(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 January 2018 (25.01.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/017455 A1

(51) International Patent Classification:
B01D 65/00 (2006.01)

(21) International Application Number:
PCT/US2017/042327

(22) International Filing Date:
17 July 2017 (17.07.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/363,637 18 July 2016 (18.07.2016) US

(71) Applicant: **ENTEGRIS, INC.** [US/US]; 129 Concord Road, Billerica, Massachusetts 01821 (US).

(72) Inventor: **PUGLIA, John**; Entegris, Inc., 129 Concord Road, Billerica, Massachusetts 01821 (US).

(74) Agent: **SZYMANSKI, Brian**; Entegris, Inc., 129 Concord Road, Billerica, Massachusetts 01821 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: SPACER FILM WITH INTEGRATED LAMINATION STRIP

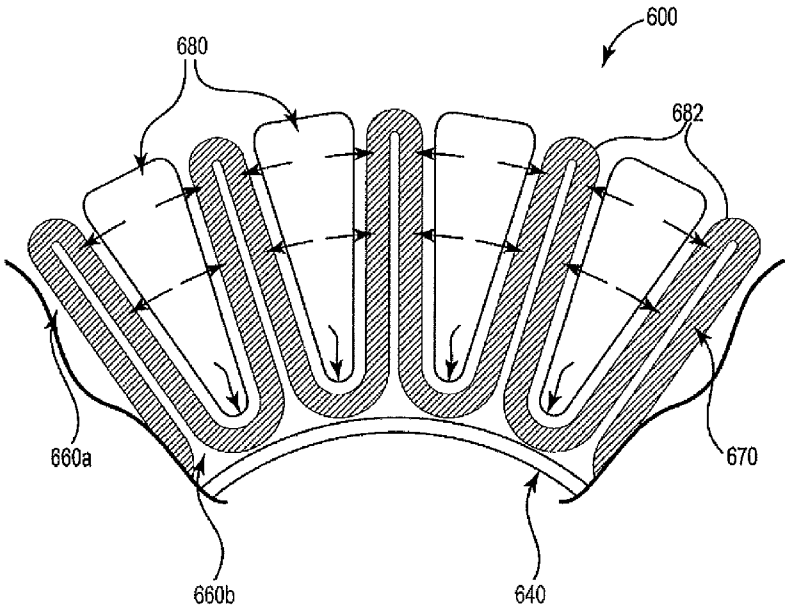

Fig. 4

(57) Abstract: Spacers for filtration membranes that are formed from perforated films. The spacer include unperforated regions, which can serve as integrated lamination strips, advantageously omitting the need for separate lamination steps required with woven and nonwoven spacer fabrics while also providing a spacer with a uniform thickness.

WO 2018/017455 A1

SPACER FILM WITH INTEGRATED LAMINATION STRIP

BACKGROUND OF THE INVENTION

[0001] Filters, as used in various gas, liquid, chemical, and water filtration applications, often include spacers next to filtration membranes to improve flow and process throughput of the filter.

SUMMARY OF THE INVENTION

[0002] This invention pertains to a spacer film for a filter, as well and methods of making and using a spacer film that allows for improved tracking and improved flow in a filter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The foregoing will be apparent from the following more particular description of example embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments of the present invention.

[0004] FIG. 1 is a schematic illustrating a spacer film in accordance with a version of the invention.

[0005] FIG. 2A is a schematic illustrating a cross-section of a spacer film prior to lamination in accordance with a version of the invention.

[0006] FIG. 2B is a schematic illustrating a cross-section of a laminated spacer film and membrane stack in accordance with another version of the invention.

[0007] FIG. 3 is a perspective view of a filter including spacer films in accordance with one version of the invention.

[0008] FIG. 4 is a diagram illustrating a cross section of a filter including a pleated filtration membrane and spacer films of the present invention.

[0009] FIG. 5 is a diagram illustrating layering of spacer films of the present invention with a filtration membrane.

[0010] FIG. 6 is a diagram illustrating a cross section of a filter including a spiral-wound filtration member and spacer films of the present invention.

[0011] FIG. 7 is a diagram illustrating a filtration process.

DETAILED DESCRIPTION OF THE INVENTION

[0012] While this invention will be particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

[0013] While various compositions and methods are described, it is to be understood that this invention is not limited to the particular compositions, designs, methodologies or protocols described, as these may vary. It is also to be understood that the terminology used in the description is for the purpose of describing the particular versions or versions only, and is not intended to limit the scope of the present invention which will be limited only by the appended claims.

[0014] It must also be noted that as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural reference unless the context clearly dictates otherwise. Thus, for example, reference to a "filter element" is a reference to one or more filter elements and equivalents thereof known to those skilled in the art, and so forth. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Methods and materials similar or equivalent to those described herein can be used in the practice or testing of versions of the present invention. All publications mentioned herein are incorporated by reference in their entirety. Nothing herein is to be construed as an admission that the invention is not entitled to antedate such disclosure by

virtue of prior invention. "Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not. All numeric values herein can be modified by the term "about," whether or not explicitly indicated. The term "about" generally refers to a range of numbers that one of skill in the art would consider equivalent to the recited value (i.e., having the same function or result). In some versions the term "about" refers to ±10% of the stated value, in other versions the term "about" refers to ±2% of the stated value. While compositions and methods are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions and methods can also "consist essentially of" or "consist of" the various components and steps, such terminology should be interpreted as defining essentially closed-member groups.

[0015] A description of example embodiments of the invention follows.

[0016] Filters often include spacers next to, between, and/or around filtration membranes. Spacers are typically formed from woven or nonwoven fabrics, such as netting or extruded fibers that form an open-meshed material to allow for flow through the filter and/or to increase turbulence of the flow while imparting no measurable contribution toward pressure drop across the filter. Spacers may alternatively be referred to as screens and can serve a variety of functions within a filter. For example, a feed spacer can be included in a filter to prevent a filtration membrane from sticking to itself and to prevent channeling of the filter feed, both of which lessen the productivity of the filter. Spacers can additionally provide support and protection to filtration membranes. For example, spacers can prevent damage to the membrane by cushioning the membrane and preventing it from abrading against itself or other elements located in a filter housing. Additionally, spacers can structurally support pleated or unpleated membrane composite structures within filtration devices.

[0017] Versions of the present invention include spacers formed from perforated films, as opposed to woven- and nonwoven-fiber screens. Spacer films of the present invention include unperforated regions, which can serve as integrated lamination strips, advantageously omitting the need for separate lamination steps required with woven and nonwoven spacer fabrics while also providing a spacer with a uniform thickness. Additionally, films are less likely to compress in the x-y plane than woven and non-woven spacer fabrics. As such, spacer films of the present

invention, when laminated to edges of a membrane, advantageously prevent membrane shrinkage during device construction and/or application processing.

[0018] FIG. 1 illustrates a sheet of spacer film in accordance with a version of the invention. The spacer film 100 has a central portion 110 that includes a plurality of perforations 120 and two unperforated regions 130a, 130b located at opposing edges 132, 134 of the film 100. The unperforated regions 130 may also be referred to as integrated lamination strips. Perforations 120 are illustrated to be substantially oval in shape; however, other configurations are possible. Spacer film perforations can have other shapes, such as circular, triangular, or irregular shapes, and varying shapes can be included in the same sheet of spacer film.

[0019] As shown in FIG. 1, perforations 120 are substantially aligned in rows and columns; however, other geometric orientations or patterns are possible. Perforation patterns can have generic configurations for use in multiple applications, or perforation patterns can be made specific for use in a particular application. For example, perforations can be offset and/or the perforations could be orientated on a diagonal. Additionally, perforations can occur at varying spacing intervals. Perforations can be spaced at about 10 μm x 10 μm or greater (e.g., about 10 μm, about 20 μm, about 30 μm, about 40, μm, about 50 μm, about 100 μm in either dimension). Alternatively, perforations can have a random spacing. The orientation of the perforations (e.g., linear or off-set), the perforation shape and size, and the perforation spacing can be selected based on the desired application.

[0020] Versions of the present invention include perforated films as spacer material, as opposed to woven-fiber and nonwoven-fiber fabrics. Typically, the thickness of woven-fiber and nonwoven-fiber spacer fabrics is from about 30 μm to about 180 μm, and typically at least about 55 to about 65 μm. Spacer films of the present invention can be cast to have a thickness that is about the same as, or less than, the typical thickness of woven-fiber and nonwoven-fiber spacer fabrics. For example, spacer films of the present invention can be cast to have a thickness of about 20 μm to about 180 μm, or of about 30 μm to about 55 μm, for example, about 29.5 μm, about 35 μm, about 40 μm, about 45 μm, about 50 μm, and about 55.5 μm. The films can be cast and perforated with geometric patterns, such as perforations 120 (FIG. 1), which permit flow through the spacer film. As filter housings are typically provided in standard sizes, it can be desirable to include a thinner spacer in the filter. A thinner spacer allows for a greater length of

filtration membrane to be included in a given filter housing than would be possible with a thicker spacer material. The additional membrane included in the filter provides additional surface area for filtration, thereby increasing productivity of the filter. Films of the present invention have a superior buckling resistance than non-woven and woven spacers, which provides a more precise flow channel to mitigate frictional loses associated with woven and non-woven surfaces.

[0021] A cross-section of a spacer film 400 is illustrated in FIG. 2A. The film 400 has a perforated center region 410 and unperforated edges 430, which can have different thicknesses prior to lamination. The thickness T_C of center region 410 can be less than the thickness T_L of the unperforated edges 430. The difference between thicknesses T_C and T_L can result from the unperforated regions 430 along the edges of the film tending to bulk-up or crimp-up relative to the perforated region 410.

[0022] The unperforated regions 430 can serve as integrated lamination strips to seal edges of the spacer film 400 to a filtration membrane. Thus, the unperforated regions 430 can eliminate the need for a separate manufacturing step to perform edge lamination of the spacer to a membrane. Contamination can occur at each step in the manufacturing process of a filter, where additional materials are introduced to the filter or components of the filter are manipulated. Aseptic devices are increasingly more difficult to produce as the number of ingredients increase. Accordingly, it can be desirable to eliminate manufacturing steps and/or the introduction of additional materials during the manufacturing process. Typically, spacers are made to adhere to filtration membranes through a lamination or sealing process. The lamination process typically involves the application of a discrete lamination strip or the coating of a sealant to the edges of the membrane and/or spacer. The process can then involve the application of heat to complete lamination and/or require a period of time for curing before the spacer and membrane can be pleated or wound into a filter element. The introduction of such additional materials and manufacturing steps introduces potential sources of contamination, both chemical and biological. Spacer films of the present invention, which have unperforated regions to serve as integrated lamination strips, advantageously omit the need to apply separate laminate or sealant, thereby eliminating a potential source of contamination in the filter assembly process. Additionally, lamination of spacer films of the present invention can be performed following

assembly into, for example, a pleat pack, thereby eliminating the need for a discrete lamination step prior to assembly.

[0023] After lamination of the spacer film to a filtration membrane, a uniform thickness across the spacer film can be obtained. For example, a spacer film 400 cast to have a 40 μm thickness may have a center region thickness T_C of 40 μm and an unperforated region thickness T_L of 80 μm. Upon lamination of the unperforated edges 430 to a filtration membrane, the spacer film 400 can have a uniform thickness across the width of the spacer film of about 40 μm.

[0024] As further illustrated in FIG. 2B, two spacer films 400a, 400b, each adjacent to and laminated to a membrane 420, have a uniform thickness. The unperforated regions of spacer films 400a, 400b, following lamination, form laminated regions 440 on opposing edges of the stack 450 of spacer films 400a, 400b and membrane 420. The unperforated region thicknesses T_{LA}, T_{LB} can be the same or approximately the same as the center region thicknesses T_{CA}, T_{CB} of the films 400a, 400b, such that a uniform thickness T is achieved over the width of the stack 450.

[0025] A uniform thickness across the spacer film assists with the pleating of a membrane-spacer stack to form a pleated filter element, or the winding of a membrane-spacer stack to form a spiral-wound filter element. Uneven spacer films typically do not track well through filter assemblies during both construction and operation and, further, uneven spacing can compromise the structure and appearance of the completed filter.

[0026] Spacer films of the present invention can be formed from, for example, perfluoroalkoxy polymer (PFA), high density polyethylene (HDPE), polyvinylidene fluoride (PVDR), polypropylene, polyethylene terephthalate (PET), polysulfone, polytetrafluoroethylene (PTFE), ultra-high-molecular-weight polyethylene (UHMWPE), polyethylene (PE), polyamide (e.g., nylon), polycarbonate, and polyimide. The material from which spacer films of the present invention are made can be compatible with the material from which a membrane is made. Membranes can be made of, for example, PTFE, polypropylene, PE, ultra-high molecular weight polyethylene (UPE), polyvinylidene fluoride (PVDF), polysulfone, polycarbonate, polyimide, and polyamide. In some versions, spacer films of the present invention are formed from the same material as that of the filtration membrane, thereby avoiding the potential for cross-contamination between the spacer film and the membrane. In other versions, spacer films and membranes can be made from different materials, depending upon the application. For example,

filters to be used for a chemical sensitive, but not temperature sensitive, process can include a membrane made of PTFE and a spacer made of polypropylene.

[0027] Spacer films of the present invention can be placed on either side of a filtration membrane, forming a stack, as illustrated in FIG. 5. Flow of the feed to be filtered through a membrane 720 is indicated in FIG. 5 by arrows. The stack 700 includes a spacer film 710a on an upstream side of membrane 720 (e.g., serving as a feed screen) and a spacer film 710b on a downstream side of membrane 720 (e.g., serving as a permeate screen). The spacer-membrane stack 700 can then be laminated and pleated to form a pleat pack for a pleated filter element (FIG. 3), or laminated and wound to form a spiral-wound filter element (FIG.6). Although stack 700 includes two spacer films (710a, 710b), more or fewer layers of spacer films can be included in a filter. For example, a filter may include only one layer of a spacer film on either an upstream side or downstream side of a filtration membrane, such as where only a feed screen or only a permeate screen is desired. Alternatively, for example, a filter may include three layers of spacer films, such as one layer of spacer film on the upstream side of the membrane and two layers of spacer film on the downstream side of the membrane, such as where a thicker permeate channel than feed channel is desired, or vice-versa.

[0028] A filter containing a pleated spacer-membrane stack is illustrated FIG. 3. The filter 500 includes a housing 510 with an endcap 520 at a first end and a fluid fitting 530 at a second end. Within the housing is a core 540, about which a pleat-pack 550 is located. Pleat-pack 550 includes an upstream spacer film 560a, a filtration membrane 570, and a downstream spacer film 560b. Pleat-pack 550 is shown in an exploded view for illustration purposes. Spacer films 560a, 560b are typically laminated to membrane 570 along the edge of the pleat-pack closest to end cap 520 (e.g., edges 562a, 562b and 572) and the edge closest to fitting 530 (e.g., edge 564b, and the corresponding edges of spacer 560a and membrane 570 not visible in FIG. 3). The lamination of spacer films 560a, 560b to membrane 570 ensure that a feed entering filter 500 does not arrive downstream of membrane 570.

[0029] A cross-sectional view of a portion of a filter that includes a pleated filtration membrane and spacer films is shown in FIG. 4, with flow paths of a feed through the filter 600 indicated by arrows. Feed enters any of volumes 680 between pleats 682 and travels through an upstream spacer film 660a. The feed is then filtered through membrane 670 and travels through

downstream spacer film 660b to core 640. Spacer films 660a, 660b are located on either side of membrane 670 and assist with maintaining open channels between pleats 682 through which a feed may travel.

[0030] A cross-sectional view of a filter containing a spiral-wound spacer-membrane stack is illustrated in FIG. 6. The filter 800 includes a housing 810 with a core 840. An upstream spacer film 860a occupies a space around membrane envelope 670, which contains a downstream spacer film 860b. Flowpaths of a feed through the filter 800 are indicated by arrows in FIG.6. Feed filtering through membrane 870 travels through downstream spacer film 860b, arriving at core 840.

[0031] A method of making a filter, such as filters 700, 600, 800 includes stacking at least one spacer film adjacent to a filtration membrane and laminating the edges to form a laminated spacer-membrane stack. The method further includes pleating, stacking, or spiraling the spacer-membrane stack about itself or a core, forming a filter element. The filter element can then be placed in a housing and a heat source can be applied to both ends of the housing, causing the lamination strips of the spacer film to bond to the ends of the housing. Alternatively, the prior lamination of the spacer film(s) to the filtration can be omitted, with the lamination of the spacer film(s) to the membrane occurring after the pleated or spiral-wound filter element is placed in the housing and the heat source is applied to the housing. Ultrasonic techniques can also be employed to provide energy directors to impart polymer flow, causing sealing to occur. Woven and nonwoven fabrics used as spacers typically do not include enough material to accomplish lamination to the membrane and/or bonding to the filter housing without additional lamination material and a separate lamination step. Spacer films of the present invention advantageously do not require a separate lamination strip and/or a separate lamination step.

[0032] FIG. 7 illustrates a flow path through a filter 900, which can contain a pleated spacer-membrane stack (FIG. 3) or a spiral-wound spacer-membrane stack (FIG. 6). Flow paths of the feed through the filter are indicated by arrows in FIG. 7. A liquid feed 912 containing contaminants 914 travels into filter housing 910. The feed is filtered as it travels through the spacer-membrane stack (not shown in FIG. 7) before arriving at core 940, from which the filtered feed 920 exits the housing 910.

[0033] Although the invention has been shown and described with respect to one or more implementations, equivalent alterations and modifications will occur to others skilled in the art based upon a reading and understanding of this specification and the annexed drawings. The invention includes all such modifications and alterations and is limited only by the scope of the following claims. In addition, while a particular feature or aspect of the invention may have been disclosed with respect to only one of several implementations, such feature or aspect may be combined with one or more other features or aspects of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms "includes", "having", "has", "with", or variants thereof are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term "comprising." Also, the term "exemplary" is merely meant to mean an example, rather than the best. It is also to be appreciated that features and/or elements depicted herein are illustrated with particular dimensions and/or orientations relative to one another for purposes of simplicity and ease of understanding, and that the actual dimensions and/or orientations may differ substantially from that illustrated herein.

[0034] Although the present invention has been described in considerable detail with reference to certain versions thereof, other versions are possible. Therefore the spirit and scope of the appended claims should not be limited to the description and the versions contained within this specification.

[0035] The teachings of all patents, published applications and references cited herein are incorporated by reference in their entirety.

What is claimed is:

1. A spacer for a filter, comprising:
a film having perforations substantially located in a central region and at least two unperforated regions located on opposing edges of the film, the unperforated regions being laminable to a filtration membrane.

2. The spacer of Claim 1, wherein the film comprises perfluoroalkoxy polymer, polyethylene, polyvinylidene fluoride, polypropylene, polyethylene terephthalate, polysulfone, polytetrafluoroethylene, polyamide, polycarbonate, or polyimide.

3. The spacer of Claim 1, wherein the film comprises perfluoroalkoxy polymer.

4. The spacer of Claim 1, wherein the film has an unlaminated thickness from about 20 μm to about 180 μm.

5. The spacer of Claim 1, wherein the film has an unlaminated thickness from about 30 μm to about 55 μm.

6. A filter element, comprising:
at least one spacer of Claim 1; and
a filtration membrane adjacent to the at least one spacer, the filtration membrane and at least one spacer pleated or rolled about a core.

7. The filter element of claim 6, wherein the film comprises perfluoroalkoxy polymer, polyethylene, polyvinylidene fluoride, polypropylene, polyethylene terephthalate, polysulfone, polytetrafluoroethylene, polyamide, polycarbonate, or polyimide.

8. The filter element of claim 6, wherein the film comprises perfluoroalkoxy polymer.

9. The filter element of claim 6, wherein the filtration membrane comprises perfluoroalkoxy polymer, polyethylene, polyvinylidene fluoride, polypropylene, polyethylene terephthalate, polysulfone, polytetrafluoroethylene, polyamide, polycarbonate, or polyimide.

10. A filter, comprising:
a housing;
a filtration membrane; and
at least one spacer adjacent to the filtration membrane, the spacer comprising a film having perforations substantially located in a central region and at least two unperforated regions located on opposing edges of the film, wherein the unperforated regions are laminated to the filtration membrane and the filtration membrane and at least one spacer are pleated or rolled about a core within the housing.

11. The filter of Claim 10, wherein the unperforated regions of the film are bonded to the housing.

12. The filter of Claim 10, wherein the at least one spacer laminated to the filtration membrane prevents shrinkage of the filtration membrane during operation.

13. The filter of claim 10, wherein the wherein the film comprises perfluoroalkoxy polymer, polyethylene, polyvinylidene fluoride, polypropylene, polyethylene terephthalate, polysulfone, polytetrafluoroethylene, polyamide, polycarbonate, or polyimide.

14. The filter element of claim 10, wherein the film comprises perfluoroalkoxy polymer.

15. The filter element of claim 10, wherein the filtration membrane comprises perfluoroalkoxy polymer, polyethylene, polyvinylidene fluoride, polypropylene, polyethylene terephthalate, polysulfone, polytetrafluoroethylene, polyamide, polycarbonate, or polyimide.

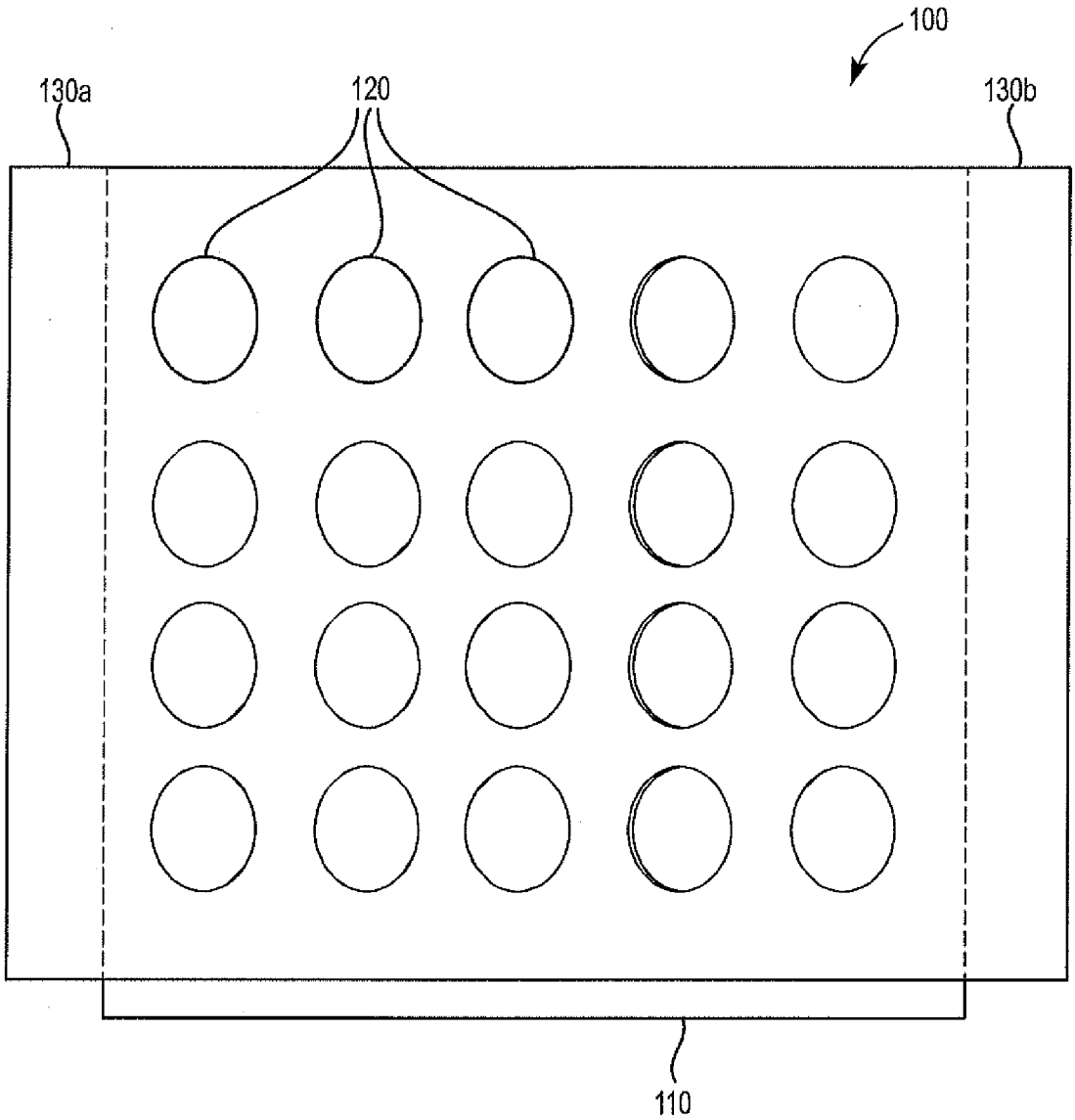

Fig. 1

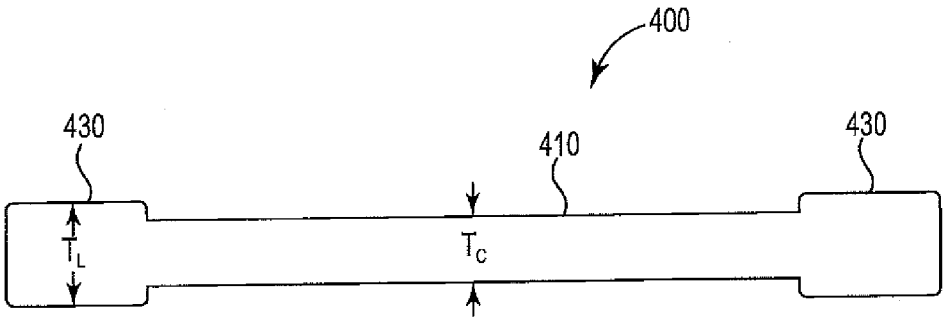

Fig. 2A

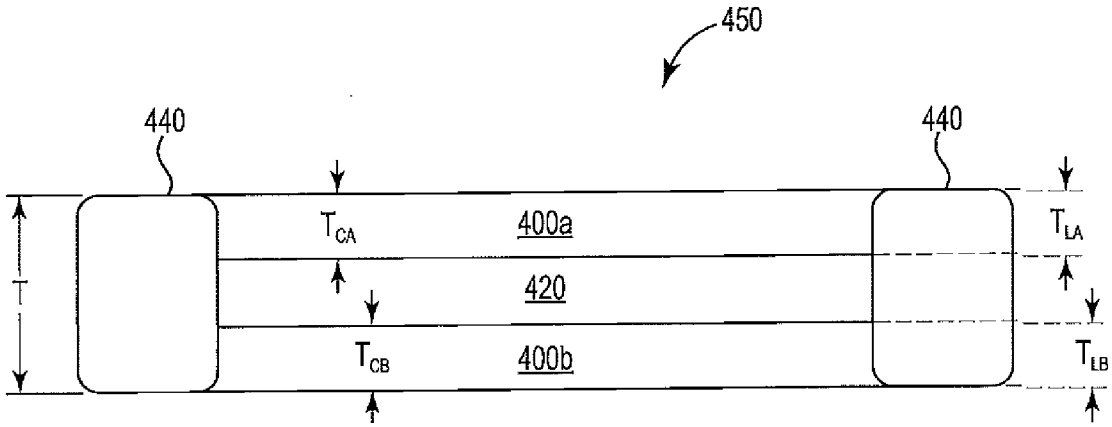

Fig. 2B

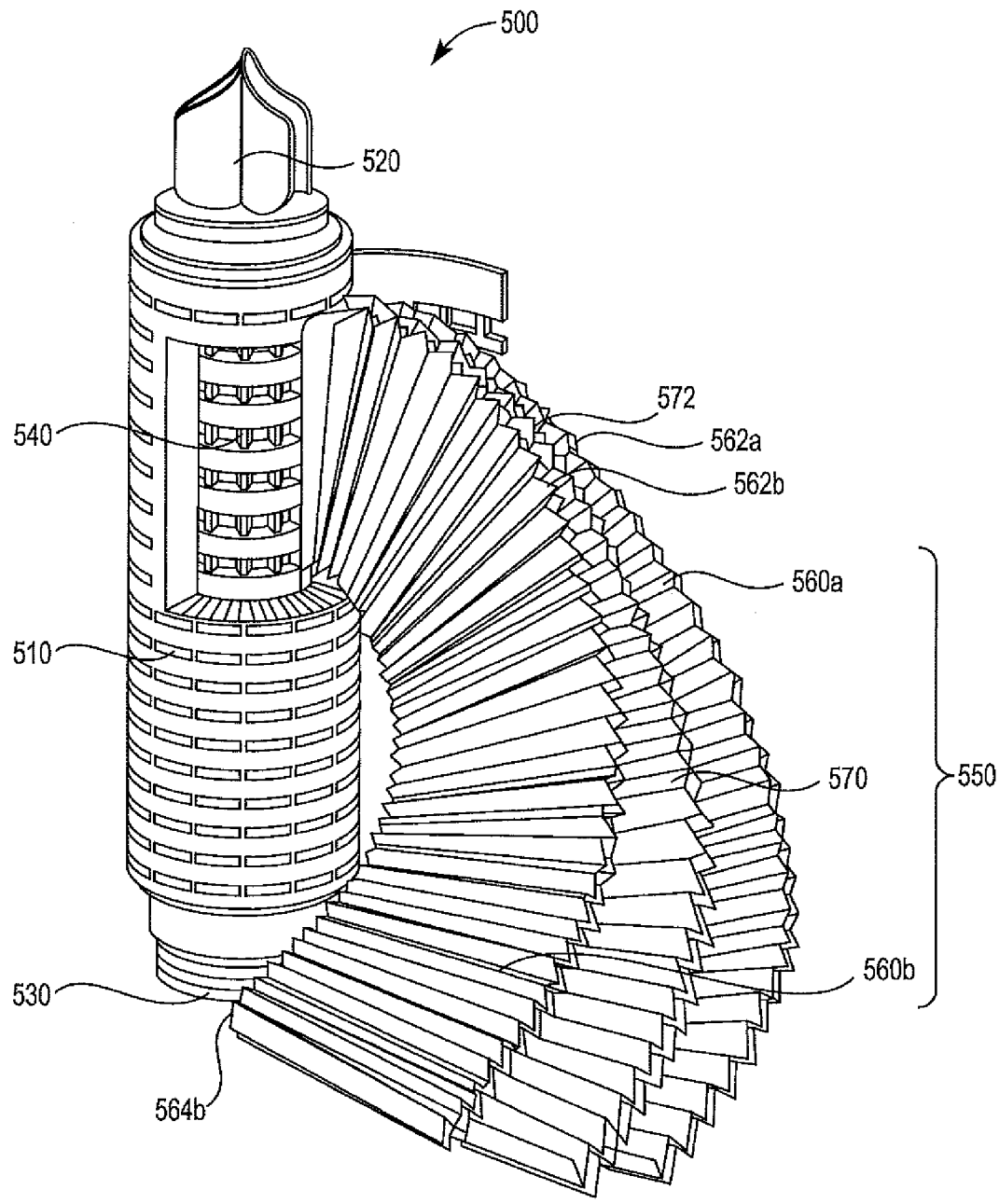

Fig. 3

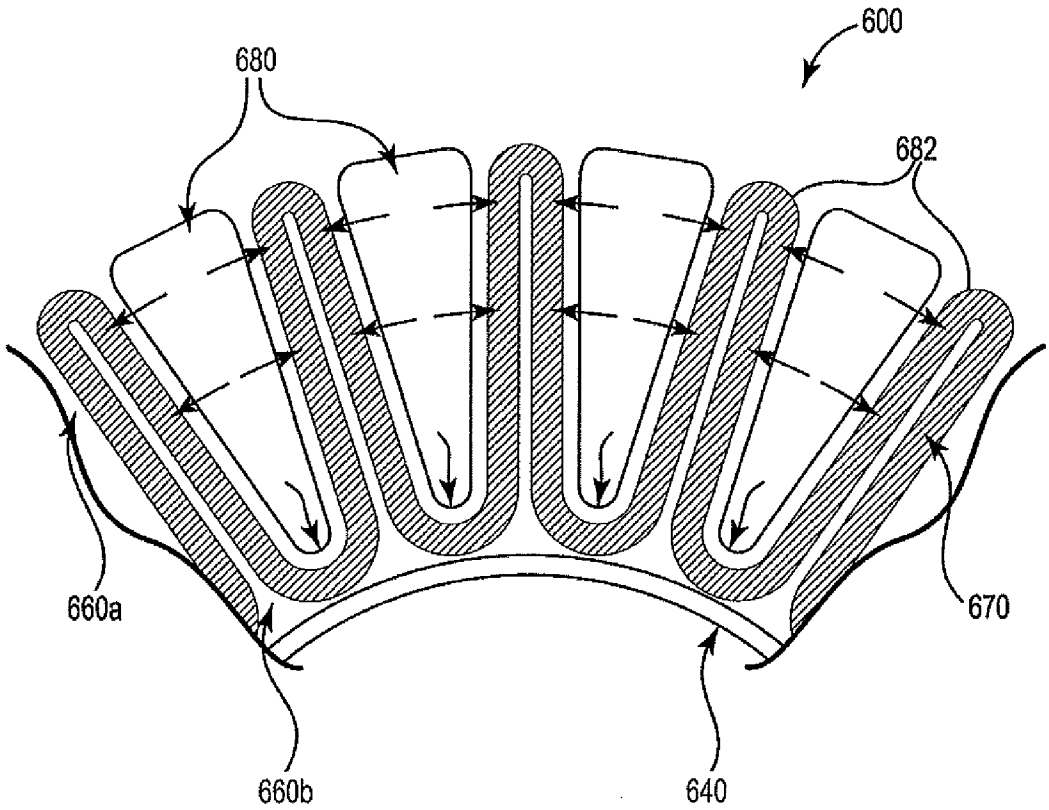

Fig. 4

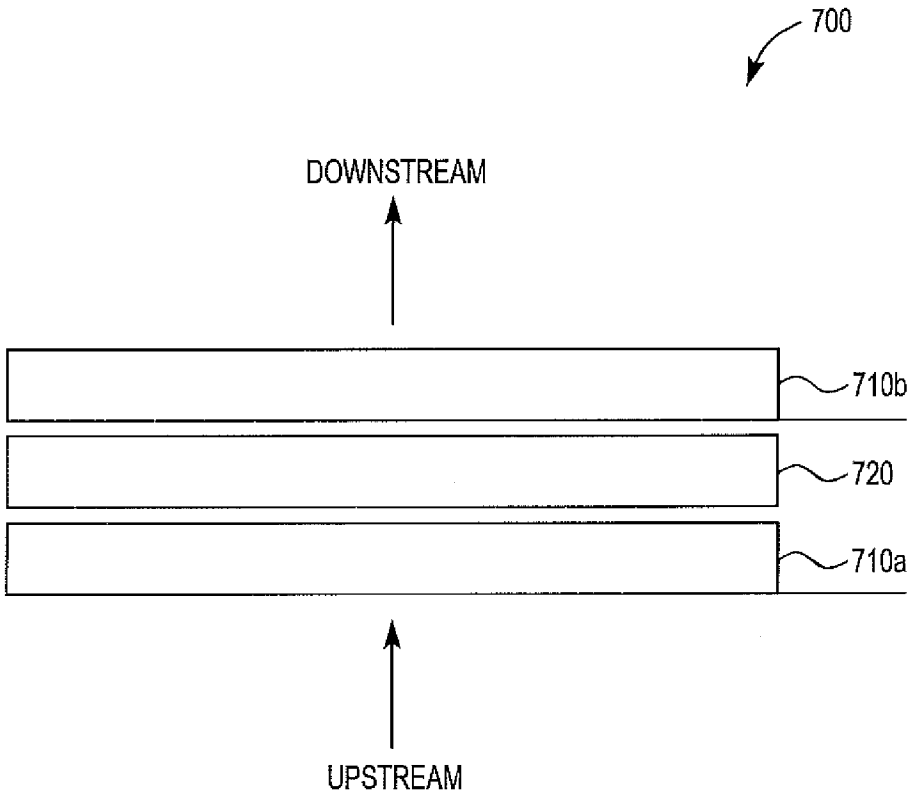

Fig. 5

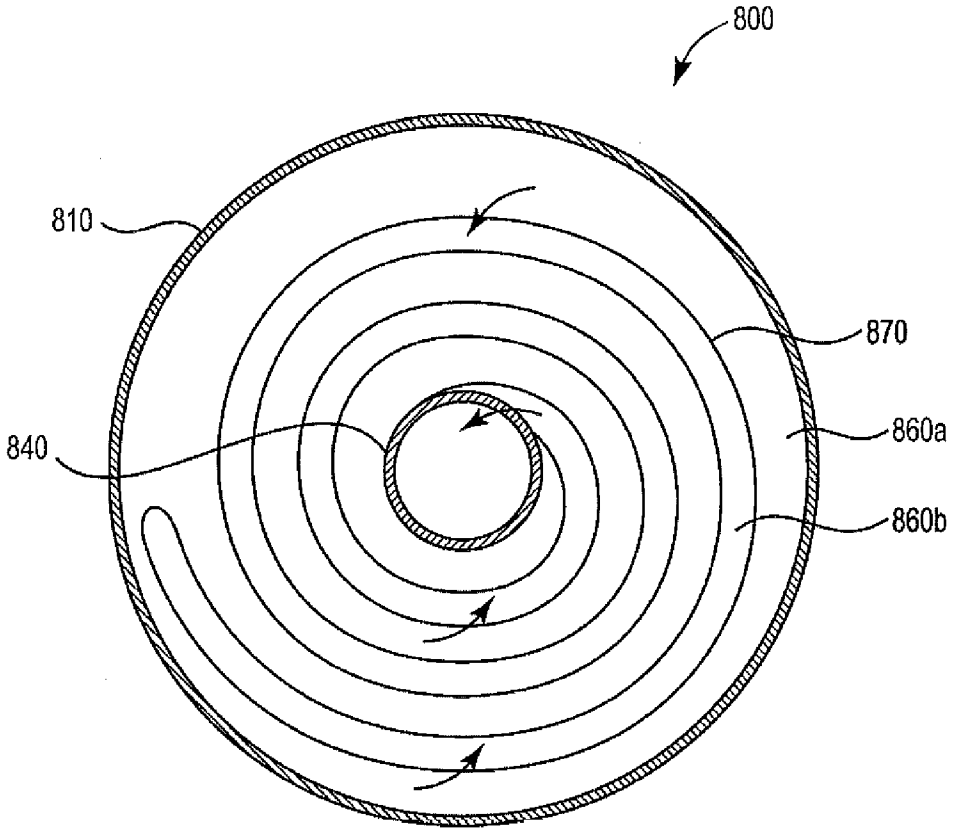

Fig. 6

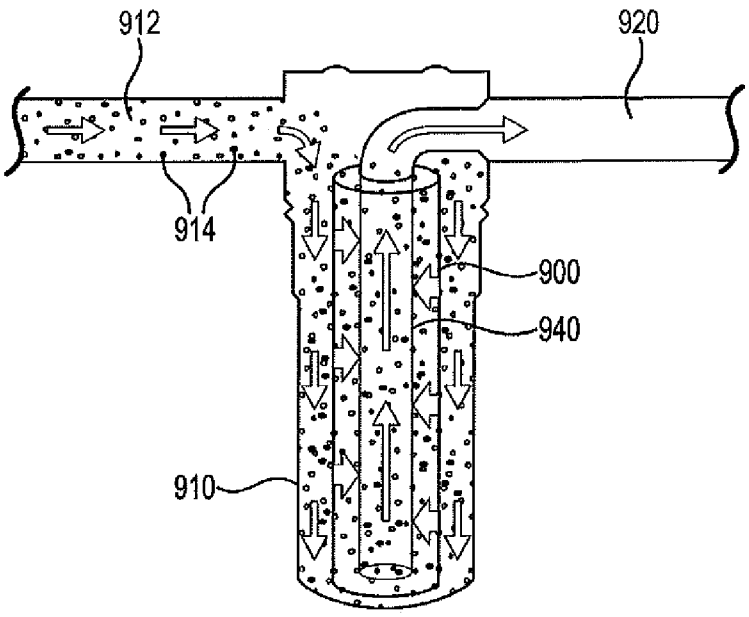

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042327

A. CLASSIFICATION OF SUBJECT MATTER

B01D 65/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D 65/00; B01D 25/00; B01D 63/00; B01D 46/52; B60H 3/06; C02F 1/44; B01D 29/06; B01D 63/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: filter, spacer, film, perforation, edge, laminate, pleated, perfluoroalkoxy

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006-091157 A1 (ALFA LAVAL CORPORATE AB) 31 August 2006 See page 8, lines 14-24; claim 1; and figures 1, 2.	1,4-5
Y		2-3,6-15
Y	WO 2010-036374 A1 (YAEGER, S. P.) 01 April 2010 See abstract; claims 1,17,25; and figures 1,4.	2-3,6-15
A	US 2010-0320139 A1 (DIEMER, W. et al.) 23 December 2010 See the entire document.	1-15
A	WO 03-105994 A1 (3M INNOVATIVE PROPERTIES COMPANY) 24 December 2003 See the entire document.	1-15
A	US 4479874 A (ROSENBERG, D. J. et al.) 30 October 1984 See the entire document.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 October 2017 (23.10.2017)	**23 October 2017 (23.10.2017)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
LEE, Dong Wook
Telephone No. +82-42-481-8163

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/042327

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2006-091157 A1	31/08/2006	AU 2006-217128 A1	31/08/2006
		AU 2006-217128 B2	11/08/2011
		CN 101128251 A	20/02/2008
		CN 101128251 B	06/03/2013
		EP 1853375 A1	14/11/2007
		JP 2008-531269 A	14/08/2008
		US 2008-0156730 A1	03/07/2008
WO 2010-036374 A1	01/04/2010	CA 2738589 A1	01/04/2010
		CA 2738589 C	26/08/2014
		CN 102165483 A	24/08/2011
		CN 102223944 A	19/10/2011
		CN 102223944 B	15/10/2014
		CN 105473212 A	06/04/2016
		DK 2352576 T3	02/09/2013
		EP 2350963 A2	03/08/2011
		EP 2350963 B1	20/11/2013
		EP 2352576 A1	10/08/2011
		EP 2352576 B1	29/05/2013
		EP 2996797 A1	23/03/2016
		JP 05616894 B2	29/10/2014
		JP 2012-504041 A	16/02/2012
		JP 2016-520001 A	11/07/2016
		KR 10-2011-0074524 A	30/06/2011
		KR 10-2016-0030107 A	16/03/2016
		TW 201013428 A	01/04/2010
		US 2010-0078378 A1	01/04/2010
		US 2010-0082750 A1	01/04/2010
		US 2013-0240434 A1	19/09/2013
		US 8454829 B2	04/06/2013
		US 9452390 B2	27/09/2016
		WO 2010-036688 A2	01/04/2010
		WO 2010-036688 A3	15/07/2010
		WO 2014-186694 A1	20/11/2014
US 2010-0320139 A1	23/12/2010	AU 2001-270594 B2	15/06/2006
		AU 7059401 A	08/01/2002
		CA 2414494 A1	03/01/2002
		DE 10029960 A1	10/01/2002
		EP 1294462 A1	26/03/2003
		EP 1294462 B1	19/01/2005
		JP 04675545 B2	27/04/2011
		JP 2004-501742 A	22/01/2004
		US 2003-0159981 A1	28/08/2003
		US 7794594 B2	14/09/2010
		US 8128824 B2	06/03/2012
		WO 02-00320 A1	03/01/2002
WO 03-105994 A1	24/12/2003	AU 2003-239928 A1	31/12/2003

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/042327

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		EP 1511551 A1	09/03/2005
		TW 200407188 A	16/05/2004
		TW I280150 B	01/05/2007
		US 2003-0230061 A1	18/12/2003
		US 6740137 B2	25/05/2004
US 4479874 A	30/10/1984	CA 1195260 A	15/10/1985
		EP 0104526 A2	04/04/1984
		EP 0104526 A3	15/05/1985
		EP 0104526 B1	13/05/1987
		JP 02-005124 B	31/01/1990
		JP 59-073019 A	25/04/1984