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(54) Pre-product for a dry transformer high voltage coil

(57) The invention is related to a pre-product (90) for a dry transformer high voltage coil (100), comprising at least two radially adjacent layers (12, 92, 94) of a wound electrical conductor (14, 16, 18) with an interim laminar insulation layer (72) inbetween, wherein the interim insulation layer (72) is foreseen to be transformed to a final insulation layer (102) by curing process. The interim insulation layer (72) comprises an inner (76) and two outer (32, 42, 62, 80) insulation layers, wherefrom the inner one (76) is of hard consistency and the outer ones (32, 42, 62, 80) are of soft consistency. The invention is also related to a method for manufacturing a dry transformer high voltage coil (100).

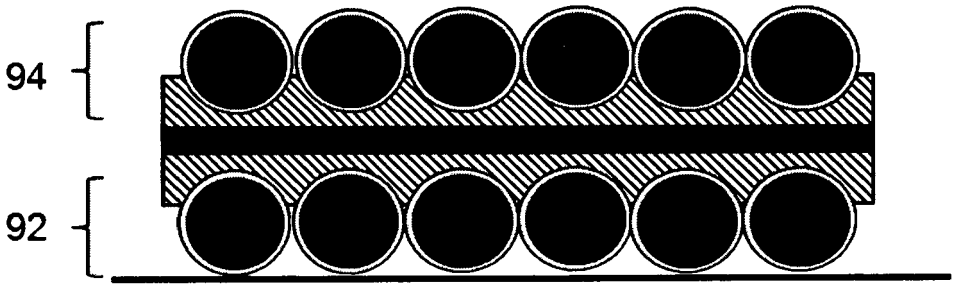

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Fig. 7

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Description

[0001] The invention is related to a pre-product for a dry transformer high voltage coil, comprising at least two radially adjacent layers of a wound electrical conductor with an interim laminar insulation layer inbetween, wherein the interim insulation layer is foreseen to be transformed to a final insulation layer by curing process.

[0002] It is known that coils for dry transformers in high voltage applications, for example with a rated voltage in the range of 6kV to 36kV, comprise an electrical conductor, which is wound layer wise in radially adjacent layers around a winding axis. The axial winding direction typically changes inbetween radially adjacent winding layers so that a meander-like winding scheme is gained. Thus during operation of such a coil a voltage difference inbetween adjacent layers occurs, which is lowest, at this axial end of a layer, where the conductor is fed up to the radially above laying layer and which is highest at the axial opposite end of the respective layer.

[0003] In order to avoid any electrical breakdown inbetween adjacent layers during operation of the coil, it is usual to provide an additional laminar insulation layer inbetween. This is for example made from a band-like wound prepreg material. Prepreg is a resin impregnated band material wherein the resin is in B-stage. So the resin respectively the band material is of harder consistency, wherein it has to become transferred to its final stage by a curing process at for example 150°C - 170°C. During this curing process the resin is melting back into a liquid state again and solidifies into a crystalline structure with extremely hard consistency. So an interim insulation layer is transformed to a final insulation layer by a curing process.

[0004] In order to improve the insulation ability of such an additional insulation layer the number of voids respectively cavities, which are not filled with resin, has to be reduced as much as possible to avoid partial discharge.

[0005] Disadvantageously within the state of the art is that a wound interim insulation layer typically comprises several voids especially in the wedge-shaped areas inbetween adjacent conductors within the same layer. Thus during the curing process there is not sufficient melted resin for filling the whole space inbetween the wound conductors and the quality of the final insulation layer is reduced therewith.

[0006] It is objective of the invention to provide a pre-product for a dry transformer high voltage coil with interim laminar insulation layer inbetween adjacent layers of conductors, which affords the manufacturing of a dry transformer high voltage coil with improved insulation layer by a curing process.

[0007] The problem is solved by a pre-product for a dry transformer high voltage coil of the aforementioned kind. This is characterized in that the interim insulation layer comprises an inner and two outer insulation layers, wherefrom the inner one is of hard consistency and the outer ones are of soft consistency.

[0008] Basic idea of the invention is to reduce the amount of voids by providing outer insulation layers with a soft consistency. So the conductor loops which are wound on an outer layer with soft consistency are embedded therein, preferably with half of their diameter. Due to the embedding also the wedge shaped areas inbetween the conductors are filled with the material of soft consistency in an advantageous way. After curing the soft material it will be of hard consistency and suitable insulation material for the insulation layer of the coil.

[0009] In order to ensure an electrically required minimum insulation thickness inbetween radially adjacent layers of conductors the interim laminar insulation layer comprises an inner insulation layer of hard consistency which is not considerably caveable so that its thickness is not reduced by the winding process whilst that a radial pressure is applied. An outer insulation layer of soft consistency is foreseen on both sides of the inner layer so that as well conductors which are under the interim insulation layer as conductors which are above the interim insulation layers are embedded therein.

[0010] Thus the number of voids in the interim insulation layer of the pre-product for a coil is reduced in an advantageous way and the number of voids in the cured final insulation layer therewith. The insulation ability of such a layer is improved in an advantageous way.

[0011] According to a further variant of the invention the consistency of the material of the inner insulation layer is as hard, that its thickness profile is not considerably caved while winding the adjacent layer of electrical conductors thereon during manufacturing process. An electrically required minimum insulation thickness inbetween adjacent layer of conductors is ensured therewith. Dependent on the electrical requirements it can be useful to adapt the thickness of the inner insulation layer along the axial length of the coil so that a wedge shaped cross section of the insulation layer is formed.

[0012] According to a further variant of the invention that the consistency of the material of the outer insulation layers is as soft that its thickness profile is nearly form-locking caved while the adjacent layer of conductors are wound thereon during manufacturing process. The coil is manufactured from the radial inner layers of conductors respectively insulation to the radial outer layers. So a layer of conductors is embedded into an outer insulation layer and afterwards an outer insulation layer is applied on the layer of conductors. In the ideal case each loop of the layer of conductors is totally embedded in outer insulation layers so that no voids are present in the interim insulation layer.

[0013] According to another embodiment of the invention the inner insulation layer comprises a foil. A foil has the advantage, that it has a constant thickness and is as hard, that the thickness is not significantly reduced when a pressure is applied thereon. A constant thickness even under pressure conditions affords a minimum insulation ability of the whole insulation layer. A suitable material for the foil is for example Kapton or PE wherein a suitable

thickness is in the range of 100 μm to 3.5mm.

[0014] According to a further embodiment of the invention the foil is covered with a coating that glues the single layers of the interim insulation layer together during the curing process. In contrast to resin a foil will not be molten during a curing process. Thus it has to be ensured, that a void-free adhesion of the foil with the both adjacent outer layers is gained. A suitable material for glue is for example resin-based, preferably resin in 'B' stage, what means, that it is in a flexible solid state wherein after remelting the resin in 'B' stage by a curing process a hardening process is initiated. Prepreg is a band-like material with resin in the 'B' stage.

[0015] According to another embodiment of the invention the outer insulation layers have a varying thickness profile corresponding roughly to the outer shape of the layer of conductors to be embedded therein. The cross section of a typical electrical conductor is round so that a helical wedge-shaped area inbetween adjacent loops of conductors is built. Accordingly the shape of the not yet impressed outer insulation layer is thicker in the helical wedge-shaped area. In this case the deformation of the outer insulation layer is not as high if the layer of conductors is wound thereon.

[0016] According to a further aspect of the invention the outer insulation layers comprise a resin impregnateable and/or resin impregnated material. In order to reduce the number of voids within the insulation material the resin is in the liquid state wherein the resin might become applied during the winding process of the transformer coil or shortly before.

[0017] According to another embodiment of the invention the outer insulation layers comprise polyester felt. This is a material with a sufficient soft consistency which additionally has the ability to suck up liquid resin like a sponge. Thus the number of voids in the outer insulation layer is reduced in an advantageous way.

[0018] According to another embodiment of the invention the resin impregnateable material respectively the polyester felt is of different color than the resin for impregnation. This facilitates an optical control of the quality of impregnation of the polyester felt. In case that the Polyester felt is of white color and the resin is of black color the impregnated and not impressed polyester felt would be of dark grey color. Any areas of poor impregnation would be white or light gray. Of course also other combinations of colors with a preferably high contrast are suitable.

[0019] According to another embodiment of the invention the interim laminar insulation layer has been impregnated at least in part during applying it on the layer of electrical conductors thereunder. Thus it is ensured that potential voids in the edge are of inner and outer insulation layers for example are completely filled with liquid resin. In case that there is more resin than voids to be filled the dispensable resin is remaining on the surface of the coil for impregnating further layers which will be applied thereon.

[0020] The problem is also solved by a method for manufacturing a dry transformer high voltage coil, comprising the step of applying heat on a pre-product for a dry transformer high voltage coil according to the invention. During such a curing process a temperature of for example 200°C is applied for 2 hours so that the resin can be completely hardened therewith. After the curing process the formally soft outer insulation layer and the inner layer are combined to a consistent insulation layer of hard consistency.

[0021] The problem of the invention is additionally solved by a dry transformer high voltage coil which has been manufactured according to the aforementioned method of the invention. Thus the quality of the insulation layers is improved by reducing the number of voids therein.

[0022] Further advantageous embodiments of the invention are mentioned in the dependent claims.

[0023] The invention will now be further explained by means of an exemplary embodiment and with reference to the accompanying drawings, in which:

Figure 1 shows an exemplary pre-product for a dry transformer high voltage coil in 1 st stage,
Figure 2 shows an exemplary pre-product for a dry transformer high voltage coil in 2nd stage,
Figure 3 shows an exemplary pre-product for a dry transformer high voltage coil in 3rd stage,
Figure 4 shows an exemplary pre-product for a dry transformer high voltage coil in 4^{th} stage,
Figure 5 shows an exemplary pre-product for a dry transformer high voltage coil in 5th stage,
Figure 6 shows an exemplary pre-product for a dry transformer high voltage coil in 6tht stage,
Figure 7 shows an exemplary pre-product for a dry transformer high voltage coil in final stage,
Figure 8 shows an exemplary dry transformer high voltage coil

[0024] Figure 1 shows an exemplary pre-product for a dry transformer high voltage coil in 1st stage of its production in a sketch 10. A layer 12 of conductor loops 14, 16, 18 is spirally wound around a winding axis 22 on a bobbin 22.

[0025] Figure 2 shows an exemplary pre-product for a dry transformer high voltage coil in 2nd stage of its production in a sketch 30. Here an outer insulation layer 32 of soft consistency, in this case strip-shaped polyester felt, has been wound around the layer of conductors. Since the material of the outer insulation layer 32 is soft, the outer shape of the layer of conductors is caved therein.

[0026] Figure 3 shows an exemplary pre-product for a dry transformer high voltage coil in 3rd stage of its production in a sketch 40. Here the outer insulation layer 42 has been impregnated with a liquid resin also in the wedged areas inbetween the loops of conductors.

[0027] Figure 4 shows an exemplary pre-product for a

dry transformer high voltage coil in 4th stage of its production in a sketch 50. Here an inner insulation layer 52, in this case a polyester foil, has been applied on the impregnated outer insulation layer.

[0028] Figure 5 shows an exemplary pre-product for a dry transformer high voltage coil in 5th stage of its production in a sketch 60. An outer insulation 62 layer from polyester felt has been applied on the inner insulation layer.

[0029] Figure 6 shows an exemplary pre-product for a dry transformer high voltage coil in 6th stage of its production in a sketch 70. The outer insulation layer 72 from polyester felt has been impregnated with liquid resin.

[0030] Figure 7 shows an exemplary pre-product for a dry transformer high voltage coil in final stage of its production in a sketch 80. Here a second layer 94 of conductors has been wound around the insulation layer and the first layer 92 of conductors below. Of course a real coil might comprise significant more layers of electrical conductors and insulation layers inbetween.

[0031] Figure 8 shows an exemplary dry transformer high voltage coil in a sketch 100. Due to a curing process the interim insulation layer with its inner and two outer insulation layers is now converted into a consistent solid final insulation layer 102.

List of reference signs

[0032]

10	exemplary pre-product for a dry transformer high voltage coil in 1 st stage
12	fist layer of wound electrical conductors
14	first conductor loop of first layer
16	second conductor loop of first layer
18	third conductor loop of first layer
20	bobbin
22	axis of rotation
30	exemplary pre-product for a dry transformer high voltage coil in 2nd stage
32	outer insulation layer
40	exemplary pre-product for a dry transformer high voltage coil in 3rd stage
42	outer insulation layer impregnated with resin
50	exemplary pre-product for a dry transformer high voltage coil in 4th stage
52	inner insulation layer
60	exemplary pre-product for a dry transformer high voltage coil in 5th stage
62	outer insulation layer
70	exemplary pre-product for a dry transformer high voltage coil in 6th stage
72	interim insulation layer
74	outer insulation layer
76	inner insulation layer
78	outer insulation layer
90	exemplary pre-product for a dry transformer high voltage coil in final stage
92	fist layer of wound electrical conductors
94	second layer of wound electrical conductors
100	exemplary dry transformer high voltage coil
102	final insulation layer

Claims

1. Pre-product (90) for a dry transformer high voltage coil (100), comprising at least two radially adjacent layers (12, 92, 94) of a wound electrical conductor (14, 16, 18) with an interim laminar insulation layer (72) inbetween, wherein the interim insulation layer (72) is foreseen to be transformed to a final insulation layer (102) by curing process,
characterized in that
the interim insulation layer (72) comprises an inner (76) and two outer (32, 42, 62, 80) insulation layers, wherefrom the inner one (76) is of hard consistency and the outer ones (32, 42, 62, 80) are of soft consistency.

2. Pre-product for a dry transformer high voltage coil according to claim 1, **characterized in that** the consistency of the material of the inner insulation layer (76) is as hard, that its thickness profile is not considerably caved while winding the adjacent layer (12, 92, 94) of electrical conductors (14, 16, 18) thereon during manufacturing process.

3. Pre-product for a dry transformer high voltage coil according to claim 1 or 2, **characterized in that** the consistency of the material of the outer insulation layers (32, 42, 62, 80) is as soft that its thickness profile is nearly form-locking caved while winding the adjacent layer (12, 92, 94) of conductors (14, 16, 18) thereon during manufacturing process.

4. Pre-product for a dry transformer high voltage coil according any of the previous claims, **characterized in that** the inner insulation layer (76) comprises a foil.

5. Pre-product for a dry transformer high voltage coil according to claim 4, **characterized in that** the foil is covered with a coating that glues the interim insulation layer (72) together during the curing process.

6. Pre-product for a dry transformer high voltage coil according to any of the previous claims, **characterized in that** the outer insulation layers (32, 42, 62, 80) have a varying thickness profile corresponding roughly to the outer shape of the layer (12, 92, 94) of conductors (14, 16, 18) to be embedded therein.

7. Pre-product for a dry transformer high voltage coil according to any of the previous claims, **characterized in that** the outer insulation layers (32, 42, 62, 80) comprise a resin impregnateable and/or resin

impregnated material.

8. Pre-product for a dry transformer high voltage coil according to claim 7, **characterized in that** the outer insulation layers (32, 42, 62, 80) comprise polyester felt.

9. Pre-product for a dry transformer high voltage coil according to any of the previous claims, **characterized in that** the resin impregnateable material respectively the polyester felt is of different color than the resin for impregnation.

10. Pre-product for a dry transformer high voltage coil according to claim 7 to 9, **characterized in that** the interim laminar insulation layer (72) has been impregnated at least in part during applying it on the layer (12, 92, 94) of electrical conductors (14, 16, 18) thereunder.

11. Method for manufacturing a dry transformer high voltage coil (100), comprising the step of applying heat on a pre-product for a dry transformer high voltage coil (90) according to claim 1 to 10.

12. Dry transformer high voltage coil, **characterized in that** it has been manufactured according to the method of claim 11.

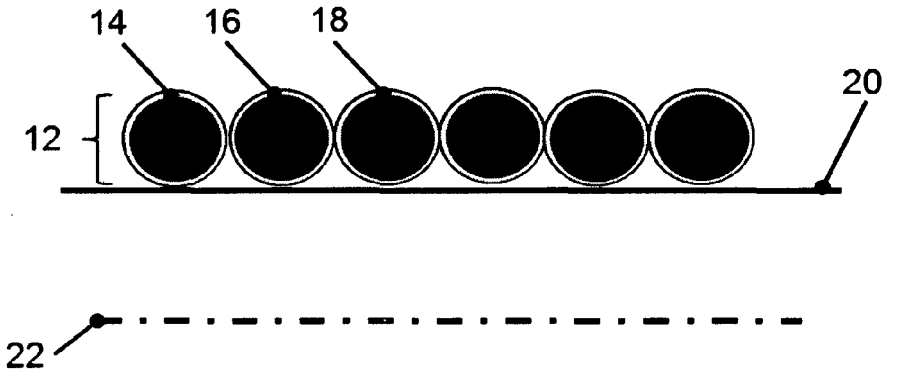

Fig. 1

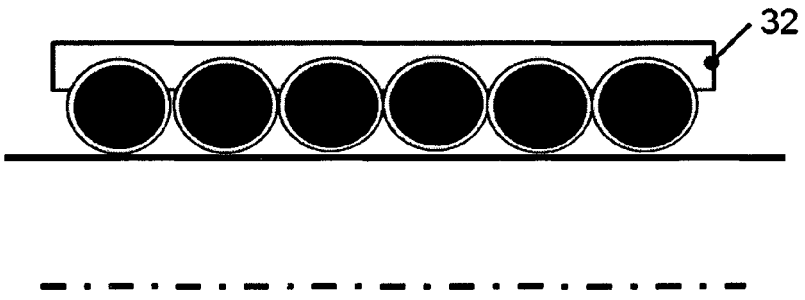

Fig. 2

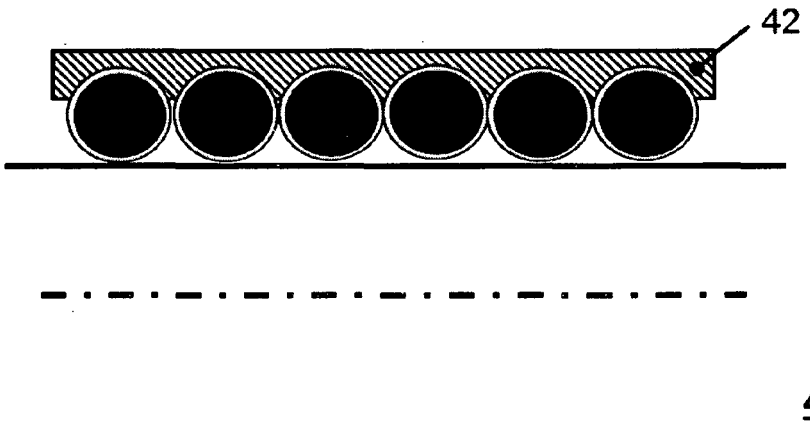

Fig. 3

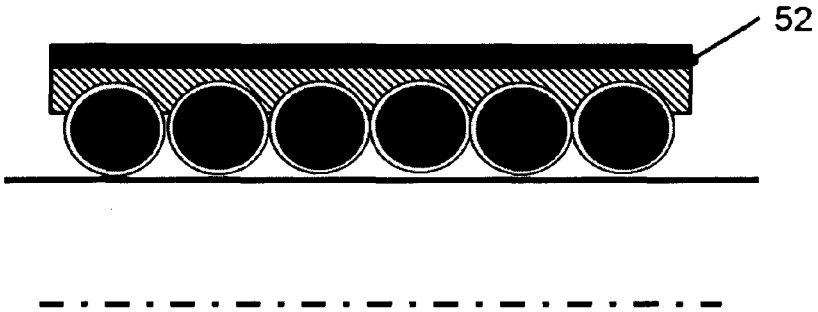

Fig. 4

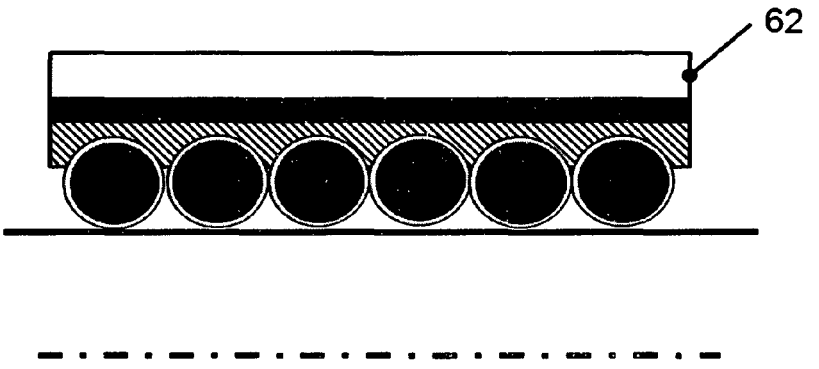

Fig. 5

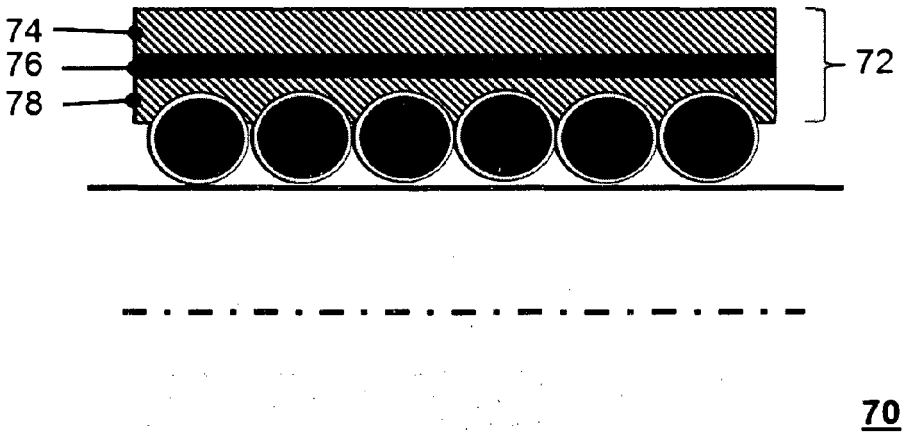

Fig. 6

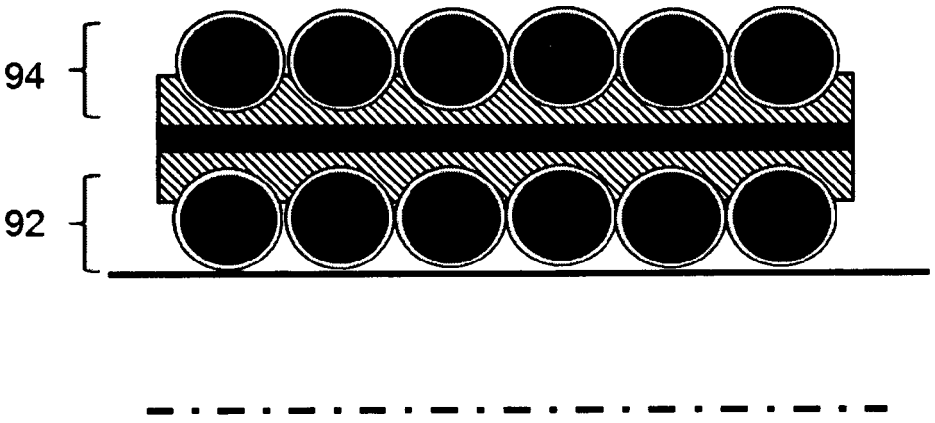

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Fig. 7

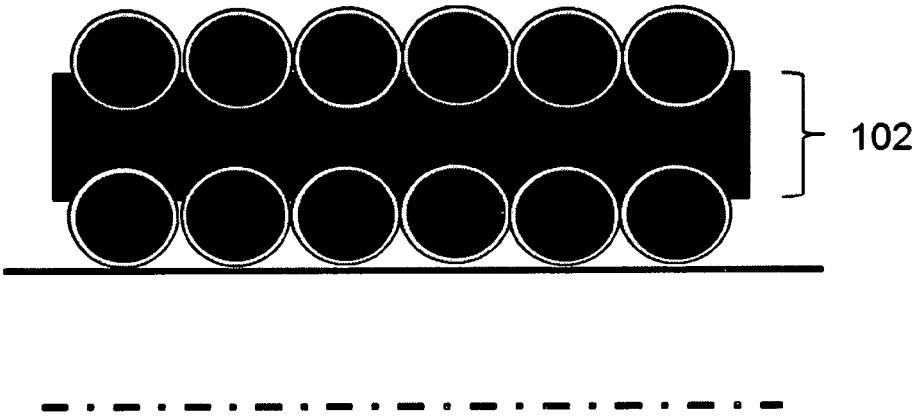

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Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 14 00 3469

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X	US 3 263 196 A (HUBERT REBER) 26 July 1966 (1966-07-26) * column 1, line 53 - column 2, line 4 * * column 3, line 27 - column 4, line 7 * * column 5, lines 53 - 69 * * figure 4 *	1-12	
A	US 2011/291791 A1 (WEBER BENJAMIN [DE] ET AL) 1 December 2011 (2011-12-01) * paragraphs [0002], [0004], [0006], [0024], [0025], [0037] - [0039] * * claims 1, 14 *	1-12	
A	EP 0 336 053 A2 (ANT NACHRICHTENTECH [DE]) 11 October 1989 (1989-10-11) * column 1, lines 1 - 9 * * column 2, lines 14 - 19 * * column 2, lines 34 - 51 * * column 3, lines 17 - 27 und 52 - 57 * * claims 1 - 3, 6, 7 * * figures 1, 2 *	1-12	TECHNICAL FIELDS SEARCHED (IPC) H01F H01B
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 April 2015	Van den Berg, G

CATEGORY OF CITED DOCUMENTS

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