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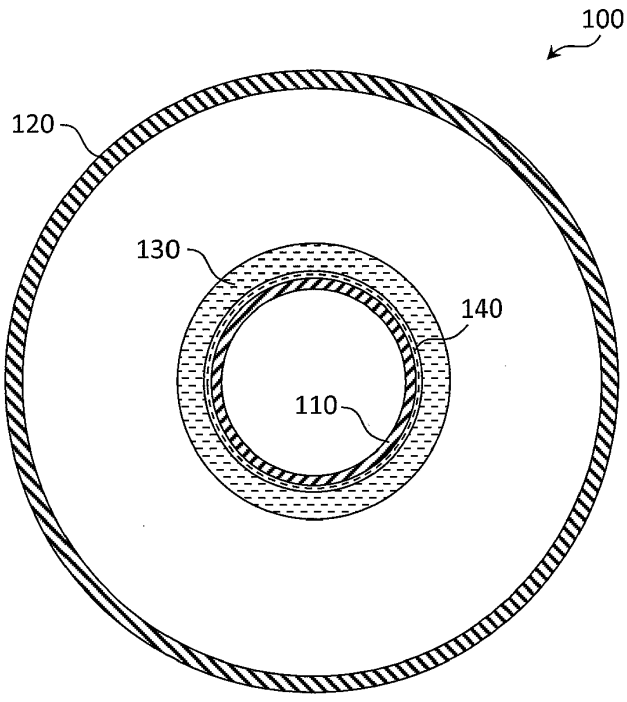
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(54) COAXIAL CABLE AND METHOD OF MANUFACTURING A COAXIAL CABLE

(57) The invention relates to a coaxial cable (100) comprising an inner conductor (110) and an outer conductor (120) which is arranged radially outside of said inner conductor (110) and which is electrically isolated from said inner conductor (110), wherein at least one stress absorbing element (130) for absorbing mechanical stress is arranged radially between said inner conductor (110) and said outer conductor (120).

Fig. 1



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Description

Field of the invention

[0001] The invention relates to a coaxial cable comprising an inner conductor and an outer conductor which is arranged radially outside of said inner conductor and which is electrically isolated from said inner conductor.

[0002] The invention further relates to a method of manufacturing a coaxial cable.

Background

[0003] Coaxial cables may be used for transmitting electrical signals, especially in the radio frequency, RF, range, e.g. for supplying telecommunications devices with signals in a frequency range between some MHz (Megahertz) up to several GHz (Gigahertz). For this purpose, the inner conductor and the outer conductor comprise or are made of an electrically conductive material such as e.g. copper.

[0004] Although especially for RF signals the penetration depth of electrical currents associated with the RF signals is comparatively low due to the skin effect, whereby a correspondingly low material thickness would be required for properly guiding the RF currents within the electrical conductors of conventional cables, the inner and/or outer conductor of conventional coaxial cables nevertheless usually comprise a comparatively large material thickness or wall thickness, respectively, which is particularly larger than required from an RF signal transmission standpoint, thus requiring large amounts of costly resources such as copper.

Summary

[0005] Consequently, it is an object of the present invention to provide an improved coaxial cable and an improved method of manufacturing a coaxial cable which avoid the abovementioned disadvantages of prior art.

Brief description of the figures

[0006] According to the present invention, regarding the coaxial cable, this object is achieved by arranging at least one stress absorbing element for absorbing mechanical stress radially between said inner conductor and said outer conductor. The at least one stress absorbing element can absorb mechanical stress applied to the cable thus protecting the inner conductor from excessive mechanical stress that would e.g. lead to a destruction of the inner conductor. This way, it is possible to reduce a material thickness for both the outer conductor and the inner conductor thus saving precious resources such as copper material and also reducing the weight of the cable per unit length.

[0007] Particularly, the at least one stress absorbing element may absorb mechanical stresses of the following types: 1. a 360° radial force which may e.g. be applied to the cable or its components during a manufacturing process, especially during a manufacturing process of an optional dielectric member of the cable, 2. a radial force along a (single) axis, which e.g. corresponds with a crush resistance of the cable, for instance if the cable is squeezed between parallel plates, and 3. bending.

[0008] In conventional coaxial cables, especially the inner conductor is much more robust (i.e., has a higher material thickness) than required from an RF signal transmission point of view to handle the aforementioned stress scenarios, particular cases 1. and 2. (where the mechanical stress tends to concentrate in the center of the cable), which wastes copper material and leads to an unnecessary high cable weight. These issues are advantageously addressed by the principle according to the embodiments thus enabling to save precious conductor material and at the same time reducing cable weight, while maintaining mechanical stability and stress resilience of the cable.

[0009] According to an embodiment, said stress absorbing element comprises or is made of an electrically isolating material, whereby advantageously an electrical isolation between the inner conductor and the outer conductor of the cable is attained, while at the same time absorbing mechanical stress and e.g. protecting the inner conductor therefrom. Alternatively or additionally, electrically insulating material may also be used to isolate the inner conductor from the outer conductor, e.g. in form of a dielectric layer radially inside the outer conductor.

[0010] According to a further embodiment, said stress absorbing element comprises or is made of a material which comprises a yield stress Rp0.2 of about 20 Newton per square millimeter, N/mm^2, or greater, preferably about 25 N/mm^2 or greater, which enables to provide a cable configuration with a particularly high stability.

[0011] According to a further embodiment, said stress absorbing element comprises or is made of a solid plastic material, particularly polyethylene or polypropylene, which reduces costs and enables an efficient manufacturing process, while providing a good mechanical stability required for absorbing mechanical stress.

[0012] According to a further embodiment, said stress absorbing element comprises a tubular, e.g. hollow circular cylindrical, shape with a basically annular shaped cross-section, wherein said cross-section has an area of at least 10 square millimeter, mm^2, preferably at least 15 mm^2. The hollow circular cylindrical shape is arranged radially between the inner and outer conductor, whereby a coaxial configuration of said conductors and the stress absorbing element is attained.

[0013] According to further embodiments, other components may optionally be provided radially between the stress absorbing element and the inner conductor and/or radially between the stress absorbing element and the outer conductor.

[0014] According to a further embodiment, said stress absorbing element comprises a geometric moment of inertia of about 185 mm^4 or greater, which ensures a suf-

ficient rigidity and stability for a wide variety of applications of the cable.

[0015] According to a further embodiment, said inner conductor comprises tubular shape, which provides an increased radially outer surface as compared with inner conductors of the solid wire type, thus effecting a comparatively low electrical resistance and comparatively low current densities.

[0016] According to a further embodiment, said stress absorbing element also comprises tubular shape, wherein preferably a ratio of a radial wall thickness of said stress absorbing element and said inner conductor ranges between 30:1 and 4:1, preferably between 20:1 and 5:1. Thereby, a particularly rugged and yet lightweight configuration is attained, as compared to conventional coaxial cables. However, other values for the ratio of radial wall thickness are also possible according to further embodiments.

[0017] According to a further embodiment, an adhesive layer is arranged radially between said inner conductor and said stress absorbing element, whereby a further stabilization of the involved cable components relative to each other is attained. Particularly, the adhesive layer may firmly couple the inner conductor to the stress absorbing element to e.g. also prevent an axial displacement of these components with respect to each other, which may e.g. arise from mounting the cable in a vertical arrangement.

[0018] According to an embodiment, said adhesive layer has a comparatively small layer thickness, particularly a layer thickness of 0.5 millimeter or less, preferably of 0.2 millimeter or less.

[0019] According to a further embodiment, said adhesive layer may comprise or consist of a polymer material, e.g. an EVA (Ethylene-vinyl acetate) copolymer.

[0020] According to a further embodiment, a dielectric layer is arranged radially between said stress absorbing element and said outer conductor. According to a variant, the cable comprises at least one dielectric layer, which preferably coaxially surrounds the inner conductor, wherein the dielectric may e.g. comprise air or a plastic material. According to an embodiment, said dielectric layer may comprise Polyethylene (PE) material, particularly foamed PE material.

[0021] According to an embodiment, said outer conductor is a corrugated tube, preferably comprising copper or made of copper, which facilitates bending of the cable. At the same time, the inner conductor is protected from inadmissible mechanical stress that could result from such bending by means of the stress absorbing element.

[0022] A further solution to the object of the present invention is provided by a method of manufacturing a coaxial cable, comprising the steps of: providing an inner conductor and an outer conductor which is arranged radially outside of said inner conductor and which is electrically isolated from said inner conductor, and providing at least one stress absorbing element for absorbing mechanical stress radially between said inner conductor and said outer conductor.

[0023] Further embodiments and advantages are provided by the dependent claims.

Brief description of the figures

[0024] Further features, aspects and advantages of the present invention are given in the following detailed description with reference to the drawings in which:

Figure 1 schematically depicts a cross-sectional view of a cable according to a first embodiment,

Figure 2 schematically depicts a cross-sectional view of a cable according to a second embodiment,

Figure 3 schematically depicts a cross-sectional view of a cable according to a third embodiment,

Figure 4 schematically depicts a cross-sectional view of a cable according to a fourth embodiment, and

Figure 5 schematically depicts a simplified flow-chart of a method according to an embodiment.

Description of the embodiments

[0025] Figure 1 schematically depicts a cross-sectional view of a coaxial cable 100 according to an embodiment. The cable 100 comprises an inner conductor 110 and an outer conductor 120 which is arranged radially outside of the inner conductor 110. The inner conductor 110 and/or the outer conductor 120 may comprise copper material or may be made of copper material, particularly pure copper.

[0026] According to the principle of the embodiments, at least one stress absorbing element 130 for absorbing mechanical stress is arranged radially between the inner conductor 110 and the outer conductor 120. I.e., the at least one stress absorbing element 130 is placed radially outside the inner conductor 110 and radially inside the outer conductor 120.

[0027] The at least one stress absorbing element 130 can absorb mechanical stress applied to the cable 100 thus protecting the inner conductor 110 from excessive mechanical stress that would e.g. lead to a destruction of the inner conductor 110. This way, it is possible to reduce a material thickness for the inner conductor 110 thus saving precious resources such as copper material and also reducing the weight of the cable 100 per unit length.

[0028] Particularly, the at least one stress absorbing element 130 may absorb mechanical stresses of the following types: 1. a 360° radial force which may e.g. be applied to the cable 100 or its components during a manufacturing process, especially during a manufacturing

process of an optional dielectric member (not shown in Fig. 1) of the cable, 2. a radial force along a (single) axis, which e.g. corresponds with a crush resistance of the cable 100, for instance if the cable 100 is squeezed between parallel plates, and 3. Bending, which e.g. regularly occurs during deployment of the cable 100 in the field.

[0029] Optionally, an adhesive layer 140 may be provided radially between the inner conductor 110 and the stress absorbing element 130, whereby a further stabilization of the involved cable components relative to each other is attained. Particularly, the adhesive layer 140 may firmly couple the inner conductor to the stress absorbing element to e.g. also prevent an axial displacement of these components with respect to each other, which may e.g. arise from mounting the cable in a vertical arrangement. Moreover, the adhesive layer 140 may be provided for sealing the inner conductor 110.

[0030] According to an embodiment, said adhesive layer 140 has a comparatively small layer thickness (as seen in a radial direction), particularly a layer thickness of 0.5 millimeter or less, preferably of 0.2 millimeter or less.

[0031] According to a further embodiment, said adhesive layer 140 may comprise or consist of a polymer material, e.g. an EVA (Ethylene-vinyl acetate) copolymer.

[0032] According to an embodiment, said stress absorbing element 130 comprises or is (completely) made of an electrically isolating material, whereby advantageously an electrical isolation between the inner conductor 110 and the outer conductor 120 of the cable is attained, while at the same time absorbing mechanical stress and e.g. protecting the inner conductor 110 therefrom.

[0033] According to a further embodiment, said stress absorbing element 130 comprises or is made of a material which comprises a yield stress Rp0.2 of about 20 Newton per square millimeter, N/mm^2, or greater, preferably about 25 N/mm^2 or greater, which enables to provide a cable configuration with a particularly high stability.

[0034] According to a further embodiment, said stress absorbing element 130 comprises or is made of a solid plastic material, particularly polyethylene or polypropylene, which reduces costs and enables an efficient manufacturing process, while providing a good mechanical stability required for absorbing mechanical stress.

[0035] According to a further embodiment, said stress absorbing element comprises a tubular, e.g. hollow circular cylindrical, shape with a basically annular shaped cross-section, as depicted by Fig. 1, wherein said cross-section has an area of at least 10 square millimeter, mm^2, preferably at least 15 mm^2. As can be seen from Fig. 1, the hollow circular cylindrical shape is arranged radially between the inner and outer conductors 110, 120, whereby a coaxial configuration of said conductors 110, 120 and the stress absorbing element 130 is attained.

[0036] According to further embodiments, other components may optionally be provided radially between the stress absorbing element 130 and the inner conductor 110 and/or radially between the stress absorbing element 130 and the outer conductor 120, which is, however, not shown in Fig. 1.

[0037] According to a further embodiment, said stress absorbing element comprises a geometric moment of inertia of about 185 mm^4 or greater, which ensures a sufficient rigidity and stability for a wide variety of applications of the cable 100.

[0038] According to a further embodiment, said inner conductor 110 comprises tubular shape, cf. Fig. 1, which provides an increased radially outer surface as compared with inner conductors of the solid wire type.

[0039] According to a further embodiment, said stress absorbing element 130 also comprises tubular shape, wherein a ratio of a radial wall thickness (measured in a radial direction) of said stress absorbing element 130 and said inner conductor ranges between 30:1 and 4:1, preferably between 20:1 and 5:1. Thereby, a particularly rugged and yet lightweight configuration is attained, as compared to conventional coaxial cables.

[0040] According to a further embodiment 100a of the cable, which is depicted by Fig. 2, a dielectric layer 150 is arranged radially between said stress absorbing element 130 and said outer conductor 120. Note that an optional adhesive layer 140 as depicted by Fig. 1 with a dashed line is omitted in Fig. 2 for the sake of clarity.

[0041] According to a further embodiment, the dielectric layer 150 between the stress absorbing element 130 and the outer conductor 120 may comprise Polyethylene (PE) material, particularly foamed PE material.

[0042] According to an embodiment, said outer conductor 120 is a corrugated tube, preferably comprising copper or made of copper.

[0043] According to yet another embodiment 100b, which is depicted by Fig. 3, the cable 100b may comprise an outer jacket 160. The outer jacket 160 may comprise or may be made of an electrically insulating material such as a PE material. Evidently, the cables 100, 100a of Fig. 1, 2 may, according to some embodiments, also comprise such an outer jacket 160.

[0044] In the following, exemplary values and/or value ranges for certain geometric parameters of the cable 100b according to some embodiments are provided.

[0045] According to a particularly preferred embodiment, the inner conductor 110, cf. Fig. 3, is made of copper and comprises a basically tubular shape, i.e. hollow circular cylinder shape. As an example, an outer diameter of the inner conductor 110 may range between about 5 mm and about 20 mm. According to a preferred embodiment, the outer diameter of the inner conductor 110 equals about 9 mm, wherein a wall thickness of said inner conductor 110 is about 0.1 mm. Such comparatively low wall thickness is advantageously enabled by the stress absorbing element 130 according to the embodiments.

[0046] According to a further preferred embodiment, the outer diameter of the stress absorbing element 130, which presently comprises PE material, equals about 10

mm, with a wall thickness of about 1 mm.

[0047] According to a further preferred embodiment, the outer conductor 120 may be a corrugated copper tube, and an outer diameter of said outer conductor 120 may equal about 25 mm.

[0048] According to a further preferred embodiment, the outer jacket 160 comprises PE material and has an outer diameter of about 28 mm.

[0049] Figure 4 depicts a further embodiment 100c of a coaxial cable, wherein the stress absorbing element 130 is arranged radially between two tubular layers 150a, 150b of dielectric material such as e.g. PE foam material. I.e., in this embodiment, the inner conductor 110 is surrounded radially outside with a first PE foam layer 150a, and the stress absorbing element 130 is surrounded radially outside with a second PE foam layer 150b.

[0050] According to further embodiments, other materials than e.g. PE foam may be used for forming one or more of the dielectric layer(s) 150a, 150b, for example air.

[0051] By using the stress absorbing element 130 according to the embodiments, the dimensions (especially, the outer diameter and/or the wall thickness) of the inner conductor 110 may primarily be chosen depending on requirements of RF signal transmissions (such as frequency (range), current density), wherein one or few multiples of the skin depth at a considered operating frequency (e.g., a center operating frequency) are sufficient from an RF signal transmission point of view, as the penetration depth of RF currents is usually comparatively low (and frequency dependent, as is well known to the skilled man). Hence, the use of copper material (or other electrically conductive material especially for constructing the inner conductor 110) may advantageously be restricted to what is required for said RF signals to be transmitted over the cable 100, 100a, 100b, 100c and is especially not required to be chosen depending on a desired mechanical stability of the cable, as this issue is dealt with by the stress absorbing element 130 according to the embodiments. This enables to save conductor material for the inner conductor 110 and reduces the weight of the cable. Advantageously, the stress absorbing element 130 absorbs mechanical stress applied to the cable 100, 100a, 100b, 100c and prevents the radially inner components of the cable (as seen from the stress absorbing element 130), especially the inner conductor 110, to support such stress absorbing function. This advantageously allows to design the inner conductor 110 in an optimized way regarding RF signal transmission properties, without the requirement of adding electrically conductive material due to mechanical stability reasons, which added material would not even contribute to conducting RF currents in view of the skin effect.

[0052] To summarize, the principle according to the embodiments advantageously enables to significantly reduce the content of electrically conductive material, e.g. copper, thus also reducing weight and cost of the cable, without any impact on the RF signal transmission performance of the cables. Further, in view of the reduced copper content, cables according to the embodiments would be less attractive to thieves.

[0053] A further solution to the object of the present invention is provided by a method of manufacturing a coaxial cable, comprising the steps of: providing an inner conductor and an outer conductor which is arranged radially outside of said inner conductor and which is electrically isolated from said inner conductor, and providing at least one stress absorbing element for absorbing mechanical stress radially between said inner conductor and said outer conductor.

[0054] Figure 5 schematically depicts a flow-chart of an embodiment of said method. In step 200, the inner conductor 110 (Fig. 1) is provided, in step 210, the outer conductor 120 is provided, and in step 220, the stress absorbing element 130 (Fig. 1) is provided. Note that the precise sequence of these steps 200, 210, 220 is not necessarily as exemplarily mentioned above with reference to Fig. 5. Rather, according to some embodiments, e.g. steps 200, 210, 220 may substantially be performed simultaneously or in any other sequence.

[0055] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

[0056] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

Claims

1. Coaxial cable (100) comprising an inner conductor (110) and an outer conductor (120) which is arranged radially outside of said inner conductor (110) and which is electrically isolated from said inner conductor (110), wherein at least one stress absorbing element (130) for absorbing mechanical stress is arranged radially between said inner conductor (110)

and said outer conductor (120).

2. Cable (100) according to claim 1, wherein said stress absorbing element (130) comprises or is made of an electrically isolating material.

3. Cable (100) according to one of the preceding claims, wherein said stress absorbing element (130) comprises or is made of a material which comprises a yield stress Rp0.2 of about 20 Newton per square millimeter, N/mm^2, or greater, preferably about 25 N/mm^2 or greater.

4. Cable (100) according to one of the preceding claims, wherein said stress absorbing element (130) comprises or is made of a solid plastic material, particularly polyethylene or polypropylene.

5. Cable (100) according to one of the preceding claims, wherein said stress absorbing element (130) comprises a tubular shape with a basically annular shaped cross-section, wherein said cross-section has an area of at least 10 square millimeter, mm^2, preferably at least 15 mm^2.

6. Cable (100) according to one of the preceding claims, wherein said stress absorbing element (130) comprises a geometric moment of inertia of about 185 mm^4 or greater.

7. Cable (100) according to one of the preceding claims, wherein said inner conductor (110) comprises tubular shape.

8. Cable (100) according to claim 7, wherein said stress absorbing element (130) also comprises tubular shape, and wherein a ratio of a radial wall thickness of said stress absorbing element (130) and said inner conductor (110) ranges between 30:1 and 4:1, preferably between 20:1 and 5:1.

9. Cable (100) according to one of the preceding claims, wherein an adhesive layer (140) is arranged radially between said inner conductor (110) and said stress absorbing element (130).

10. Cable (100) according to one of the preceding claims, wherein a dielectric layer (150) is arranged radially between said stress absorbing element (130) and said outer conductor (120).

11. Cable (100) according to one of the preceding claims, wherein said outer conductor (120) is a corrugated tube, preferably comprising copper or made of copper.

12. Method of manufacturing a coaxial cable (100), comprising the steps of: providing an inner conductor (110) and an outer conductor (120) which is arranged radially outside of said inner conductor (110) and which is electrically isolated from said inner conductor (110), and providing at least one stress absorbing element (130) for absorbing mechanical stress radially between said inner conductor (110) and said outer conductor (120).

13. Method according to claim 12, wherein said stress absorbing element (130) comprises or is made of a material which comprises a yield stress Rp0.2 of about 20 Newton per square millimeter, N/mm^2, or greater, preferably about 25 N/mm^2 or greater.

14. Method according to one of the claims 12 to 13, wherein said stress absorbing element (130) comprises a tubular shape with a basically annular shaped cross-section, wherein said cross-section has an area of at least 10 square millimeters, mm^2, preferably at least 15 mm^2.

Fig. 1

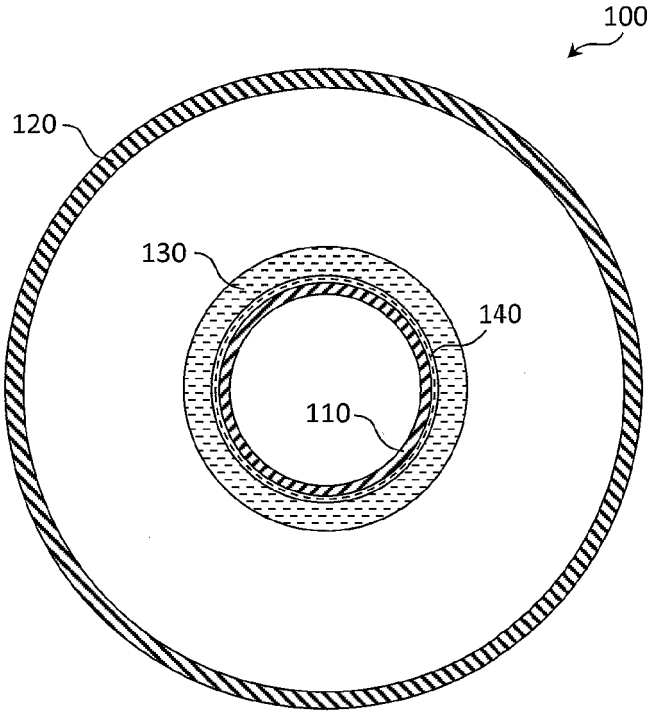


Fig. 2

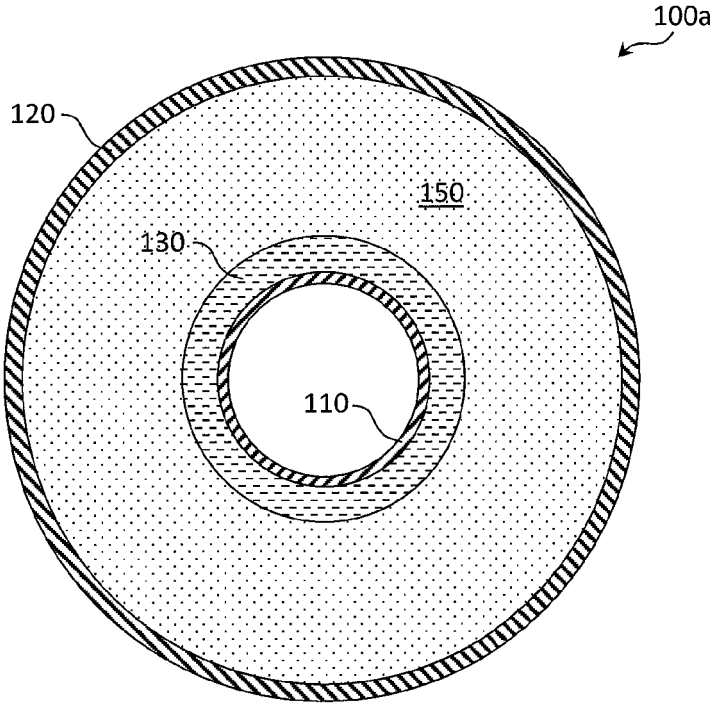


Fig. 3

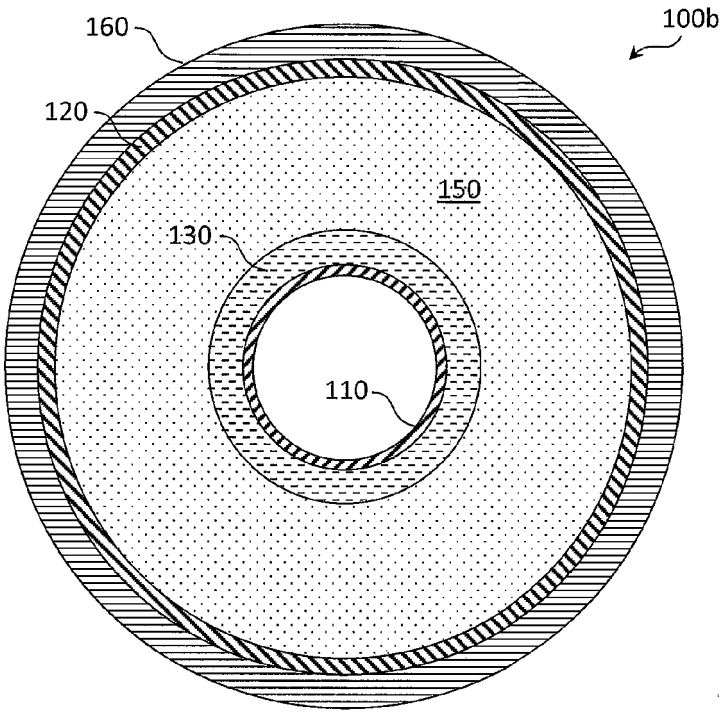


Fig. 4

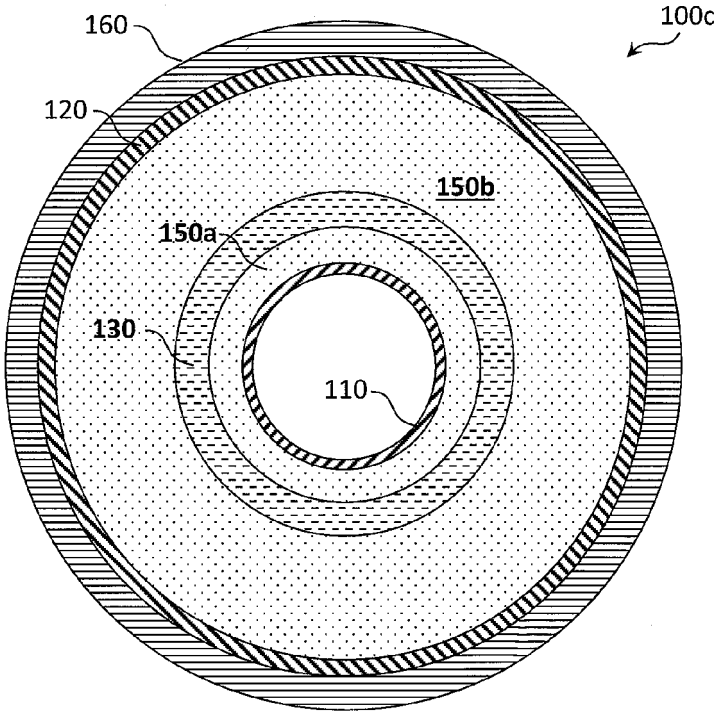
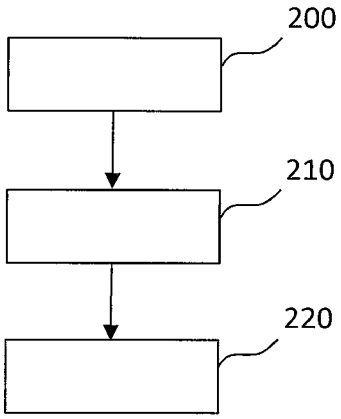


Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 2824

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

H01B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	12 January 2017	Salm, Robert

CATEGORY OF CITED DOCUMENTS

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12-01-2017

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