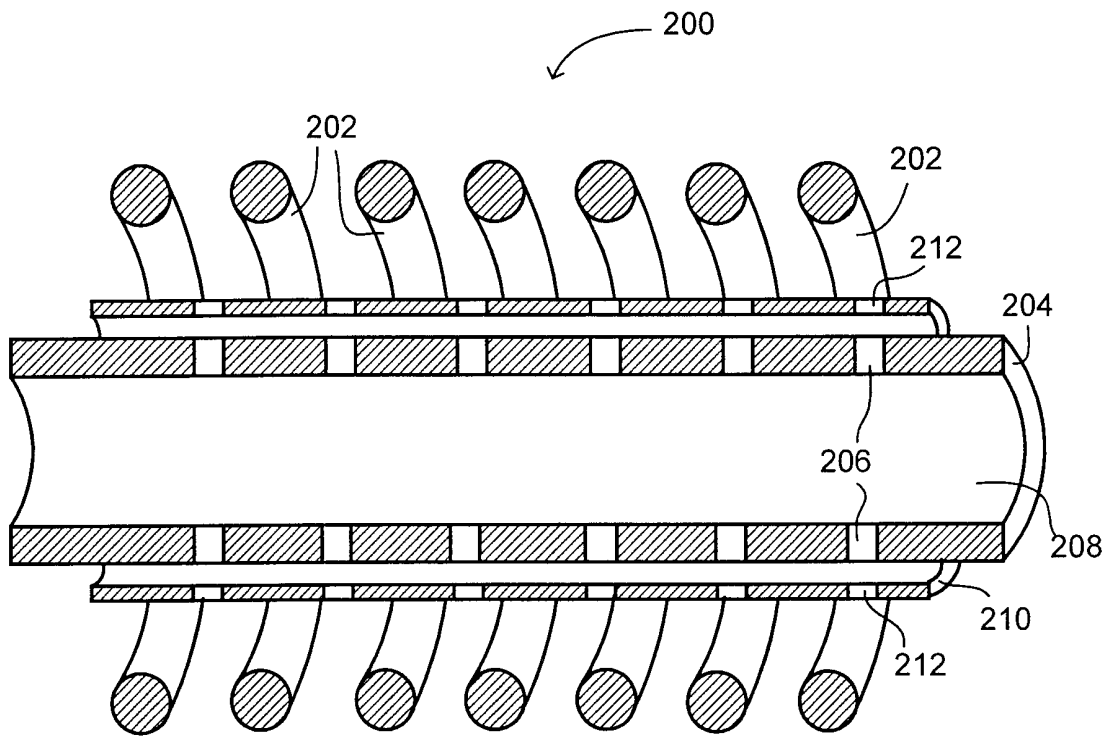


FIG. 3A

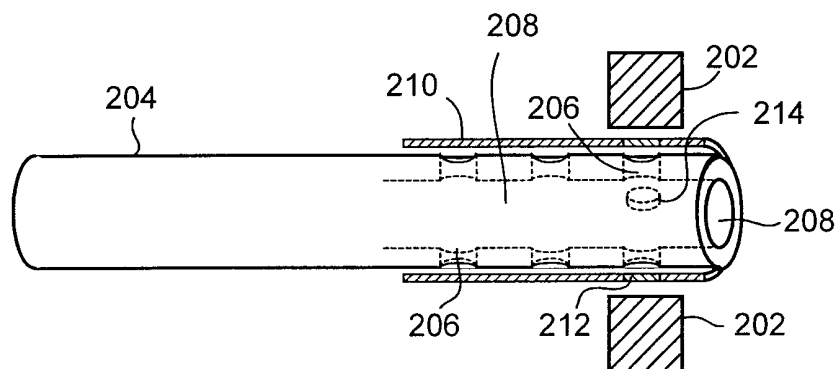


FIG. 3B

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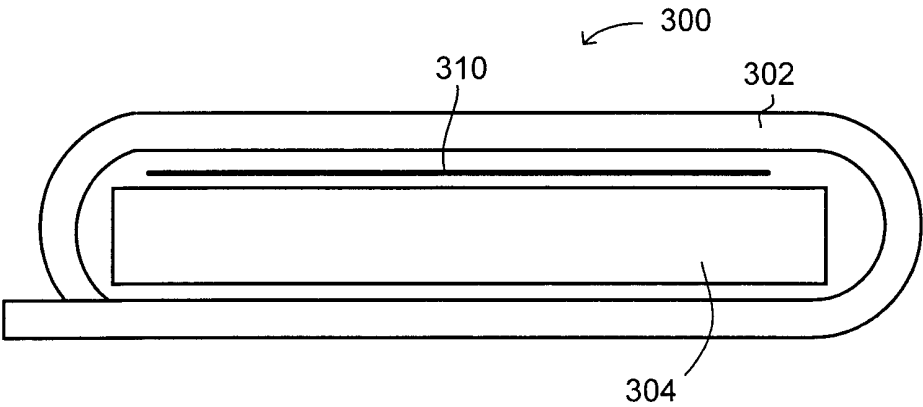


FIG. 4A

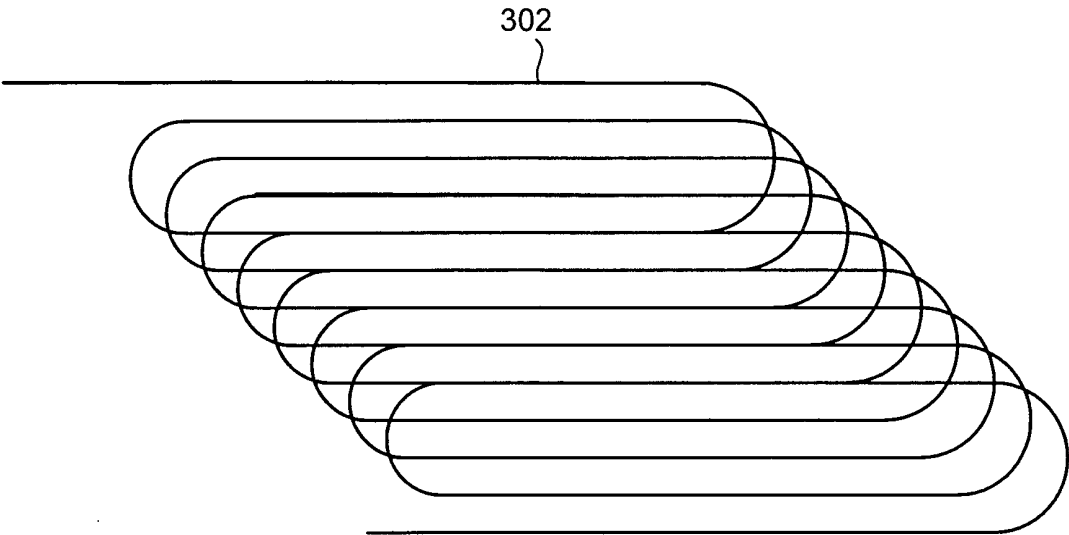


FIG. 4B

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FIG. 4C

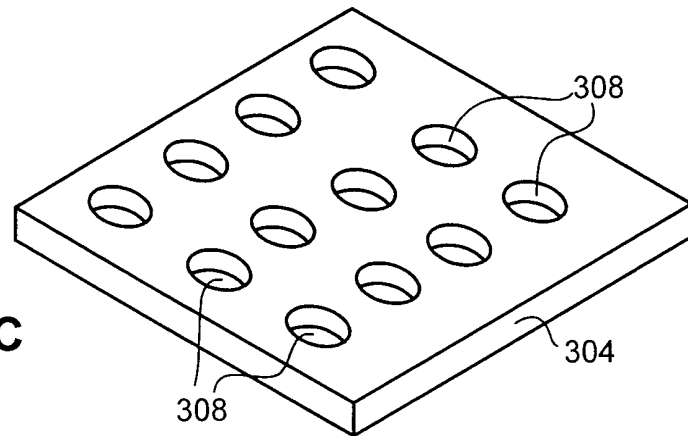


FIG. 4D

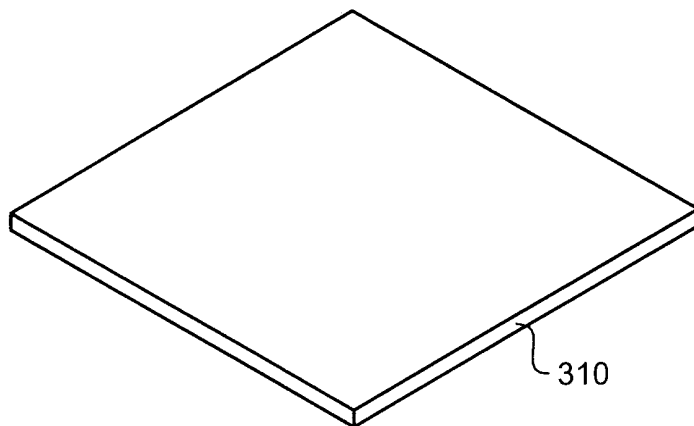
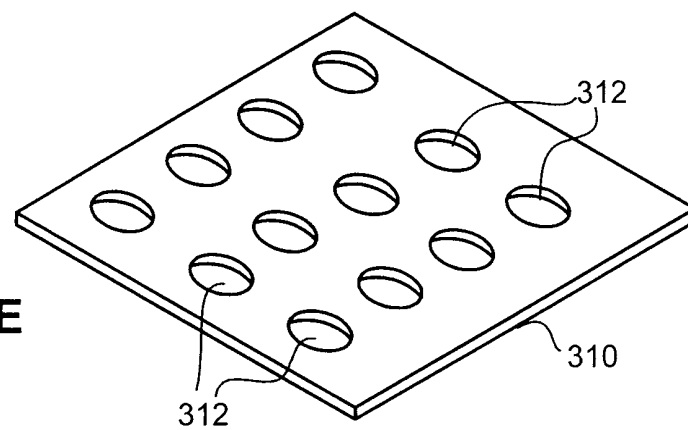


FIG. 4E



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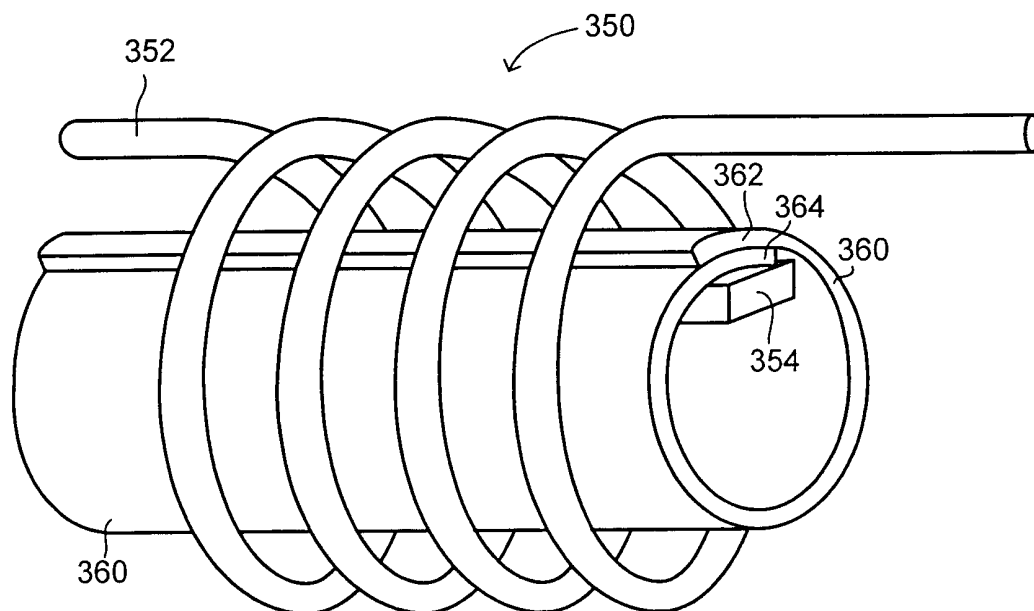


FIG. 5

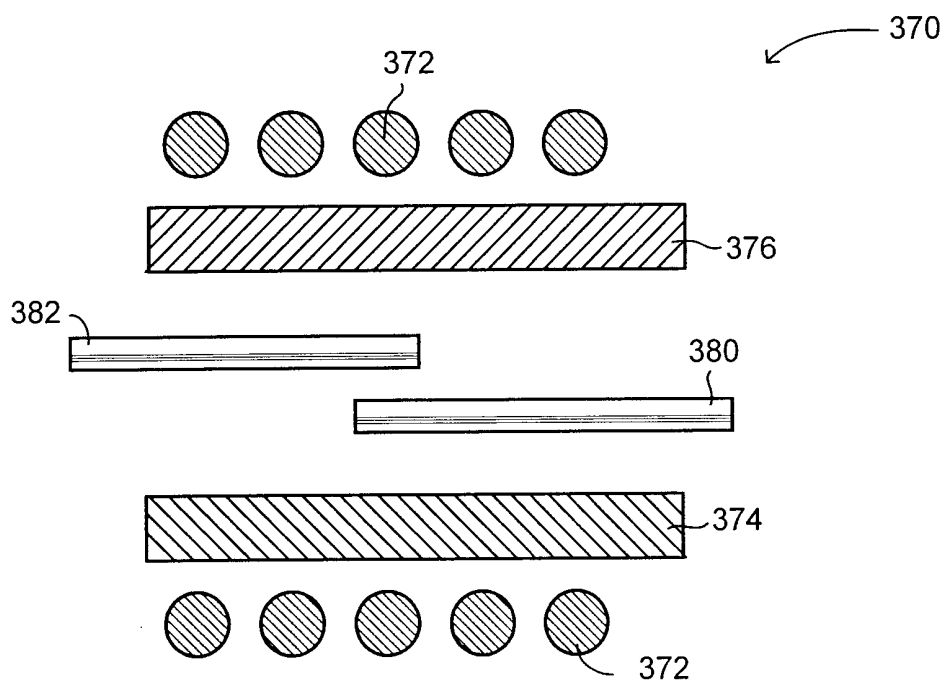


FIG. 6

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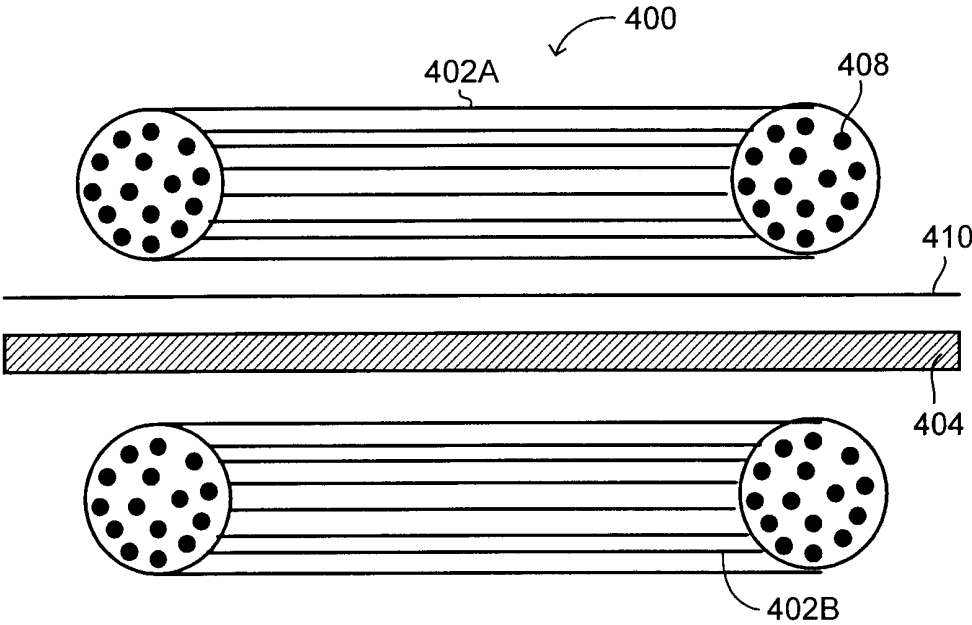


FIG. 7A

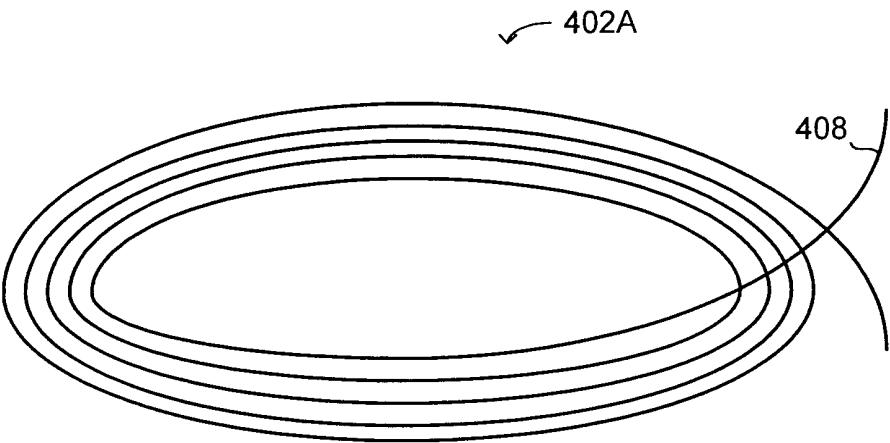


FIG. 7B

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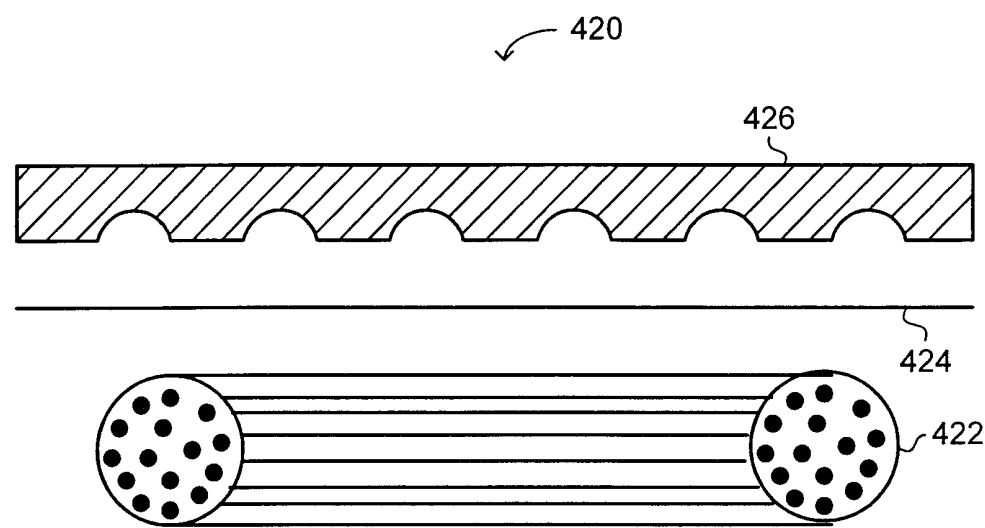


FIG. 7C

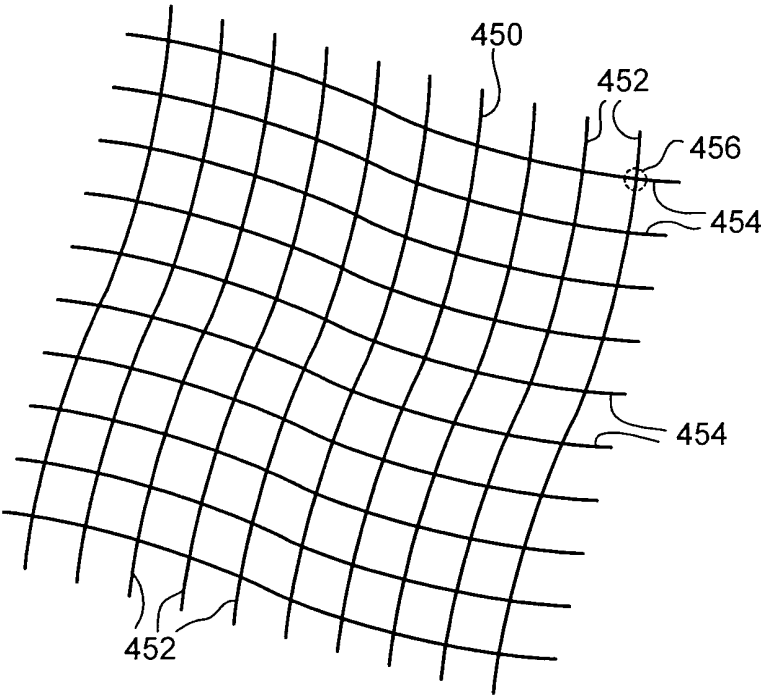


FIG. 8

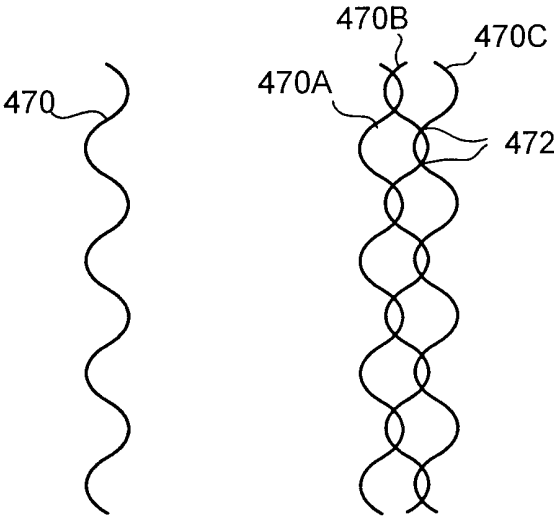


FIG. 9A

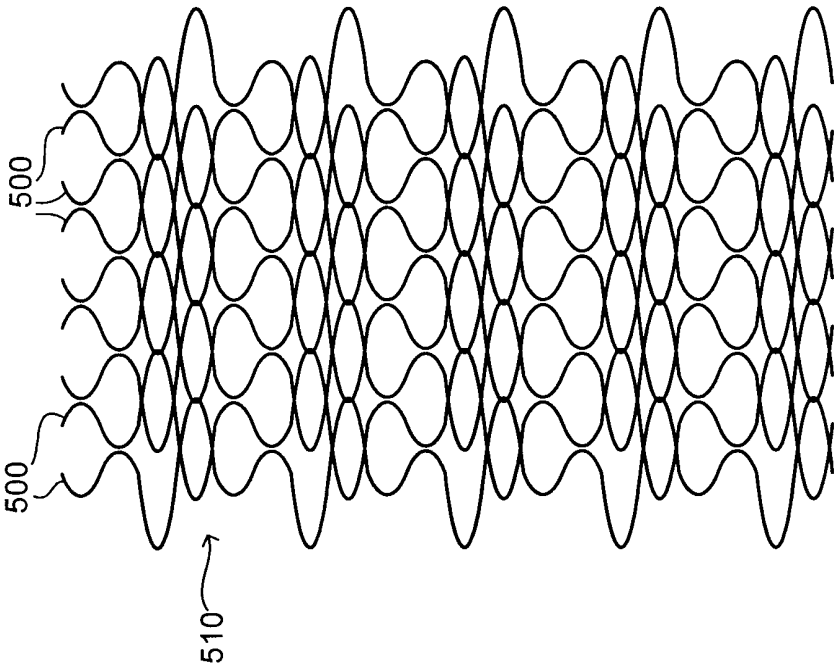


FIG. 9C

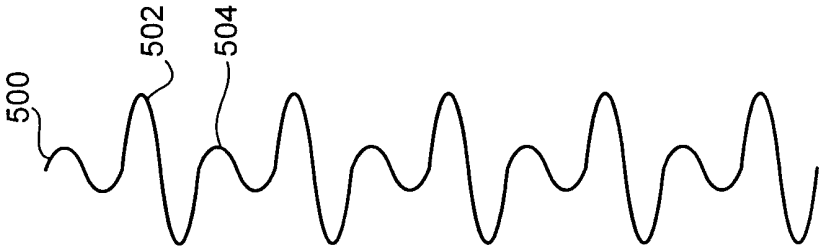


FIG. 9B

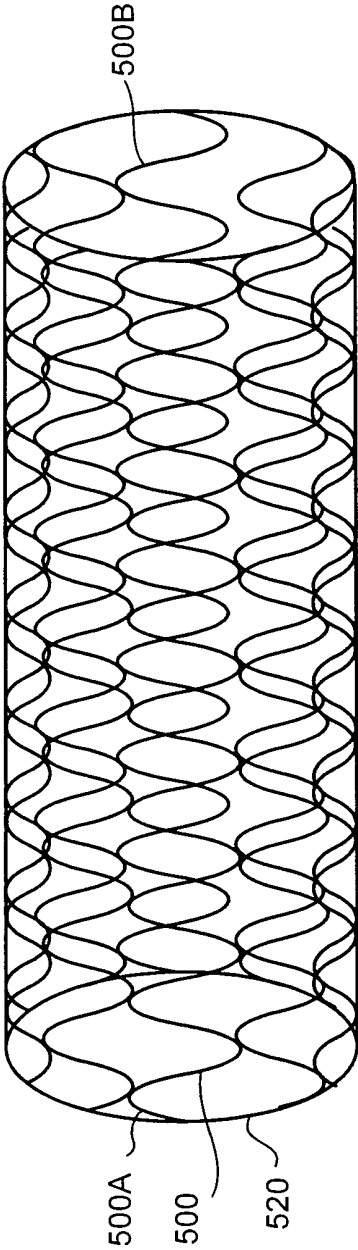


FIG. 9D

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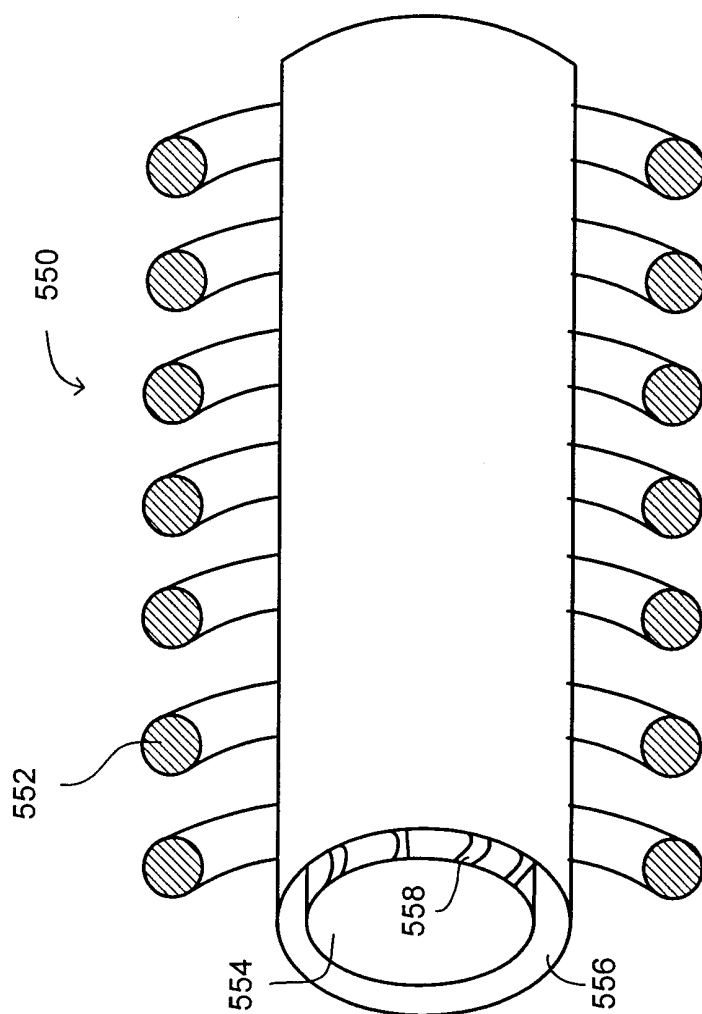


FIG. 10A

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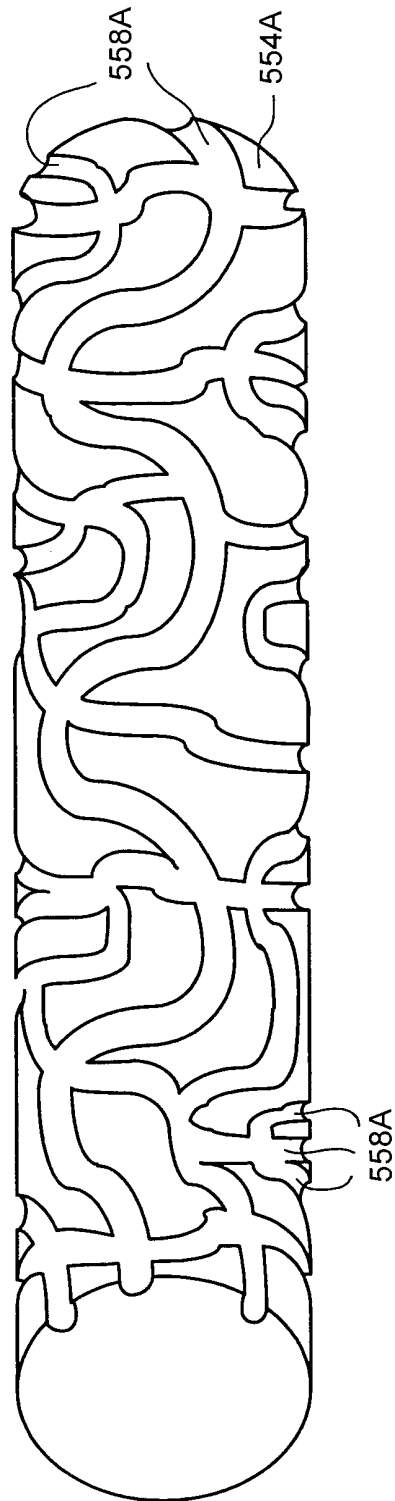


FIG. 10B

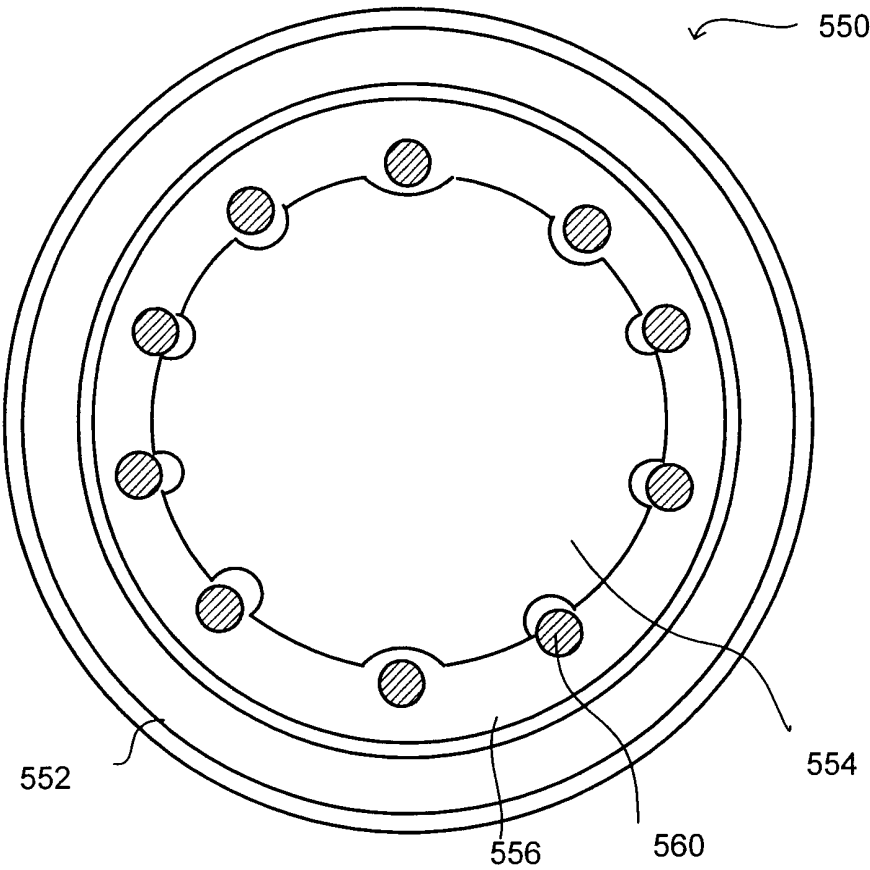


FIG. 10C