

(12) **United States Patent**
Kusleika et al.

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(54) **SYSTEMS FOR ATTAINING A
PREDETERMINED POROSITY OF A
VASCULAR DEVICE**

(58) **Field of Classification Search**
CPC A61F 2/07; A61F 2/82; A61F 2/86; A61F
2/90; A61F 2/91; A61F 2/958;
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patent is extended or adjusted under 35
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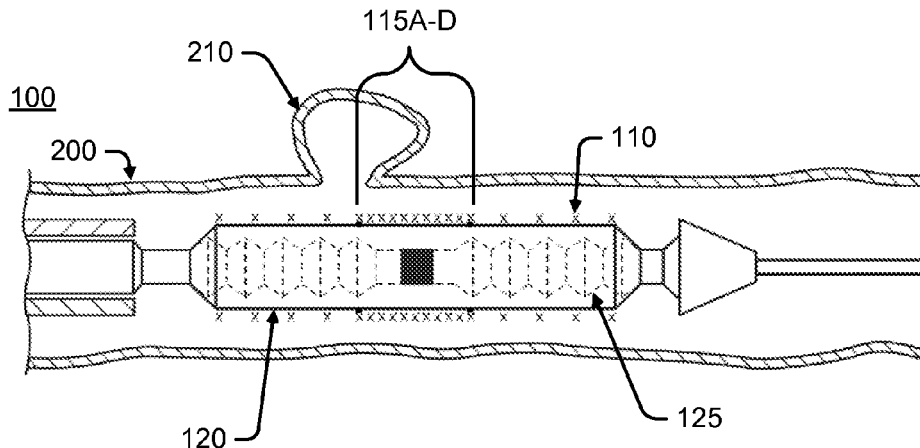
(57) **ABSTRACT**

(51) **Int. Cl.**
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A61F 2/07 (2013.01)
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A system for treating a patient is provided that includes an
expandable vascular device having a body having a sub-
stantially uniform porosity that is adapted to change by
adjusting an axial length of the body. The system also
includes an expanding member positioned within a central
lumen of the device, the expanding member configured to
engage the body, as the body is radially expanded from a
collapsed configuration, and to reduce a porosity of the body
within a body region more than the body porosity is reduced
outside the region.

(52) **U.S. Cl.**
CPC **A61F 2/07** (2013.01); **A61F 2/844**
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(52) **U.S. Cl.**

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(58) **Field of Classification Search**

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See application file for complete search history.

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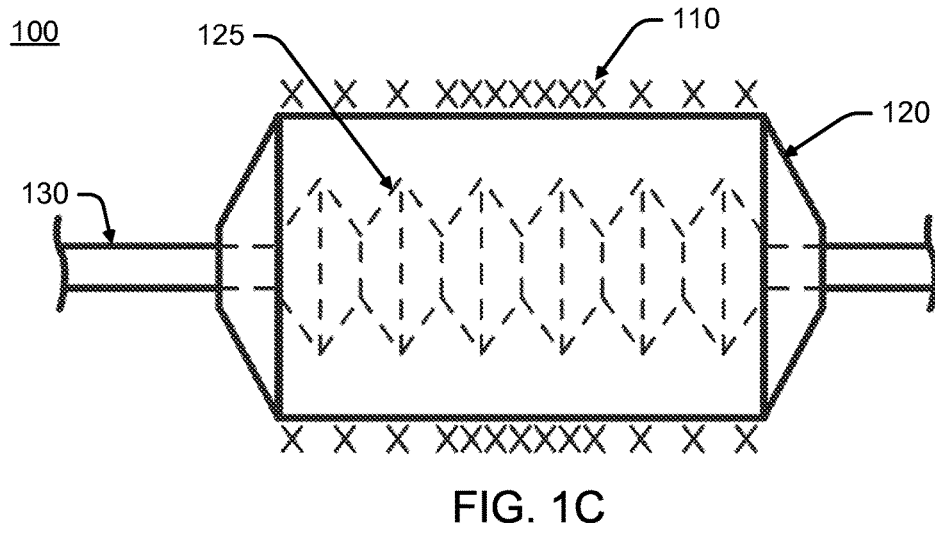
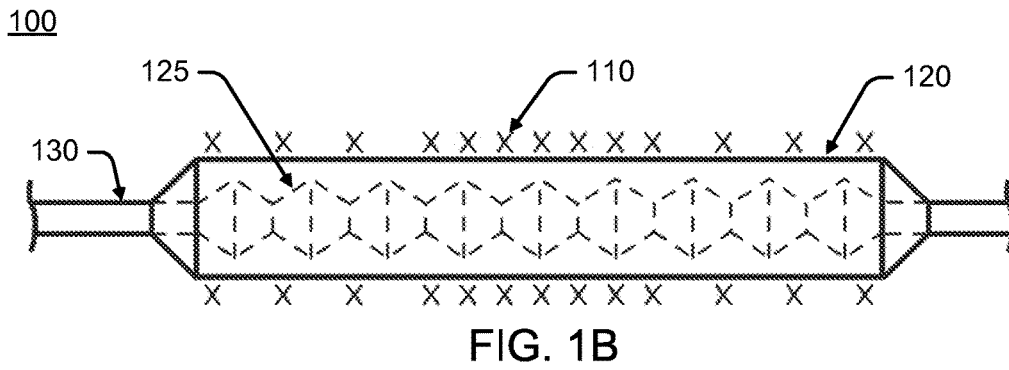
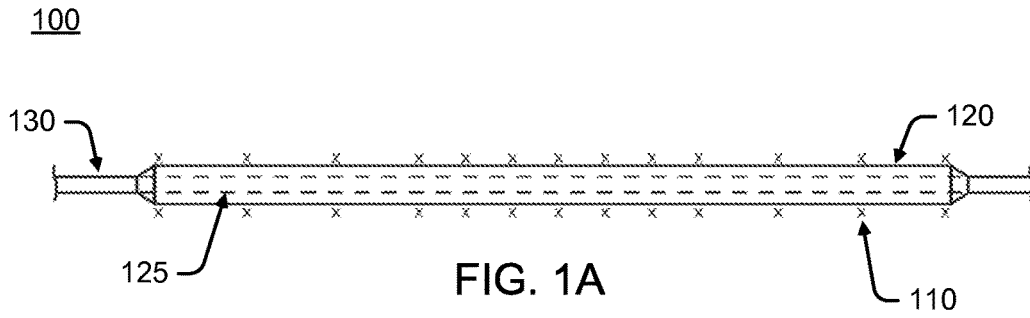
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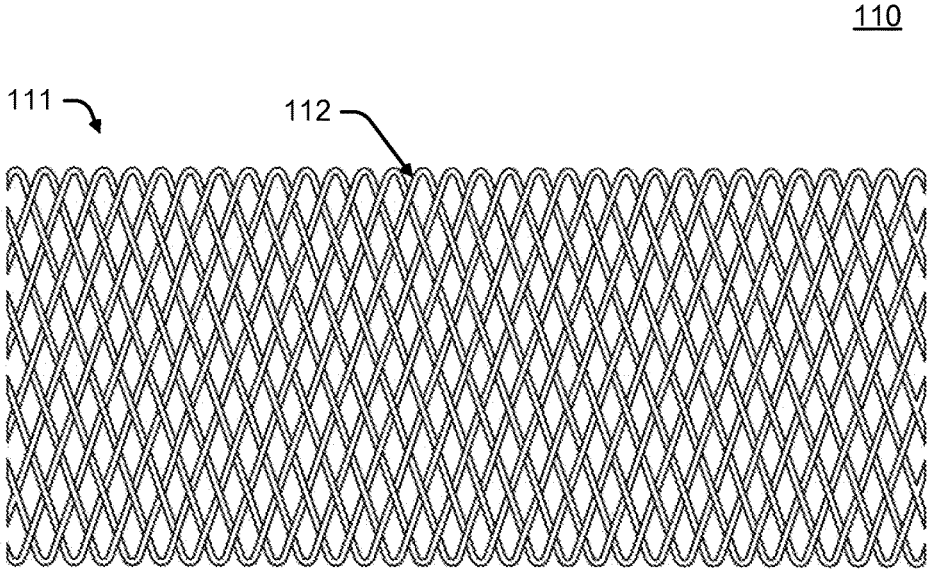
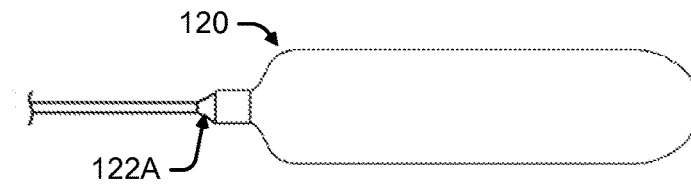
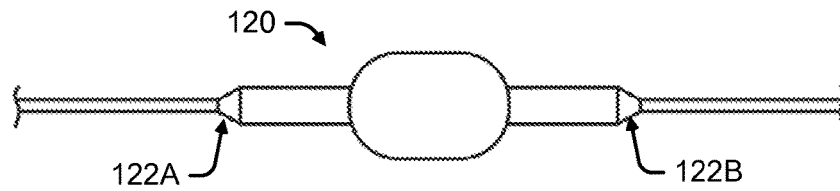
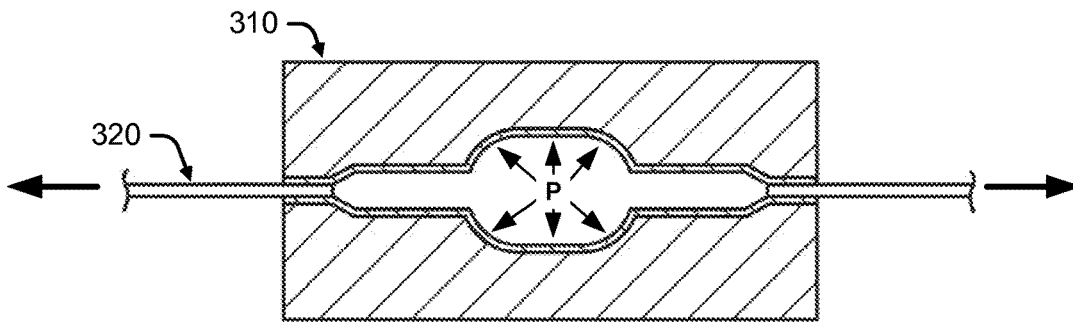
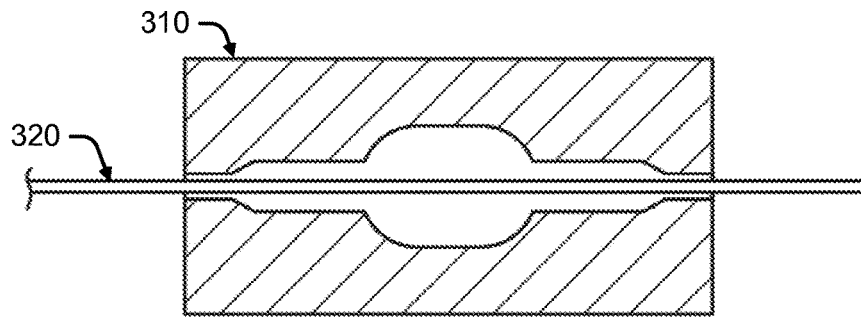
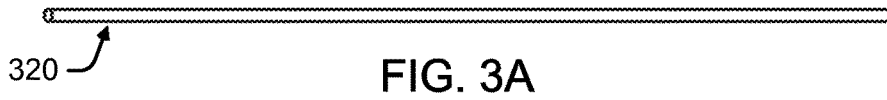


FIG. 2



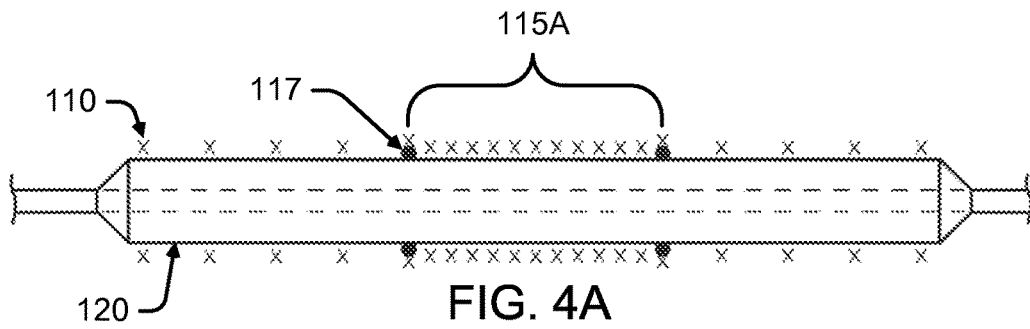


FIG. 4A

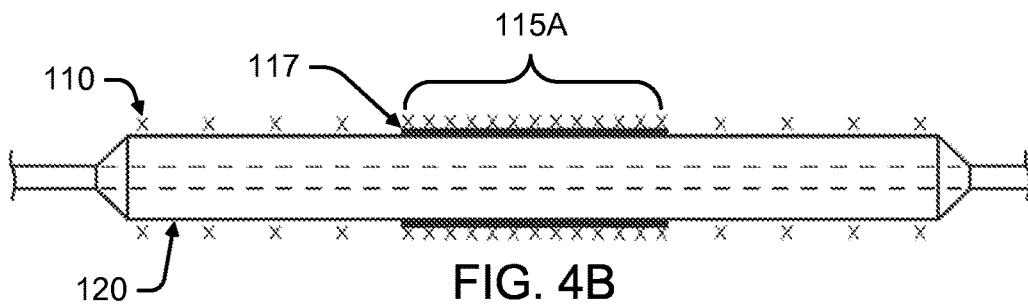


FIG. 4B

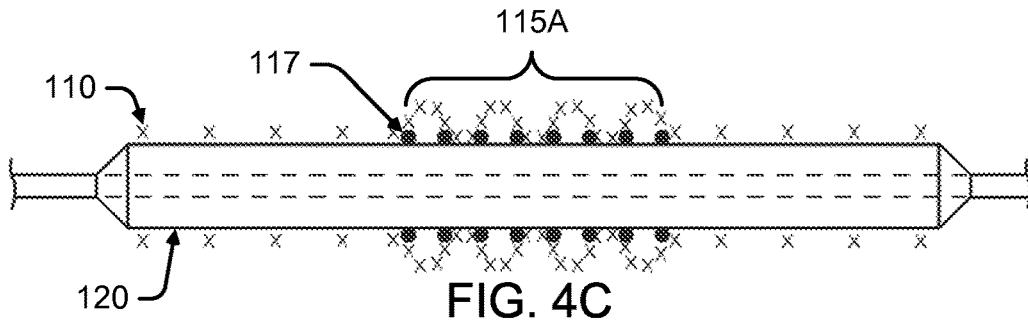


FIG. 4C

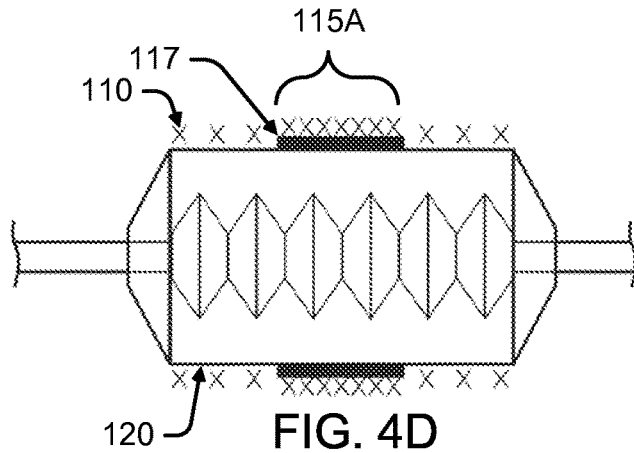


FIG. 4D

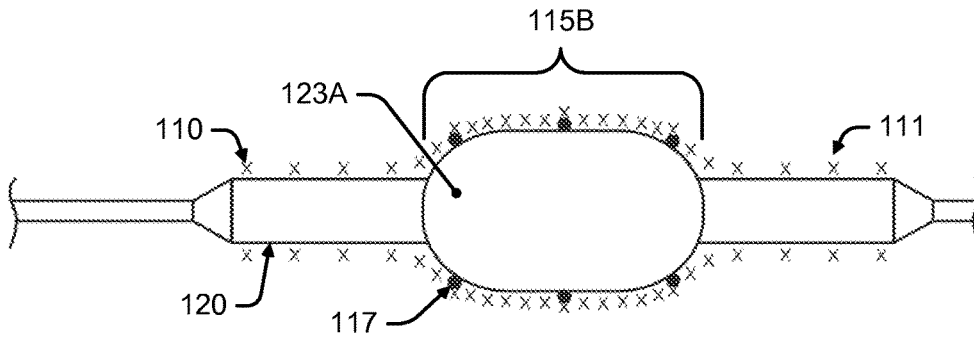


FIG. 5A

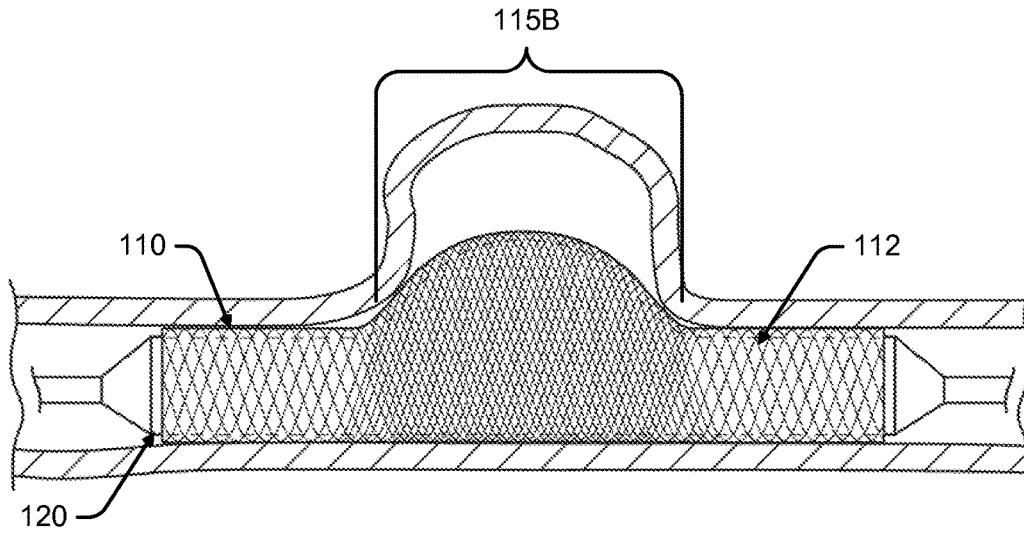


FIG. 5B

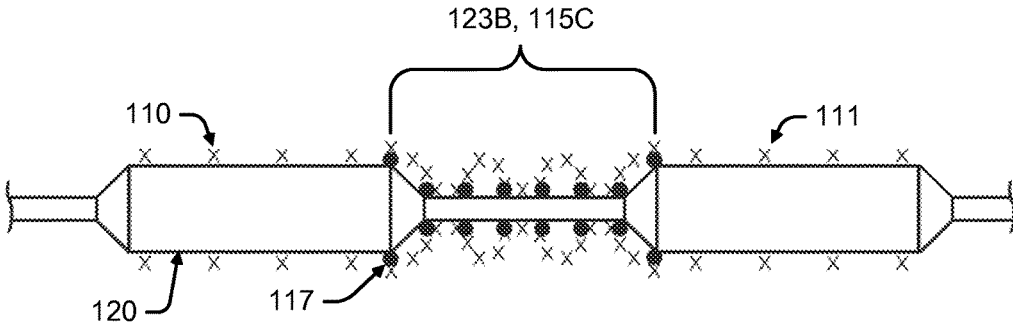


FIG. 6A

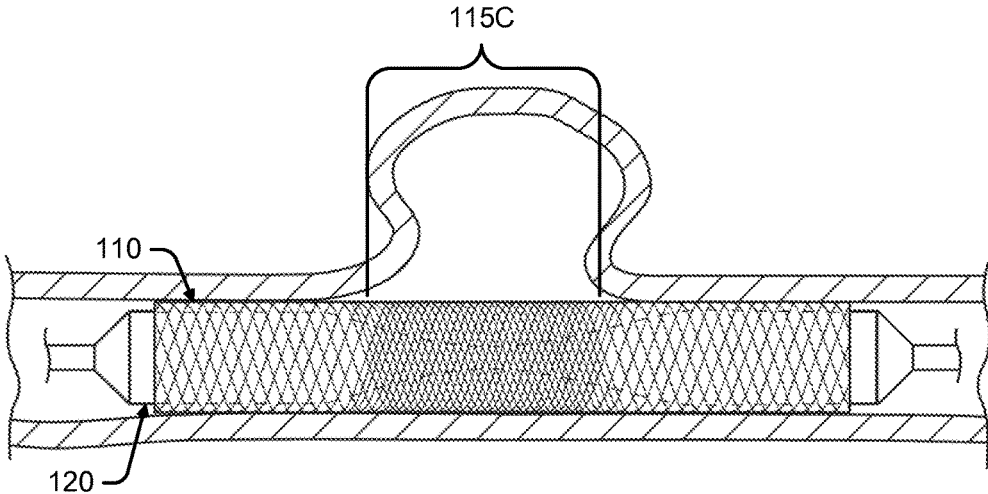


FIG. 6B

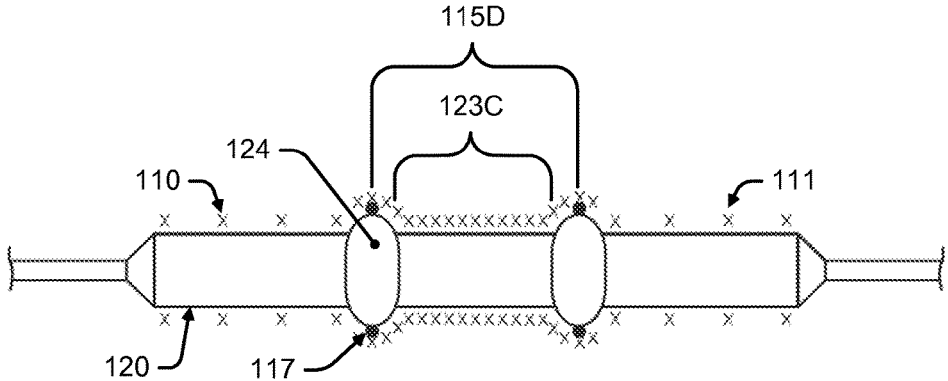


FIG. 7A

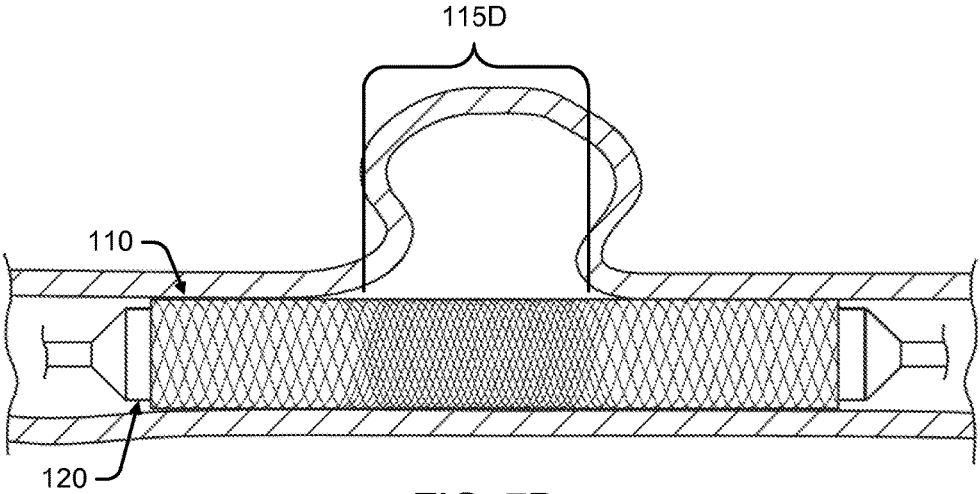


FIG. 7B

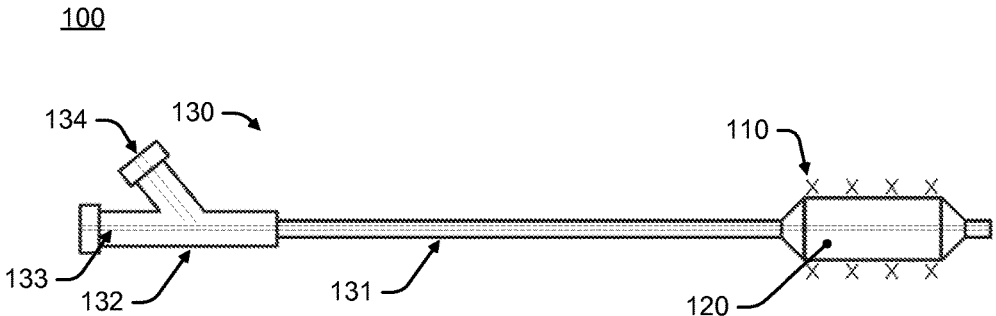


FIG. 8A

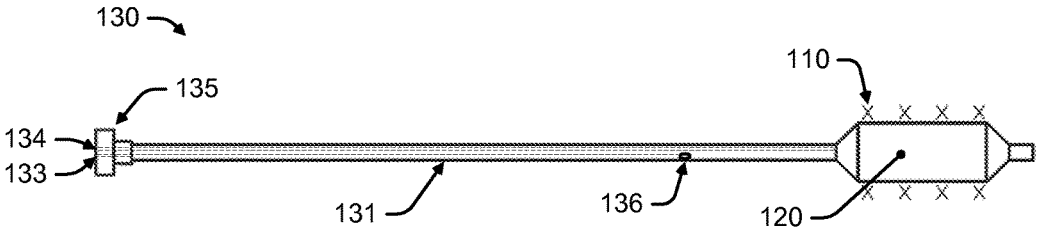


FIG. 8B

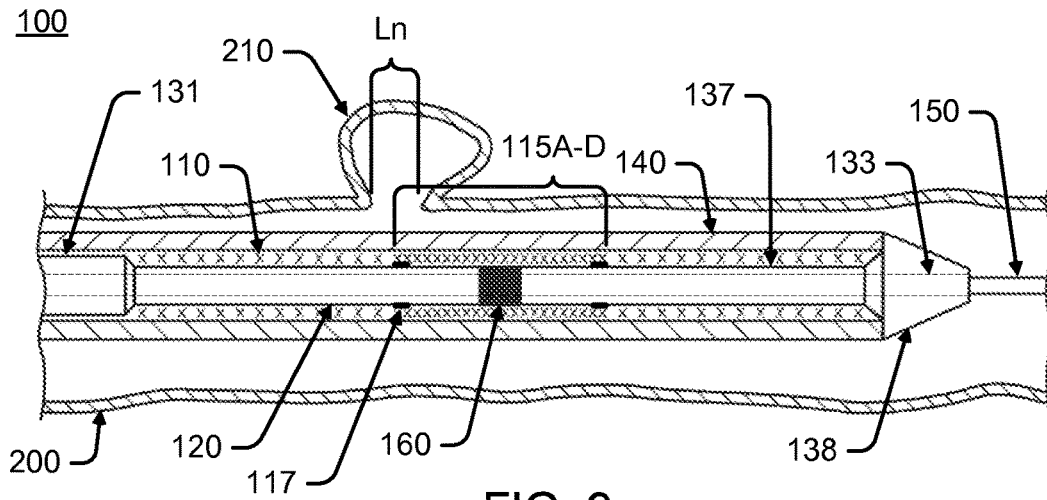


FIG. 9

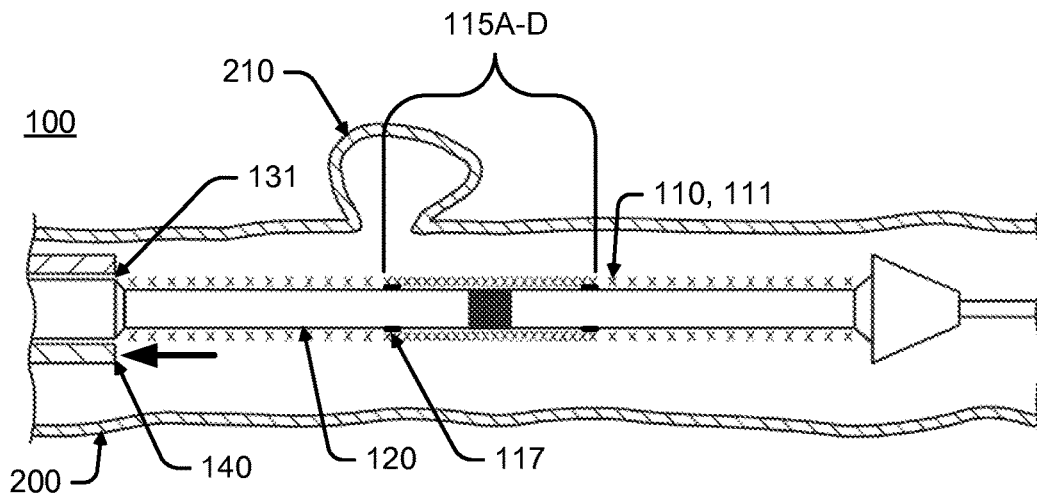


FIG. 10

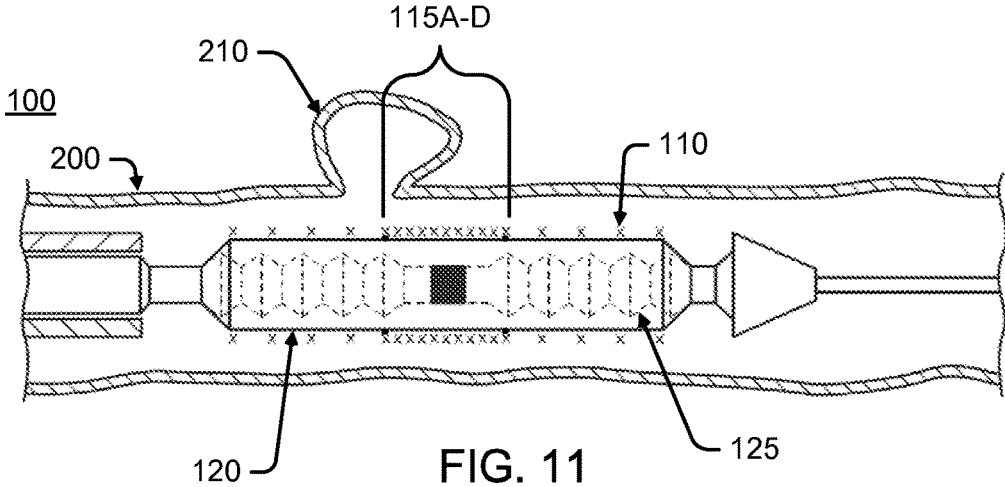


FIG. 11

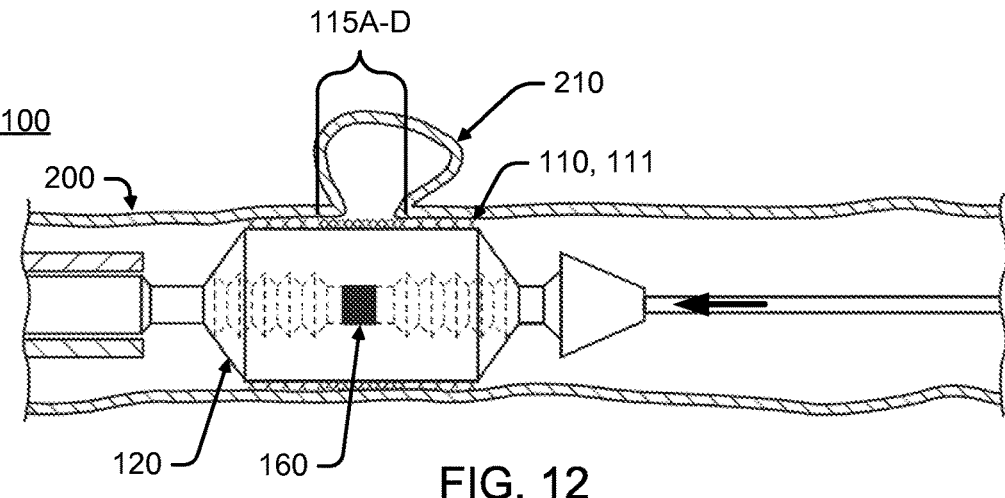


FIG. 12

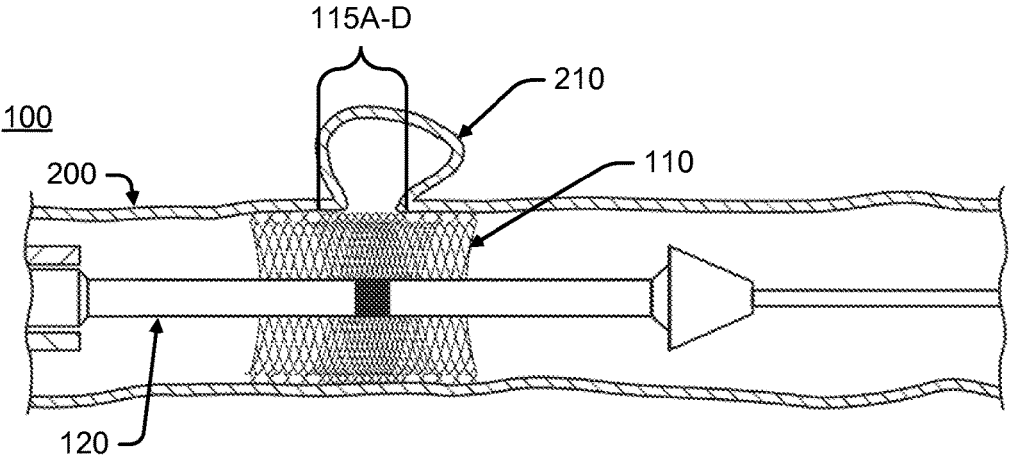


FIG. 13

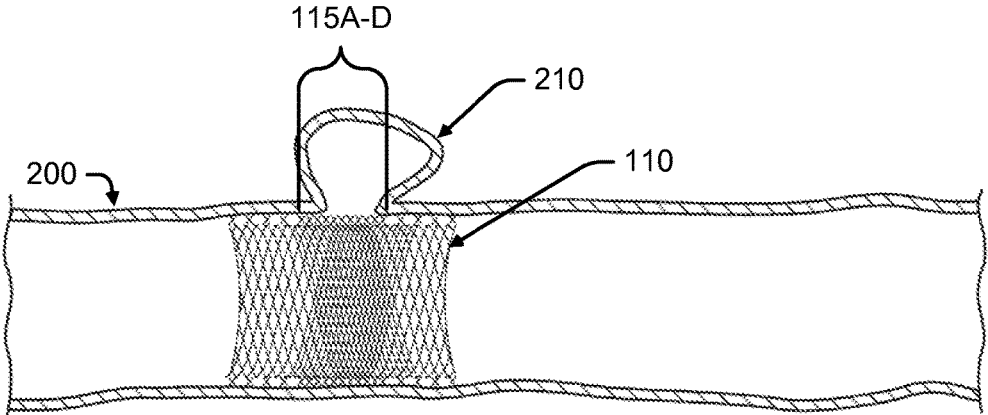


FIG. 14

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**SYSTEMS FOR ATTAINING A
PREDETERMINED POROSITY OF A
VASCULAR DEVICE**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/826,971, filed Mar. 14, 2013, which claims priority benefit of U.S. Provisional Application Ser. No. 61/720,154, filed Oct. 30, 2012, each of which is hereby incorporated herein by reference in its entirety.

BACKGROUND

Lumens in a patient's body can change in size, shape, and/or patency, and such changes can present complications or affect associated bodily functions. For example, the walls of the vasculature, particularly arterial walls, may develop a pathological dilatation, commonly called an aneurysm. Aneurysms are observed as a ballooning-out of the wall of an artery. This is a result of the vessel wall being weakened by disease, injury, or a congenital abnormality. Aneurysms have thin, weak walls and have a tendency to rupture and are often caused or made worse by high blood pressure. Aneurysms can be found in different parts of the body; the most common being abdominal aortic aneurysms (AAA) and the brain or cerebral aneurysms. The mere presence of an aneurysm is not always life-threatening, but an aneurysm can have serious health consequences such as a stroke if one should rupture in the brain. Additionally, a ruptured aneurysm can also result in death.

SUMMARY

The subject technology is illustrated, for example, according to various aspects described below. Various examples of aspects of the subject technology are described as numbered clauses (1, 2, 3, etc.) for convenience. These are provided as examples, and do not limit the subject technology. It is noted that any of the dependent clauses may be combined in any combination, and placed into a respective independent clause, e.g., clause 1, 16 and 23. The other clauses can be presented in a similar manner.

1. A system for treating a patient, the system comprising: an expandable vascular device comprising a body having a substantially uniform porosity that is adapted to change by adjusting an axial length of the body, and an expanding member positioned within a central lumen of the device, the expanding member configured to engage the body, as the body is radially expanded from a collapsed configuration, and to reduce a porosity of the body within a body region more than the body porosity is reduced outside the region.
2. The system of clause 1, wherein the body comprises a braided structure.
3. The system of clause 1, wherein the body comprises a cut metal tube.
4. The system of clause 1, wherein the body comprises a self-expanding structure.
5. The system of clause 1, wherein an axial length of the expanding member in the collapsed configuration is about 200-500% longer than the axial length of the expanding member in an expanded configuration.
6. The system of clause 5, wherein a change in the axial length of the expanding member from the collapsed configuration to the expanded configuration is the same as a

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change in the axial length of the body from a body collapsed configuration to a body expanded configuration.

7. The system of clause 1, further comprising an adhesive disposed between the expanding member and the region for adhering a portion of the region to the expanding member.

8. The system of clause 7, wherein the adhesive comprises biodegradable material.

9. The system of clause 1, further comprising a corrugated tube disposed within the expanding member, the corrugated tube configured to axially shorten as the expanding member is inflated.

10. The system of clause 1, wherein the expanding member comprises, when expanded, an enlarged region having an enlarged diameter relative to other regions of the expanding member, the enlarged region being substantially axially aligned with the body region.

11. The system of clause 10, further comprising an adhesive disposed between the enlarged region of the expanding member and the body region.

12. The system of clause 1, wherein the expanding member comprises, when expanded, a reduced region having a reduced diameter relative to other regions of the expanding member, the reduced region being substantially axially aligned with the body region.

13. The system of clause 12, further comprising an adhesive disposed proximally or distally of the reduced region of the expanding member.

14. The system of clause 1, wherein the expanding member comprises, when expanded, two enlarged regions having an enlarged diameter relative to a reduced region therebetween, having a reduced diameter, the reduced region being substantially axially aligned with the body region.

15. The system of clause 14, further comprising an adhesive disposed between the enlarged regions and the body.

16. A delivery system for a vascular device, the delivery system comprising:

- a catheter having a lumen;
- a guide wire extending through the catheter lumen;
- a vascular device having a porosity that is altered by adjustment of an axial length of the device; and
- an expanding member disposed within a distal portion of the catheter, the expanding member configured to axially shorten as the expanding member is radially expanded;

wherein the expanding member is configured to engage a region of the device and reduce, as the expanding member axially shortens, a porosity of the device within the region more than the porosity is reduced outside the region.

17. The system of clause 16, wherein an axial length of the expanding member in a collapsed configuration is about 200-500% longer than the axial length of the expanding member in a radially expanded configuration.

18. The system of clause 17, wherein a change in the axial length of the expanding member from the collapsed configuration to the radially expanded configuration is the same as a change in the axial length of the device from a device collapsed configuration to a device expanded configuration.

19. The system of clause 16, further comprising an adhesive disposed between the expanding member and the region for adhering a portion of the region to the expanding member.

20. The system of clause 16, wherein the expanding member comprises, when radially expanded, an enlarged region having an enlarged diameter relative to other regions

of the expanding member, the enlarged region being substantially axially aligned with the region of the device.

21. The system of clause 16, wherein the expanding member comprises, when radially expanded, a reduced region having a reduced diameter relative to other regions of the expanding member, the reduced region being substantially axially aligned with the region of the device.

22. The system of clause 16, wherein the expanding member comprises, when radially expanded, two enlarged regions having an enlarged diameter relative to a reduced region therebetween, having a reduced diameter, the reduced region being substantially axially aligned with the region of the device.

It is understood that other configurations of the subject technology will become readily apparent to those skilled in the art from the following detailed description, wherein various configurations of the subject technology are shown and described by way of illustration. As will be realized, the subject technology is capable of other and different configurations and its several details are capable of modification in various other respects, all without departing from the scope of the subject technology. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description will be made with reference to the accompanying drawings:

FIG. 1A depicts a system for controllably deploying a vascular device in a collapsed configuration, according to some embodiments of the subject technology.

FIG. 1B depicts a system for controllably deploying a vascular device in an intermediate configuration, according to some embodiments of the subject technology.

FIG. 1C depicts a system for controllably deploying a vascular device in an expanded configuration, according to some embodiments of the subject technology.

FIG. 2 depicts a vascular device, according to some embodiments of the subject technology.

FIG. 3A depicts a parison used for manufacturing an expanding member, according to some embodiments of the subject technology.

FIG. 3B depicts an example process for manufacturing an expanding member, according to some embodiments of the subject technology.

FIG. 3C depicts an example process for manufacturing an expanding member, according to some embodiments of the subject technology.

FIG. 3D depicts an expanding member, according to some embodiments of the subject technology.

FIG. 3E depicts an expanding member, according to some embodiments of the subject technology.

FIG. 4A depicts a vascular device coupled to an expanding member using an adhesive, according to some embodiments of the subject technology.

FIG. 4B depicts a vascular device coupled to an expanding member using an adhesive, according to some embodiments of the subject technology.

FIG. 4C depicts a vascular device coupled to an expanding member using an adhesive, according to some embodiments of the subject technology.

FIG. 4D depicts a vascular device coupled to an expanded expanding member using an adhesive, according to some embodiments of the subject technology.

FIG. 5A depicts an expanding member having an enlarged region, according to some embodiments of the subject technology.

FIG. 5B depicts an expanding member having an enlarged region disposed within a vessel, according to some embodiments of the subject technology.

FIG. 6A depicts an expanding member having a reduced region, according to some embodiments of the subject technology.

FIG. 6B depicts an expanding member having a reduced region disposed within a vessel, according to some embodiments of the subject technology.

FIG. 7A depicts an expanding member having two enlarged regions, according to some embodiments of the subject technology.

FIG. 7B depicts an expanding member having two enlarged regions disposed within a vessel, according to some embodiments of the subject technology.

FIG. 8A depicts an example of a catheter, according to some embodiments of the subject technology.

FIG. 8B depicts another example of a catheter, according to some embodiments of the subject technology.

FIG. 9 depicts a cross section view of a vessel and delivery of a vascular device according to some embodiments of the subject technology.

FIG. 10 depicts a cross section view of a vessel and delivery of a vascular device according to some embodiments of the subject technology.

FIG. 11 depicts a cross section view of a vessel and delivery of a vascular device according to some embodiments of the subject technology.

FIG. 12 depicts a cross section view of a vessel and delivery of a vascular device according to some embodiments of the subject technology.

FIG. 13 depicts a cross section view of a vessel and delivery of a vascular device according to some embodiments of the subject technology.

FIG. 14 depicts a cross section view of a vessel and a vascular device according to some embodiments of the subject technology.

DETAILED DESCRIPTION

The detailed description set forth below is intended as a description of various configurations of the subject technology and is not intended to represent the only configurations in which the subject technology may be practiced. The appended drawings are incorporated herein and constitute a part of the detailed description. The detailed description includes specific details for the purpose of providing a thorough understanding of the subject technology. However, it will be apparent to those skilled in the art that the subject technology may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring the concepts of the subject technology.

Aneurysms may be located, for example, along vessel side walls. A neck of an aneurysm typically defines an opening of between about 2 to 25 mm, though other sizes and ranges are also possible. The neck connects an anatomical lumen to a fundus of the aneurysm. In some embodiments, “vessel” or “lumen” may refer to blood vessels (including arteries and veins) or other suitable body organs having a lumen, such as the gastrointestinal tract (e.g., esophagus, stomach, small intestine, colon, rectum), bile ducts, urinary bladder, ureter, urethra, trachea, bronchi, and the like. Blood flow within the anatomical lumen flows

through the neck and into the fundus. In response to the constant blood flow into the fundus of the aneurysm, the wall of the aneurysm continues to distend and presents a significant risk of rupturing. When the blood within the aneurysm causes pressure against the wall of the aneurysm that exceeds the wall strength, the aneurysm ruptures.

Reduction of blood flow to or within the aneurysm results in a reduction in force against the wall of the aneurysm and a corresponding reduction in the risk of rupturing. A reduction of the force and volume of blood entering the aneurysm may be accomplished by an occluding device. Occluding devices may be dependent on a physician's skill during deployment, to ensure that a desired porosity is attained at the neck of the aneurysm. If the porosity too high at the neck, then the occluding device may fail in sufficiently reducing the blood flow into the fundus. The porosity of some occluding devices may be reduced by applying a longitudinally compressive force to a proximal portion of the occluding device towards the direction of a distal portion. Because the porosity of the occluding device may be modified by application of the compressive force, achieving the desired porosity consistently and reliably is heavily dependant on physician skill.

The methods and systems of the subject technology solve some or all of the foregoing problems by controlling the deployment of a vascular device such that the device occludes blood flow into the aneurysm consistently and reliably, to thereby prevent or reduce likelihood of aneurysm ruptures. The system includes an expandable vascular device and an expanding member positioned within a central lumen of the vascular device. The expanding member is configured to attain a predetermined porosity for a region of the device during deployment. Accordingly, controlling the deployment of the vascular device using the expanding member to attain the predetermined porosity for the region, reduces or stops the laminar flow into the aneurysm, thereby allowing the blood within the aneurysm to begin to stagnate. Stagnation of blood, as opposed to continuous flow through a fundus of the aneurysm, results in thrombosis in the aneurysm, which also helps protect the aneurysm from rupturing.

FIGS. 1A-1C depict a system 100 for controllably deploying a vascular device 110, according to some embodiments of the subject technology. The system 100 includes an expandable vascular device 110, an expanding member 120 positioned within a central lumen of the vascular device 110, and a catheter 130.

Referring to FIG. 2, the vascular device 110 comprises a body 111 having a substantially uniform porosity. The body 111 may be formed of a plurality of substantially uniformly spaced members 112. The porosity of the body 111 is adapted to change by adjusting an axial length of the body 111. For example, the body 111 may be configured to decrease in porosity as a result of being axially shortened during and/or after diametrical, or radial, expansion. The body 111 may be a self-expanding stent made of two or more round or ovoid wire filaments 112. Accordingly, the body 111 has a first, collapsed configuration, and a second, expanded configuration. The filaments 112 may be formed of known flexible materials including shape memory materials, such as nitinol, platinum and stainless steel. The body 111 may be fabricated from platinum/8% tungsten and 35N LT (cobalt nickel alloy, which is a low titanium version of MP35N alloy) alloy wires. In other embodiments, one or more of the filaments 112 can be formed of a biocompatible metal material or a biocompatible polymer. The filaments 112 may be braided into a resulting lattice-like structure. In

at least one embodiment, during braiding or winding of the body 111, the filaments 112 may be loosely braided using a 1-over-2-under-2 system. In other embodiments, however, other methods of braiding may be followed, without departing from the scope of the disclosure.

Alternatively, the body 111 may be formed, for example, by laser cutting a pre-formed tube or sheet, by interconnecting a multitude of members 112 by laser welding, or by other suitable methods such as electrochemical etching, grinding, piercing, electroforming, or other means. In another example, the body 111 may comprise a tubular stent.

The body 111 has a porosity configured to reduce hemodynamic flow into, for example, an aneurysm. The porosity of the body 111, determined by the plurality of members 112, may be adjusted by axially shortening the body 111. The ends of the body 111 may be cut to length and therefore remain free for radial expansion and contraction. The body 111 may exhibit a high degree of flexibility due to the materials used, the porosity of the body 111, and the fact that the ends are not secured.

Referring to FIGS. 1A-1C, the expanding member 120 is configured to engage the body 111 of the vascular device 110, as the body 111 is expanded from the first, collapsed configuration. The expanding member 120 may comprise an elastomeric balloon capable of being very elastic, such that an axial length of the expanding member 120 in a collapsed configuration is about 200-500% longer than the axial length of the expanding member 120 in an expanded configuration. The expanding member 120 may be formed from polyurethane, silicone, or other similar materials.

The expanding member 120 is configured to geometrically deform in a similar manner as the vascular device 110, as the body 111 moves from the first, collapsed configuration to the second, expanded configuration. For example, during expansion of the expanding member 120 from the collapsed configuration to the expanded configuration, the expanding member 120 may be configured to shorten in axial length and increase in radial dimension, or diameter, by the same amounts as the body 111 does when the body 111 moves from the first, collapsed configuration to the second, expanded configuration. In other words, a change in the axial length and radial dimension of the expanding member 120 from the collapsed configuration to the expanded configuration is the same as a change in the axial length and radial dimension of the body 111 from the first, collapsed configuration to the second, expanded configuration.

The expanding member 120 may have an inner member 125 disposed within a central longitudinal axis of the expanding member 120 that is configured to axially shorten during expansion or inflation of the expanding member 120. The inner member 125 may be configured to axially shorten by the same amount as the expanding member 120 axially shortens during expansion or inflation. The inner member 125 may, for example, comprise a corrugated tube, telescoping tube, or other structure configured to axially shorten or collapse. A proximal and distal end of the expanding member 120 may be attached, coupled, or adhered to a proximal and distal portion of the inner member 125.

In some aspects, to reduce the tendency of the expanding member 120 to creep or stress relax, the material of the expanding member 120 may be cross-linked. Cross-links are bonds, bi-functional polymer chains or multi-functional polymer chains that link one polymer chain of the expanding member 120 material to another. Cross-links can be formed by chemical reactions that are initiated by heat, pressure, change in pH, radiation, or other means. For example, mixing of an unpolymerized or partially polymerized resin

with specific chemicals called cross-linking reagents results in a chemical reaction that forms cross-links between the polymer chains of the expanding member 120 material. If further protection from creep or stress relaxation is desired, the expanding member 120 could be shipped in an axially shortened and radially expanded configuration, or in the expanded configuration. In this example, the expanding member 120 may be configured to be "at rest" when the expanding member 120 is at its largest diameter and its shortest length.

Referring to FIGS. 3A-3D, the expanding member 120 may be manufactured using molds 310. In this process, a length of polymer tubing (parison) 320 is placed into the mold. Heater elements bring the parison to the working temperature and the parison is then axially stretched and internally pressurized "P" to form the expanding member 120. Using this process, the expanding member 120 may have varying cross sectional shapes either along the expanding member 120 length or normal to the expanding member 120 longitudinal axis, or both. This expanding member 120 manufacturing process may impart axial or biaxial orientation to the polymer chains of which the expanding member 120 may be comprised.

Alternatively, the expanding member 120 may be manufactured by solution casting. Solution casting is a process in which the mold is rotated, causing a solution in the mold to conform to the interior surface of the mold due to centrifugal force. After the solution has cured into a film, the mold is disassembled, thereby releasing the expanding member 120.

Other known methods may also be used to manufacture the expanding member 120. In some examples the expanding member 120 is comprised of wound or braided filaments imbedded in the elastomeric polymer. In another example the expanding member 120 may be comprised of braided filaments which can be axially lengthened or shortened using a telescoping rod and tube, the rod being attached to distal ends of the braided filaments and the tube being attached to proximal ends of the braided filaments.

The expanding member 120 may have a proximal cuff 122A and a distal cuff 122B for attachment to a catheter 130. In another embodiment, the expanding member 120 may only have a proximal cuff 122A, as shown in FIG. 3E. This embodiment is particularly useful for attaching to a distal end of a fixed wire catheter, as discussed further below.

FIGS. 4A-7B depict the vascular device 110 and the expanding member 120, according to some embodiments of the subject technology. The expanding member 120 is positioned within the central lumen of the vascular device 110 before and during deployment of the vascular device 110 within a patient's vasculature. The expanding member 120 may be configured to controllably expand the vascular device 110 such that the vascular device 110 attains a predetermined porosity at a particular region, such as near a treatment site which may be near a neck of an aneurysm. For example, during deployment, the expanding member 120 may cause a reduction in a porosity of the body 111 within a region 115A-D that is more than the reduction of the porosity of the body 111 outside the region 115A-D, thereby attaining a predetermined porosity for the region 115A-D.

Alternatively, the expanding member 120 may be configured to controllably expand the vascular device 110 such that the vascular device 110 attains a predetermined porosity in more than one region, such as proximal and distal to the neck of the aneurysm where pressure may be higher.

Referring to FIGS. 4A-4D, the expanding member 120 may controllably expand the vascular device 110 and attain the predetermined porosity for the region 115A by positively

engaging a portion of the vascular device 110 before and during deployment. For example, an adhesive 117 may be used to positively engage, couple, attach, or adhere a portion of the vascular device 110 to an outer surface of the expanding member 120. The adhesive 117 assists in utilizing the axial shrinkage and radial expansion characteristics of the expanding member 120 to control the porosity of the vascular device 110 by positively engaging, coupling, attaching, or adhering the expanding member 120 to the vascular device 110.

The adhesive 117 may comprise biodegradable materials, or materials that dissolve in the body or in the bloodstream. For example, the adhesive 117 may include sugar, carbowax, polyethylene oxide, poly vinyl alcohol, poly lactic acid (PLA), poly glycolic acid (PGA), poly lactic glycolic acid (PLGA), poly (ε-caprolactone) copolymers, polydioxanone, poly(propylene fumarate) poly(trimethylene carbonate) copolymers, polyhydroxy alkanoates, polyphosphazenes, polyanhydrides, poly(ortho esters), poly(amino acids), or "pseudo"-poly(amino acids).

In some aspects, the expanding member 120 may be configured to allow perfusion of tissues downstream of the expanding member during expansion or inflation of the expanding member 120. Allowing perfusion of tissues downstream also aids in dissolution of the adhesive 117.

Referring to FIG. 4A, in one example, the adhesive 117 may be disposed between the expanding member 120 and a region 115A. The adhesive 117 adheres a portion of the region 115A to the outer surface of the expanding member 120. The adhesive 117 may be applied on the expanding member 120 and/or the vascular device 110, such that it only adheres a proximal and/or distal portion of the region 115A. Referring to FIG. 4C, alternatively, the adhesive 117 may be applied either throughout or at a particular portion of the region 115A. Referring to FIG. 4B, the adhesive 117 may be applied continuously or intermittently on the outer surface of the expanding member 120 or the vascular device 110, depending on the dissolvability and/or fracturability of the adhesive 117. The adhesive 117 may be applied by spray, dip, or other processes.

Referring to FIG. 4D, in one aspect, the adhesive 117 may be applied on the outer surface of the expanding member 120 while the expanding member 120 is uniformly stretched, inflated, partially expanded, and/or in the expanded configuration. For example, the adhesive 117 may be applied on the outer surface of the expanding member 120 when the expanding member 120 is in the expanded configuration and uniformly stretched along its length. In this example, the adhesive 117 may be applied intermittently within the region 115A, such that unadhered areas are formed, as shown in FIG. 4C. The unadhered areas facilitate folding or collapsing of the expanding member 120 and vascular device 110 as the expanding member 120 and vascular device are prepared for deployment within the vasculature and moved to the collapsed configuration.

Alternatively, the adhesive 117 may be applied on the outer surface of the expanding member 120 while the expanding member 120 is deflated, partially collapsed, and/or in the collapsed configuration. In this example, the adhesive 117 may be applied continuously within the region 115A, as shown in FIG. 4B.

In another example, the adhesive 117 may be applied on the outer surface of the expanding member 120 while the expanding member 120 has a portion that is stretched along its length. The stretched portion may correspond to the region 115A of the vascular device 110.

In some aspects, the expanding member 120 and the vascular device 110 are positively engaged, coupled, attached, or adhered such that there is no shear strain in the adhesive 117 when the expanding member 120 and the vascular device 110 are in the expanded configuration. In other aspects, the expanding member 120 and the vascular device 110 are positively engaged, coupled, attached, or adhered such that there is enough shear strain in the adhesive 117, when the expanding member 120 and the vascular device 110 are fully expanded or in the expanded configuration, to fracture or sever the adhesive 117 and thereby release the vascular device 110 from the expanding member 120. In other aspects, the expanding member 120 and the vascular device 110 are positively engaged, coupled, attached, or adhered such that there is enough shear strain in the adhesive 117 when the expanding member 120 and the vascular device 110 are partially expanded to fracture or sever the adhesive 117 and thereby release the vascular device 110 from the expanding member 120 prior to full expansion of the expanding member 120. The shear strain of interest could be axial strain, hoop strain, or a combination of both.

Prior to deployment, the expanding member 120 may be moved to the collapsed configuration, with the vascular device 110 disposed thereon. When in the collapsed configuration, the region 115A of the body 111 will have a higher braid density and lower porosity than other portions of the body 111 due to the adhesive 117 bonding the region 115A to the expanding member 120. During subsequent expansion of the expanding member 120 and the vascular device 110, the overall porosity of the body 111 will decrease as the diameter of the vascular device 110 increases and the axial length of the vascular device 110 shortens. The porosity of the region 115A, however, also decreases and remains less porous than other portions of the body 111 during and after expansion.

Referring to FIGS. 5A-5B, the expanding member 120 may controllably expand the vascular device 110 and attain the predetermined porosity for the region 115B by increasing a diameter of the region 115B of the vascular device 110 to a diameter that is larger than other portions of the vascular device 110. The expanding member 120 may comprise, when expanded, an enlarged region 123A having an enlarged diameter relative to other regions of the expanding member 120. The enlarged region 123A is substantially axially aligned with the region 115B.

The enlarged region 123A of the expanding member 120 increases the diameter of the region 115B to a diameter that is larger than the diameter in other portions of the body 111. Enlarging the diameter of the region 115B causes the members 112 disposed on the other portions of the body 111 to be pulled toward the region 115B, thereby decreasing the porosity within the region 115B. Accordingly, the expanding member 120 causes a reduction in the porosity of the body 111 within the region 115B that is more than the reduction of the porosity of the body 111 outside the region 115B, to thereby attain the predetermined porosity for the region 115B.

In one aspect, the adhesive 117 may be used to positively engage, couple, attach, or adhere the region 115B of the vascular device 110 to the enlarged region 123A of the expanding member 120. The adhesive 117 assists in utilizing the axial shrinkage and radial expansion characteristics of the expanding member 120 to control the porosity of the vascular device 110 by positively engaging, coupling, attaching, or adhering the expanding member 120 to the vascular device 110. The adhesion between the region 115B

of the vascular device 110 and the expanding member 120 ensures that upon deployment, the region 115B attains the predetermined porosity.

Once near the treatment site, the adhesive 117 would begin to dissolve. As the expanding member 120 is expanded, the remaining adhesive 117 will be fractured, thereby further facilitating dissolution of the adhesive 117. The expanding member 120 and the vascular device 110 would expand in the same manner, shortening in axial length while increasing in diameter. The enlarged region 123A of the expanding member 120 would expand to a diameter greater than other portions of the expanding member 120, thereby causing the density within the region 115B to increase and the porosity within the region 115B to decrease, more than the other portions of the body 111.

Referring to FIGS. 6A-6B, the expanding member 120 may controllably expand the vascular device 110 and attain the predetermined porosity for the region 115C by storing excess material of the region 115C of the vascular device 110 within a reduced region 123B of the expanding member 120. For example, the expanding member 120 may comprise, when expanded, the reduced region 123B having a reduced diameter relative to other regions of the expanding member 120. The reduced region 123B is substantially axially aligned with the region 115C and provides an area to store the excess material of the region 115C. In other words, the vascular device 110 may be arranged over the expanding member 120 so that the material of the region 115C may be bunched up and collected, in a highly dense arrangement, within the reduced region 123B of the expanding member 120.

In one aspect, the adhesive 117 may be used to adhere the proximal and/or distal portions of the body 111, with the region 115C unadhered, to the expanding member 120. In another example, the adhesive 117 may be disposed intermittently along the reduced region 123B, as shown in FIG. 6A. The adhesive 117 assists in maintaining the excess material of the region 115C within the reduced region 123B of the expanding member 120 so that upon deployment, the region 115C attains the predetermined porosity. Thus, upon expansion of the expanding member 120, the excess material of the region 115C stored at the reduced region 123B of the expanding member 120 will be deployed with comparatively reduced porosity.

Once near the treatment site, the adhesive 117 would begin to dissolve. As the expanding member 120 is expanded, the remaining adhesive 117 will be fractured, thereby further facilitating dissolution of the adhesive 117. The expanding member 120 and the vascular device 110 would expand in the same manner, shortening in axial length while increasing in diameter. The reduced region 123B of the expanding member 120, which houses the excess material of the region 115C, will begin to enlarge and deploy the excess material contained therein.

Referring to FIGS. 7A-7B, the expanding member 120 may controllably expand the vascular device 110 and attain the predetermined porosity for the region 115D by storing excess material of the region 115D of the vascular device 110 within a region 123C disposed between two enlarged regions 124 of the expanding member 120. For example, the expanding member 120 may comprise, when expanded, two enlarged regions 124 having an enlarged diameter relative to a reduced region 123C therebetween. The reduced region 123C has a reduced diameter, is substantially axially aligned with the region 115D, and provides an area to store the excess material of the region 115D. In other words, the vascular device 110 may be arranged over the expanding

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member 120 so that the material of the region 115D may be bunched up and collected, in a highly dense arrangement, within the reduced region 123C of the expanding member 120.

In one aspect, the adhesive 117 may be used to adhere the proximal and/or distal portions of the body 111, with the region 115D unadhered, to the enlarged regions 124 of the expanding member 120. The adhesive 117 assists in maintaining the excess material of the region 115D within the reduced region 123C of the expanding member 120 so that upon deployment, the region 115D attains the predetermined porosity. Thus, upon expansion of the expanding member 120, the excess material of the region 115D stored at the reduced region 123C of the expanding member 120 will be deployed with comparatively reduced porosity.

Once near the treatment site, the adhesive 117 would begin to dissolve. As the expanding member 120 is expanded, the remaining adhesive 117 will be fractured, thereby further facilitating dissolution of the adhesive 117. The expanding member 120 and the vascular device 110 would expand in the same manner, shortening in axial length while increasing in diameter. The reduced region 123C of the expanding member 120, which houses the excess material of the region 115D, will begin to enlarge and deploy the excess material contained therein.

Radiopaque markers may be located adjacent the proximal or distal portions of the vascular device 110, and may be located at any position along the length of the vascular device 110 between a proximal and distal end of the vascular device 110, including the region 115A-D. The markers may be attached to the vascular device 110 by techniques such as adhesives, heat fusion, interference fit, fasteners, intermediate members, coatings, or by other techniques.

In some embodiments, the markers are comprised of ultrasonic markers, MRI-safe markers, or other markers. In some embodiments ultrasonic markers permit a physician to accurately determine the position of the vascular device 110 within a patient under ultrasonic visualization. Materials for an ultrasonic marker have an acoustical density sufficiently different from the vascular device 110 to provide suitable visualization via ultrasonic techniques. Exemplary materials comprise polymers, metals such as tantalum, platinum, gold, tungsten and alloys of such metals, hollow glass spheres or microspheres, and other materials.

In some embodiments, MRI-safe markers permit a physician to accurately determine the position of the vascular device 110 within a patient under magnetic resonance imaging. Exemplary materials for making MRI-safe marker have a magnetic signature sufficiently different from the vascular device 110 to provide suitable visualization via MRI techniques. Exemplary materials comprise polymers, metals such as tantalum, platinum, gold, tungsten and alloys of such metals, non-ferrous materials, and other materials.

A technique for treating an aneurysm will now be discussed with reference to FIGS. 8A-14. The vascular device 110 may be delivered into a treatment site using the system 100. The system 100 includes the catheter 130, which may for example, be an over the wire (OTW) catheter, a rapid exchange (multiple lumen) catheter, or a fixed wire catheter.

Referring to FIG. 8A, the OTW catheter includes a shaft 131. A proximal portion of the shaft 131 has a manifold 132 affixed thereto. A distal portion of the shaft 131 has the expanding member 120 affixed thereto. The shaft 131 also includes two lumens, a guide wire lumen 133 and an inflation lumen 134 for expanding or inflating the expanding member 120. A proximal end of each lumen 133, 134 is configured to interface with the manifold 132.

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Referring to FIG. 8B, the rapid exchange catheter includes a shaft 131 having an inflation lumen 134 extending therethrough. A proximal portion of the shaft 131 has a hub 135 affixed thereto. A distal portion of the shaft 131 has the expanding member 120 affixed thereto. The shaft 131 has two lumens over a distal portion only. The inflation lumen 134 and a guide wire lumen 133 which extends from a distal end of the shaft 131, to a skive 136. At the skive 136, the guide wire lumen 133 terminates and a guide wire communicates with an outer surface of the shaft 131. The inflation lumen 134 is configured to expand or inflate the expanding member 120.

The fixed wire catheter includes a shaft having an inflation lumen only, to which is affixed a hub and the expanding member 120.

Referring to FIG. 9, prior to delivery, the vascular device 110 is mounted to the expanding member 120 either with or without adhesive 117. An outer sheath 140 is disposed over the vascular device 110 and the expanding member 120 to confine, within an annular space between the outer sheath 140 and the expanding member 120, the vascular device 110 in the first, collapsed configuration. The outer sheath 140 also retains the vascular device 110 and the expanding member 120 in an axial elongated and diametrically reduced configuration.

The vascular device 110 and the expanding member 120 may be cooperatively movable within the outer sheath 140 in order to deliver the vascular device 110 to a treatment site, such as an aneurysm, within the vasculature of a patient.

The outer sheath 140 may be configured to be introduced and advanced through the vasculature of the patient. The outer sheath 140 may be made from various thermoplastics, e.g., PTFE, FEP, HDPE, PEEK, etc., which may optionally be lined on the inner surface of the outer sheath 140 or an adjacent surface with a hydrophilic material such as PVP or some other plastic coating. Additionally, either surface may be coated with various combinations of different materials, depending upon the desired results.

The shaft 131 includes the guide wire lumen 133 for allowing a guide wire 150 to extend therethrough. The shaft 131 may also include a reduced diameter at a distal region 137 to provide sufficient annular space in which the vascular device 110 is stowed. In this example, the expanding member 120 would be disposed on the reduced diameter region 137 of the shaft 131.

Radiopaque markers may be provided at various locations along the length of the system 100. For example, an enlarged distal tip 138 of the shaft 131 may be radiopaque. In another example, radiopaque markers may be provided on the reduced diameter distal region 137 of the shaft, beneath the distal and proximal end of the vascular device 110. In yet another example, a radiopaque marker 160 may be disposed on the shaft 131 adjacent to a longitudinal center of the vascular device 110 and/or the expanding member 120.

In one aspect, the vascular devices 110 may be configured with regions 115A-D having different axial lengths. A physician may select the appropriate vascular device 110 based on a size of the neck of the aneurysm and the axial length of the region 115A-D. For example, based on the axial length of the region 115A-D and a length of a neck of the aneurysm "Ln," the vascular device 110 may be selected such that the axial length of the region 115A-D, when the vascular device 110 is in the second, expanded configuration, is longer than the length of the neck of the aneurysm.

In another aspect, the system 100 may be manufactured to ship with the expanding member 120 and the vascular device 110 in the expanded configuration. In this example,

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after the system **100** is selected such that the as-delivered axial length of the region **115A-D** is longer than the length of the aneurysm, the physician may draw the vascular device **110** and the expanding member **120** assembly proximally into the outer sheath **140** to compress the vascular device and the expanding member **120** assembly. In an alternative embodiment, the system **100** may be manufactured to ship with the expanding member **120** and the vascular device **110** in the collapsed configuration, preloaded in the outer sheath **140**.

Referring to FIG. 9, the system **100** is advanced percutaneously over the guide wire **150** to the treatment site, in this example to the site of an aneurysm **210**. Specifically, the vascular device **110** may be positioned in a vessel **200** at an ostium or the neck of the aneurysm **210**. In one aspect, the radiopaque marker **160** may be positioned distal to a distal lateral wall of the aneurysm **210**, thereby offsetting the region **115A-D** from the ostium of the aneurysm **210** prior to expanding the vascular device **110**. During delivery, any dissolvable adhesive **117** disposed between the vascular device **110** and the expanding member **120** is protected from dissolving by the outer sheath **140**. Specifically, the outer sheath **140** covers the vascular device **110** and the expanding member **120** assembly and thereby prevents any fluids, such as blood, from coming into contact with the adhesive **117**.

Referring to FIG. 10, after navigating the system **100** to the treatment site within the patient, the outer sheath **140** is withdrawn proximally while maintaining the position of the shaft **131** to thereby expose a distal portion of the shaft **131**, the expanding member **120**, and the vascular device **110**. The outer sheath **140** is withdrawn until a distal end of the outer sheath **140** is proximal of the vascular device **110** and the expanding member **120** assembly.

If the vascular device **110** comprises a self-expanding stent, then portions of the vascular device that may be unadhered to the expanding member **120** may partially diametrically expand and partially axially shorten. In this example the region **115A-D** will maintain a higher density and lower porosity than other portions of the body **111**, during and after deployment, because of the adhesive **117** disposed between the region **115A-D** and the expanding member **120**. The adhesive **117** thereby allows the expandable member **120** to controllably expand the vascular device **110** and attain the predetermined porosity for the region **115A-D** by positively engaging the vascular device **110**. Alternatively, if the vascular device **110** does not comprise a self-expanding stent, then the vascular device **110** remains on the expanding member **120**. As the outer sheath **140** is withdrawn, thereby exposing the vascular device **110** and the expanding member **120** assembly, the adhesive **117** begins to make contact with fluids, such as blood. The adhesive **117** begins to dissolve due to the contact with the fluid.

Referring to FIG. 11, as the expanding member **120** is partially expanded or inflated using the inflation lumen **134**, the expanding member **120** and hence, the vascular device **110**, partially diametrically expand and partially axially shorten. During expansion of the expanding member **120**, the inner member **125** also axially shortens by the same amount as the expanding member **120** and/or the vascular device **110**.

Referring to FIG. 12, the system **100** is then withdrawn proximally, until the radiopaque marker **160** is centered along the length of the ostium or neck of the aneurysm **210**. In other words, after the vascular device **110** has been repositioned such that the region **115A-D** is centered along the length of the ostium, the region **115A-D** will cover the

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ostium or neck of the aneurysm **210** when the vascular device **110** is in the second, expanded configuration.

The expanding member **120** is then expanded to the fully expanded configuration, thereby fully deploying the vascular device **110**. The expanding member **120** will diametrically expand and axially shrink, while maintaining the vascular device **110** to its outer surface due to the remaining adhesive **117** disposed between the vascular device **110** and the expanding member. The expanding member **120** controllably expands the vascular device **110** such that the vascular device **110** attains the predetermined porosity at the region **115A-D**. During deployment, the expanding member **120** causes a reduction in the porosity of the body **111** within the region **115A-D** that is more than the reduction of the porosity of the body **111** outside the region **115A-D**, thereby attaining the predetermined porosity for the region **115A-D**.

The adhesive **117** disposed between the expanding member **120** and the vascular device **110** may dissolve and/or fracture during or after expansion of the expanding member **120**, thereby releasing the vascular device **110** from the expanding member **120**.

The expanding member **120** thereby causes the region **115A-D** to attain the pre-programmed porosity regardless of the endless variety of physician induced movements that can occur during the deployment of the vascular device **110**. Stated another way, the porosity of the region **115A-D** is relatively insensitive to physician applied motions during deployment of the vascular device **110**.

Referring to FIG. 13, once the entire vascular device **110** is fully expanded, the expanding member **120** is collapsed or deflated. Referring to FIG. 14, thereafter, the catheter **130**, along with the outer sheath **140**, shaft **131**, expanding member **120**, and guide wire **150** may be withdrawn from the body.

The region **115A-D** of the vascular device **110** has a significantly lower porosity compared to other portions of the body **111**. Due to the lower porosity of the region **115A-D**, less blood flows into the aneurysm **210** such that substantial thrombosis may occur within the aneurysm **210**.

In one arrangement, the vascular device **110** may be comprised of metal, polymer, ceramic, permanent enduring materials, and may comprise either of or both of non-bioabsorbable and bioabsorbable materials. Exemplary materials include, but are not limited to, NITINOL®, stainless steel, cobalt chromium alloys, Elgiloy, magnesium alloys, polylactic acid, poly glycolic acid, poly ester amide (PEA), poly ester urethane (PEU), amino acid based bio-analogous polymers, tungsten, tantalum, platinum, polymers, bio-polymers, ceramics, bio-ceramics, or metallic glasses. Part or all of the medical device may elute over time substances such as drugs, biologics, gene therapies, anti-thrombotics, coagulants, anti-inflammatory drugs, immunomodulator drugs, anti-proliferatives, migration inhibitors, extracellular matrix modulators, healing promoters, re-endothelialization promoters, or other materials. In some embodiments, the vascular device **110** may be formed from materials having shape memory properties. In some embodiments, the vascular device **110** may be finished by processes to remove slag. In some embodiments, the vascular device **110** may be subjected to a tempering treatment at temperatures customarily applied to the material so that the impressed structure is permanently established.

The vascular device **110** may have various lengths and diameters. For example, the vascular device **110** may have specific cross-sectional diameters, the diameters being measured when the vascular device **110** is fully free to expand, ranging from about 2 mm to about 6 mm. If the vascular

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device **110** has a diameter between 3 mm and 4 mm, it may be used in a size 18 microcatheters (i.e., microcatheters with an inner diameter of approximately 0.21 inch). If the vascular device **110** has a diameter between 5 mm and 6 mm, it may be used in a size 27 microcatheters (i.e., microcatheters with an inner diameter of approximately 0.027 inch). However, other suitable cross-sectional diameters may be used without deviating from the scope of the subject technology. In some embodiments, the vascular device **110** may have lengths, measured proximally to distally along the longitudinal axis of the vascular device **110**, ranging from 15 mm to 40 mm, though other ranges and sizes are also possible.

Skilled artisans may implement the described functionality in varying ways for each particular application. Various components and blocks may be arranged differently (for example, arranged in a different order, or partitioned in a different way) all without departing from the scope of the subject technology. It is understood that the specific order or hierarchy of steps in the processes disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged. Some of the steps may be performed simultaneously. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. The previous description provides various examples of the subject technology, and the subject technology is not limited to these examples. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. Pronouns in the masculine (for example, his) include the feminine and neuter gender (for example, her and its) and vice versa. Headings and subheadings, if any, are used for convenience only and do not limit the invention.

A phrase such as an "aspect" does not imply that such aspect is essential to the subject technology or that such aspect applies to all configurations of the subject technology. A disclosure relating to an aspect may apply to all configurations, or one or more configurations. An aspect may provide one or more examples. A phrase such as an aspect may refer to one or more aspects and vice versa. A phrase such as an "aspect" does not imply that such aspect is essential to the subject technology or that such aspect applies to all configurations of the subject technology. A disclosure relating to an aspect may apply to all aspects, or one or more aspects. An aspect may provide one or more examples. A phrase such as an "aspect" may refer to one or more aspects and vice versa. A phrase such as a "configuration" does not imply that such configuration is essential to the subject technology or that such configuration applies to all configurations of the subject technology. A disclosure relating to a configuration may apply to all configurations, or one or more configurations. A configuration may provide one or more examples. A phrase such as a "configuration" may refer to one or more configurations and vice versa.

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The word "exemplary" is used herein to mean "serving as an example or illustration." Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs.

All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for." Furthermore, to the extent that the term "include," "have," or the like is used in the description or the claims, such term is intended to be inclusive in a manner similar to the term "comprise" as "comprise" is interpreted when employed as a transitional word in a claim.

What is claimed is:

1. A system for treating a patient, the system comprising: an expandable vascular device comprising a body having a porosity affectable by adjusting an axial length of the body, and an expanding member positioned within a central lumen of the device, the expanding member being engageable with the body such that, as the body is radially expanded from a collapsed configuration and while engaged by the expanding member, a porosity within a region of the body is changed more than a porosity outside the region of the body is changed.
2. The system of claim 1, wherein the body comprises a braided structure.
3. The system of claim 1, wherein the body comprises a self-expanding structure.
4. The system of claim 1, wherein an axial length of the expanding member in the collapsed configuration is about 200-500% longer than the axial length of the expanding member in an expanded configuration.
5. The system of claim 4, wherein a change in the axial length of the expanding member from the collapsed configuration to the expanded configuration is the same as a change in the axial length of the body from a body collapsed configuration to a body expanded configuration.
6. The system of claim 1, further comprising an adhesive disposed between the expanding member and the region for adhering a portion of the region to the expanding member.
7. The system of claim 1, further comprising a corrugated tube disposed within the expanding member, the corrugated tube configured to axially shorten as the expanding member is inflated.
8. The system of claim 1, wherein the expanding member comprises, when expanded, an enlarged region having an enlarged diameter relative to other regions of the expanding member, the enlarged region being substantially axially aligned with the body region.
9. The system of claim 8, further comprising an adhesive disposed between the enlarged region of the expanding member and the body region.
10. The system of claim 1, wherein the expanding member comprises, when expanded, a reduced region having a reduced diameter relative to other regions of the expanding member, the reduced region being substantially axially aligned with the body region.

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11. The system of claim 10, further comprising an adhesive disposed proximally or distally of the reduced region of the expanding member.

12. The system of claim 1, wherein the expanding member comprises, when expanded, two enlarged regions having an enlarged diameter relative to a reduced region therebetween, having a reduced diameter, the reduced region being substantially axially aligned with the body region.

13. The system of claim 12, further comprising an adhesive disposed between the enlarged regions and the body.

14. A delivery system for a vascular device, the delivery system comprising:

a catheter having a lumen;

a guide wire extending through the catheter lumen;

a vascular device having a porosity affectable by adjustment of an axial length of the device; and

an expanding member disposed within a distal portion of the catheter, the expanding member having an axial length that is adjustable as the expanding member is radially expanded;

wherein the expanding member is engageable with a region of the device such that, during adjustment of the axial length of the expanding member and while the expanding member engages the region, a porosity within the region of the device is changed more than a porosity outside the region of the device is changed.

15. The system of claim 14, wherein the axial length of the expanding member in a collapsed configuration is about

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200-500% longer than the axial length of the expanding member in a radially expanded configuration.

16. The system of claim 15, wherein a change in the axial length of the expanding member from the collapsed configuration to the radially expanded configuration is the same as a change in the axial length of the device from a device collapsed configuration to a device expanded configuration.

17. The system of claim 14, further comprising an adhesive disposed between the expanding member and the region for adhering a portion of the region to the expanding member.

18. The system of claim 14, wherein the expanding member comprises, when radially expanded, an enlarged region having an enlarged diameter relative to other regions of the expanding member, the enlarged region being substantially axially aligned with the body region.

19. The system of claim 14, wherein the expanding member comprises, when radially expanded, a reduced region having a reduced diameter relative to other regions of the expanding member, the reduced region being substantially axially aligned with the body region.

20. The system of claim 14, wherein the expanding member comprises, when radially expanded, two enlarged regions having an enlarged diameter relative to a reduced region therebetween, having a reduced diameter, the reduced region being substantially axially aligned with the body region.

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