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(71) Applicant: **ABB Schweiz AG**
5400 Baden (CH)

(72) Inventors:
- **MICHALIK, Adam**
  32-087 Bibice (PL)
- **ADAMCZYK, Bartlomiej**
  31-038 Kraków (PL)
- **WYSOCKI, Wojciech**
  31-271 Kraków (PL)
- **PIASECKI, Wojciech**
  31-347 Kraków (PL)
- **BANASZCZYK, Jedrzej**
  93-313 Lodz (PL)
- **SMUGALA, Dariusz**
  30-638 Kraków (PL)

(74) Representative: **Kransell & Wennborg KB**
P.O. Box 27834
115 93 Stockholm (SE)

(54) **ELECTRICAL DEVICE WITH GEL COMPOSITE INSULATION**

(57) The present disclosure relates to an electrical device (1) comprising a composite insulation (3) comprising an inorganic particulate filler impregnated with an oil-based thermo-reversible gel comprising a thickener, the gel being in solid form.

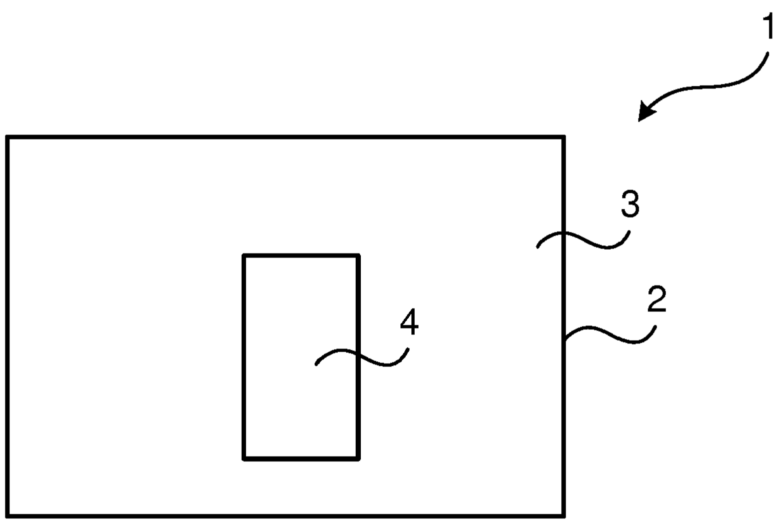

Fig. 1a

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an electrical device with electrical insulation of a composite material.

BACKGROUND

[0002] In general, there are two major groups of transformers based on the type of main insulation used: oil based and dry insulation. Each of these technologies have they own advantages and disadvantages. One drawback of the oil insulation is possible leakage of the oil, which creates environmental risks. Another issue is high flammability of the oil, which in case of e.g. transformer failure might lead to fire and explosions.

[0003] The dry technology, typically using epoxy, benefits from the lack of flammable liquids creating potential danger. For this reason, these transformers are usually used when fire and environmental safety are of special importance. Unfortunately, these transformers are much more expensive compared to their oil-filled counterparts. This is due to the different insulation medium and a complicated production process requiring usage of the moulding tools and/or careful controlling of the epoxy curing process.

[0004] Taking into account the increasing demand of the customers for more safe and environmentally friendly transformers, and constant pressure for cost reduction, new insulation technologies combining the safety benefits of the dry technology and the simpler, cheaper manufacturing process of oil transformers is desirable.

[0005] One way of obtaining this is by mixing the transformer oil with sand, as disclosed in GB 571,119. The sand provides mechanical support to the transformer during transportation and handling, and reduces the flammability of the insulation and the amount of oil needed. However, the risk of oil leakage and explosions remain at least to some extent.

SUMMARY

[0006] It is an objective of the present invention to provide an electrical device with an improved insulation which reduces the problems of the prior art. In accordance with the present invention, a composite material made from an inorganic particulate filler material, e.g. sand, and an oil-based thermo-reversible gel. Thus, a dry insulation is obtainable which can be easily provided in a similar way as a liquid insulation, by impregnating the filler with the gel in liquid form at a temperature which is above the transition temperature (gelling temperature) of the thermo-reversible gel. At the operating temperature of the electrical device, which is below the transition temperature of the gel, the insulation is essentially solid.

[0007] Advantages with using a gel instead of a liquid oil include reduced risk of leakage into the environment and reduced risk of splashing of hot or burning oil during an (unlikely) explosion due to e.g. transformer fault.

[0008] According to an aspect of the present invention, there is provided an electrical device comprising a composite insulation comprising an inorganic particulate filler impregnated with an oil-based thermo-reversible gel comprising a thickener, the gel being in solid form.

[0009] According to another aspect of the present invention, there is provided a method of encasing an electrical power device in a composite insulation. The method comprises forming an oil-based thermo-reversible gel by adding a thickener to an electrically insulating oil. The method also comprises filling the tank comprising the electrical power device with an inorganic particulate filler such that the electrical power device is surrounded by said filler. The method also comprises heating the formed thermo-reversible gel to a temperature which is above the transition temperature of the gel, whereby the gel transitions to its liquid form. The method also comprises pouring the heated gel into the filled tank, whereby the inorganic particulate filler is impregnated with the gel in liquid form to form the composite insulation. The method also comprises cooling the thermo-reversible gel to a temperature which is below the transition temperature of the gel, whereby the gel impregnating the filler transitions to its solid form, encasing the electrical power device in the solid composite insulation within the tank.

[0010] It is to be noted that any feature of any of the aspects may be applied to any other aspect, wherever appropriate. Likewise, any advantage of any of the aspects may apply to any of the other aspects. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following detailed disclosure, from the attached dependent claims as well as from the drawings.

[0011] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of "first", "second" etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Embodiments will be described, by way of example, with reference to the accompanying drawings, in which:

Fig 1a is a schematic block diagram in top view of an embodiment of an electrical device in the form of a power transformer in a composite insulation filled tank.

Fig 1b is a schematic block diagram in longitudinal section of an embodiment of a transformer with composite insulation around its primary winding.

Fig 2 is a schematic graph showing the complex viscosity at different temperatures for an oil based gel, where the gel is solid at temperatures below a transition temperature (corresponding to a knee in the graph), and liquid at temperatures above said transition temperature, in accordance with embodiments of the present invention.

Fig 3 is a schematic flow chart of an embodiment of the method of the present invention.

DETAILED DESCRIPTION

[0013] Embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments are shown. However, other embodiments in many different forms are possible within the scope of the present disclosure. Rather, the following embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Like numbers refer to like elements throughout the description.

[0014] The use of electrically insulating thermo-reversible gels are known for impregnating power cable insulation, where the gel can be made sufficiently soft and resilient to allow the cable to be flexible.

[0015] WO 97/04466 relates to a High-Voltage Direct Current (HVDC) power cable comprising an insulation of a plurality of permeable tapes wound around the conductor. An impregnating compound fills all voids among the tape layers. The impregnating compound has a very steep slope of change of viscosity characteristics, the viscosity being high with a solid gel type structure at temperatures equal to and below the maximum operating temperature of the cable and being low with a thin liquid type structure at higher temperatures at which impregnation takes place. Preferably, 95% of the impregnating compound consists of alkane chains with chain lengths above 15 carbon units but no more than 2% of the chains have chain lengths above 28 carbon units.

[0016] WO 99/33066 discloses a dielectric gelling composition, exhibiting a thermo-reversible liquid-gel transition at a transition temperature, wherein the gel comprises an oil and a gelator with a block copolymer. The gelling composition is used as an impregnant in an insulated direct current (DC) cable having at least one conductor and an impregnated insulation system. The insulation system comprises a solid electrically insulating dielectric part with a porous, fibrous and/or laminated structure impregnated with the dielectric gelling composition.

[0017] US 6,391,447 relates to a method for manufacture of an electric device having at least one conductor and a porous, fibrous and/or laminated electrically insulating dielectric system comprising a solid electrically insulating part impregnated with a dielectric fluid, wherein the method comprises impregnating with a dielectric fluid, wherein a gelling additive is added to impart a high viscosity and elasticity to the fluid at conditions for which the device is designed to operate under.

[0018] However, none of these documents discloses a composite in accordance with the present invention. Rather, the inclusion of a particulate filler would be detrimental to the flexible properties of a cable.

[0019] Figure 1a illustrates an electrical device 1, here in the form of an electrical power device, here a transformer, 4 immersed in a composite insulation 3 within a transformer tank 2. The composite insulation 3 is as discussed herein, a composite between an oil-based thermo-reversible gel and an inorganic particulate filler, e.g. sand.

[0020] Figure 1b illustrates another embodiment of an electrical device 1 here in the form of a transformer 4, which may or may not be combined with the embodiment of figure 1a. The transformer 4 comprises a primary winding 5 which is immersed in the composite insulation 3 of the present disclosure, enclosed by a shell 6, the shell separating the primary winding 5 from the secondary winding 7. The primary winding 5 is wound around a transformer core 8, outside of the secondary winding 7 which is also wound around the core 8. The composite insulation 3 is as discussed herein, a composite between an oil-based thermo-reversible gel and an inorganic particulate filler, e.g. sand.

[0021] The electrical device 1 may comprise a transformer 4, e.g. as in any of the figures 1a and 1b, e.g. in the form of an instrument transformer or a power transformer, or any other type of voltage transformer, or a capacitor. However, the electrical device 1 may be any electrical device with solid insulation, and a bushing is only an example thereof. Other examples include, but are not limited to, instrument transformers, power transformers e.g. current and voltage transformers, capacitors and cable endings. In most oil insulated devices, the oil can be replaced with a composite insulation 3 as per the present invention. The insulation 3 may provide insulation to ground in the electrical device 1.

[0022] The operating voltage of the electrical device 1 may preferably be medium voltage (MV), up to 72 kV, but high voltage (HV) applications above 72 kV are possible as well. The insulating gel 4 may act as a major insulation (between the high potential and ground) of the electrical device 1.

[0023] The oil may be any electrically insulating oil, e.g. mineral oil, aromatic oil, ester oil and/or paraffinic oil, e.g. iso-paraffinic oil, or a mixture thereof.

[0024] The thickener may be a polymeric thickener e.g.

SEPTON styrene thermoplastic elastomer containing block copolymers - e.g. SEPTON™ 1000-SERIES (SEP), SEPTON™ 4000-SERIES (SEEPS) from Kuraray. As an example, a thickener comprising or consisting of SEEPS™ 4099 (a tri-block copolymer consisting of polystyrene-b-poly(ethylene-ethylene/propylene)-b-polystyrene) and/or SEP™ 1020 (a di-block copolymer consisting of polystyrene-b-poly(ethylene/propylene)) may be used. However, this is non-exhaustive and the skilled person recognizes that other polymeric thickeners may be used. The thickener may be present in an amount of at most 10 wt% of the gel (4), e.g. 1-5 wt%.

[0025] In some embodiments, the gel 4 may, in addition to the oil and thickener, one or several additives, such as an anti-oxidant as mentioned above, or any other additive may be added, e.g. up to 1 wt% of the gel 4. For instance, it has been realised that boron nitride (BN), e.g. 2D hexagonal BN (h-BN) improves the electrical properties of the gel, and reduces problems with oxidation. By suspending particles, e.g. nano-structures, of BN in the gel 4, the particles remain dispersed.

[0026] Figure 2 illustrates the change in viscosity over a temperature range of an oil-based gel which may be used in the composite insulation 3. The gel should have a high viscosity (be in its solid form) at operating temperatures of the electrical device 1 but should also have a relatively low viscosity (be in its liquid form) at a manufacturing temperature when the insulation 3 is formed by mixing/impregnating the particulate filler with the gel. This makes the gel thermo-reversible, being in a solid form below at temperatures below a transition temperature and in a liquid form at temperatures above said transition temperature, forming a knee in the viscosity curve of figure 2. In the example of figure 2, the gel has a complex viscosity above 10 Pa·s (is in its solid form) below about 50°C and a complex viscosity below 0.01 Pa·s (is in its liquid form) above about 90°C. The transition temperature may be within the range of 30-200°C.

[0027] The preferred viscosity of the gel 4 at the operating temperature of the electrical device 1, as well as the transition temperature and preferred viscosity of the gel when in liquid form (when the insulator (3) is repaired, may vary depending on the application. As an example, the gel may have a viscosity in solid form, e.g. below 90°C, of at least 10 Pa·s, and a viscosity in liquid form, e.g. above 110°C, of at most 0.1 Pa·s, e.g. for an operating temperature of the electrical device of 8o°C.

[0028] The gel of the composite insulation 3 is based on an insulating oil, e.g. mineral oil, ester oil and/or paraffinic oil, e.g. iso-paraffinic oil. The gel is formed by mixing of the oil with a polymeric thickener (e.g. thermoplastic rubber) at an elevated temperature (e.g. above about 100°C). The polymeric thickener thus dissolves in the oil. The gel increases its viscosity while cooling down until it has passed its transition temperature and becomes solid. The process is fully reversible. After heating up above the transition temperature, the gel returns to liquid form. The viscosity and transition temperature of the gel can be adjusted by the amount and type of thickener added to the oil. The more thickener, the higher transition temperature (corresponding to the knee in figure 2). The transition temperature can be adjusted depending on application and requirements of each particular device 1, to above or below the operating temperature of the device, typically above.

[0029] By using the composite insulation 3, the advantages of the traditional oil and dry technologies may be combined. The composite insulation 3 comprises or consists of the oil-based gel and particulate filler (sand) which is used as an inorganic filler. The gel is used as a main insulation matrix and is manufactured from the oil by addition of the thickener (belonging to the group of e.g. styrene thermoplastic elastomers, block copolymer, etc.). This results in the thermo-reversible gel which may be in solid or liquid form, depending on temperature. In both forms, the viscosities remain relatively stable in certain temperature ranges until the change of the phase appears. The solid and liquid zones are separated by the transition zone in which the viscosity of the substance significantly drops (forms a knee as in figure 2) and the gel undergoes the phase change.

[0030] In a first example embodiment, cf. figure 1b, the insulated part, e.g. High-Voltage (HV) transformer winding 5 of the electrical device 1 is placed in an insulating or conductive shell 6 made of polymeric material or metal. After that, the shell 6 containing the part 5 is filled with the filler in form of sand. In the next step, the whole arrangement filler filled shell and part is heated up over the transition temperature of the gel. Than the heated gel in liquid form is poured into the shell containing the filler sand and the part, and the liquid gel impregnates the filler and the part and fills the shell. In order to improve the impregnation and eliminate possible voids in the thus formed composite 3, the impregnation step might be performed under vacuum conditions. After the impregnation, the gel-filler mixture is cooled which leads to solidification of the gel and creation of solid gel-filler insulation composite 3.

[0031] In a second example embodiment, cf. figure 1a, the gel-filler composite insulation 3 insulates the active part 4 of a Medium-Voltage (MV) instrument transformer. The active part of the instrument transformer was placed in a plastic tank 2, filled with the filler (here sand) and finally impregnated with the oil-based gel in liquid form at a temperature of 140°C for 5 hours. Initially impregnation was done under vacuum for 1h and later it was continued in an oven. The impregnation gel consisted of Oil (Nynas NS100™) 99 wt%, and a thickener consisting of SEEPS™ 4099 (a tri-block copolymer consisting of polystyrene-b-poly(ethylene-ethylene/propylene)-b-polystyrene) 0.5 wt%, and SEP™ 1020 (a di-block copolymer consisting of polystyrene-b-poly(ethylene/propylene)) 0.5 wt% of the gel, both from Septon™.

[0032] In order to verify the arc fault behaviour of the gel-fill mixture of the second example embodiment, the following test was performed. Two electrodes were placed in the plastic tank 2 and filled with the composite insulation 3. In case of a reference sample, the common transformer oil was used as insulation material instead of the composite. Such prepared samples were subjected to an arc fault test. In case of the reference sample, performing of the test resulted in explosion leading to complete destruction of the tank 2, splashing of the oil in large radius around the experimental setup and contamination of the surrounding environment. In case of the gel-filler composite 3 sample, the result was completely different. The plastic tank 2 remained intact and the whole composite insulation 3 remained inside the tank. There was only visible a relatively small crater in the middle of the tank where the insulation 3 was burned. Only a small explosion was observed and no contamination of the environment resulted. The composite insulation 3 with gel in solid form thus absorbed most of the explosion and, in conformity with solid resin (e.g. epoxy) insulation, there is no splashing of combustive and polluting material.

[0033] The use of the composite insulator 3 of the present disclosure has numerous advantages to conventional insulation, including:

- Gel-filler insulation 3 has self-solidifying property providing leakage free operation, which is typical for dry eco-friendly transformers and do not create environmental risk.

- The gel-filler composite 3 behaviour during the internal arc fault and explosion is much safer compared to the typical solid epoxy insulation or oil insulation. As proven by experiments, gel-filler insulation has significantly lower flammability. Thus, the consequences of fire are less dangerous compared to normal oil. Moreover, the explosion is not accompanied by splash of the burning oil. Additionally, sand filler has the ability to extinguish the electric arc (similarly as in case of fuses).

- The gel absorbs a part of the explosion energy and thus consumes it for elastic deformation of the gel-filler composite 3. For this reason, the broken pieces of the device 1 or part 4 thereof are trapped in the elastic gel and do not pose a danger to the surroundings as is the case with epoxy insulation.

- The filler (e.g. sand) provides mechanical support of the device 1 or part 4 thereof during transportation and in the event of a short circuit.

- Application of the filler-gel composite 3 as winding 5 insulation may lead to reduction of the noise created by the device 1 due to the viscoelastic character of the gel.

- Simple waste management.

- Simpler manufacturing process, which eliminates risks of cracking of any solid insulation during curing process and thus decreases the potential risk of partial discharges. Such a manufacturing process will reduce the scrap rate.

- The phase changing nature of the gel allows for simple recycling of parts of the device 1, which could be done by heating of the gel to over the transition temperature. Alternatively, due to the elastic nature of the gel-filler composite 3, in most cases the parts could be recycled without heating of the insulation 3. This can reduce the scrap cost and the components of the failed devices could be reused.

- Encapsulation of windings 5 in a shell 6 filled with filler leads to significant reduction of the amount of gel needed. This entails a significant cost reduction of the composite insulation 3.

- The use of a shell 6 opens new possibilities for the design of the electric device 1, such as e.g. transformer. Particularly the shape of the outer surface of the winding shell 6 could be designed to ensure additional functionalities e.g. increased creepage distance between terminals or improvement of the heat evacuation. These could be achieved e.g. by creation of ribs or fins on the outer surface, allowing for better heat exchange or by using a shell material having increased heat conductivity.

- The technology is easy scalable to larger sizes and voltage levels.

[0034] Figure 3 is a schematic flow chart of an embodiment of the method of the present invention. The method is for encasing an electrical power device 4 or 5 in a composite insulation 3. The method comprises forming M1 an oil-based thermo-reversible gel by adding a thickener to an electrically insulating oil. The method also comprises filling M2 the tank 2 or 6 comprising the electrical power device 4 or 5 with an inorganic particulate filler such that the electrical power device is surrounded by said filler. The method also comprises heating M3 the formed M1 thermo-reversible gel to a temperature which is above the transition temperature of the gel, whereby the gel transitions to its liquid form. The method also comprises pouring M4 the heated M3 gel into the filled M2 tank, whereby the inorganic particulate filler is impregnated with the gel in liquid form to form the composite insulation 3. The method also comprises cooling M5 the thermo-reversible gel to a temperature which is below the transition temperature of the gel, whereby the gel impregnating the filler transitions to its solid form, encasing the electrical power device 4 in the solid composite insulation 3 within the tank 2.

[0035] In some embodiments of the present invention, the inorganic particulate filler comprises or consists of sand. Sand may be preferred as filler since it is easily obtainable and relatively cheap.

[0036] In some embodiments of the present invention, the thickener comprises a styrenic block copolymer, e.g. a di- and/or a tri-block copolymer.

[0037] In some embodiments of the present invention, the gel is based on an oil selected among mineral oil, aromatic oil, ester oil and paraffinic oil, e.g. iso-paraffinic oil, or a mixture thereof.

[0038] In some embodiments of the present invention, the gel comprises dispersed particles of boron nitride.

[0039] In some embodiments of the present invention, the electrical device 1 comprises a bushing, an instrument transformer, a power transformer, a capacitors or a cable ending.

[0040] In some embodiments of the present invention, the electrical device 1 comprises a transformer 4, and the transformer is encased within the composite insulation 3 within a transformer tank 2.

[0041] In some other embodiments, the electrical device 1 comprises a transformer 4, and a primary winding 5 of the transformer is encased within the composite insulation 3 within a shell 6 enclosing the primary winding and separating the primary winding from a secondary winding 7 of the transformer.

[0042] In some embodiments of the present invention, the device 1 has an operating temperature of up to 8o°C, e.g. within the range of 50-80°C or 30-60°C.

[0043] In some embodiments of the present invention, the transition temperature is within the range of 60-110°C, e.g. within the range of 60-90°C or 80-110°C.

[0044] In some embodiments of the present invention, the heating M3 of the gel is to a temperature above 90°C or above 110°C, e.g. to within the range of 110-150°C.

[0045] The present disclosure has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the present disclosure, as defined by the appended claims.

Claims

1. An electrical device (1) comprising a composite insulation (3) comprising an inorganic particulate filler impregnated with an oil-based thermo-reversible gel comprising a thickener, the gel being in solid form.

2. The device of claim 1, wherein the inorganic particulate filler comprises or consists of sand.

3. The device of any preceding claim, wherein the thickener comprises a styrenic block copolymer, e.g. a di- and/or a tri-block copolymer.

4. The device of any preceding claim, wherein the gel is based on an oil selected among mineral oil, aromatic oil, ester oil and paraffinic oil, e.g. iso-paraffinic oil, or a mixture thereof.

5. The device of any preceding claim, wherein the gel comprises dispersed particles of boron nitride.

6. The device of any preceding claim, wherein the electrical device (1) comprises a bushing, an instrument transformer, a power transformer, a capacitors or a cable ending.

7. The device of any preceding claim, wherein the electrical device (1) comprises a transformer (4), and wherein the transformer is encased within the composite insulation (3) within a transformer tank (2).

8. The device of any claim 1-6, wherein the electrical device (1) comprises a transformer (4), and wherein a primary winding (5) of the transformer is encased within the composite insulation (3) within a shell (6) enclosing the primary winding and separating the primary winding from a secondary winding (7) of the transformer.

9. The device of any preceding claim, wherein the device (1) has an operating temperature of up to 80°C, e.g. within the range of 50-80°C or 30-60°C.

10. A method of encasing an electrical power device (4) in a composite insulation (3), the method comprising:

    forming (M1) an oil-based thermo-reversible gel by adding a thickener to an electrically insulating oil;
    filling (M2) the tank (2) comprising the electrical power device (4) with an inorganic particulate filler such that the electrical power device is surrounded by said filler;
    heating (M3) the formed (M1) thermo-reversible gel to a temperature which is above the transition temperature of the gel, whereby the gel transitions to its liquid form;
    pouring (M4) the heated (M3) gel into the filled (M2) tank (2), whereby the inorganic particulate filler is impregnated with the gel in liquid form to form the composite insulation (3); and
    cooling (M5) the thermo-reversible gel to a temperature which is below the transition temperature of the gel, whereby the gel impregnating the filler transitions to its solid form, encasing the electrical power device (4) in the solid composite insulation (3) within the tank (2).

11. The method of claim 10, wherein the electrical power device is a transformer (4) and the tank (2) is a transformer tank, or wherein the electrical power device is a primary winding (5) of a transformer and the tank is a shell (6) enclosing the primary winding and separating the primary winding from a secondary wind-

ing (7) of the transformer.

12. The method of claim 10 or 11, wherein the transition temperature is within the range of 60-110°C, e.g. within the range of 60-90°C or 80-110°C.

13. The method of any claim 10-12, wherein the heating (M3) of the gel is to a temperature above 90°C or above 110°C, e.g. to within the range of 110-150°C.

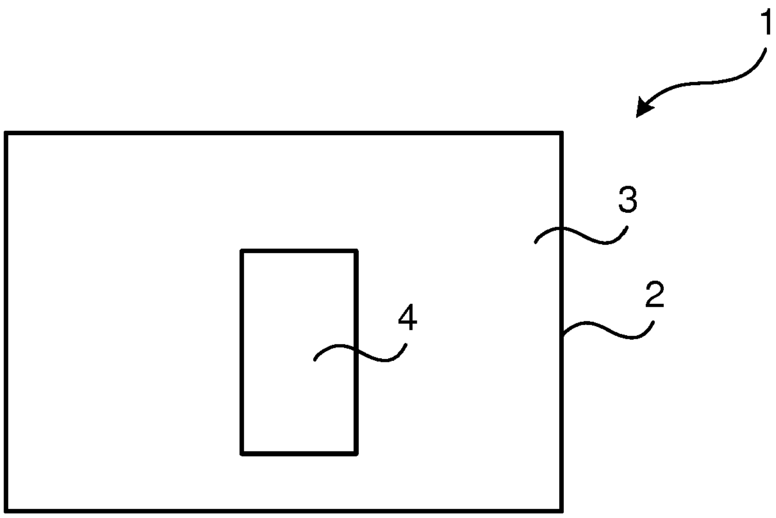

Fig. 1a

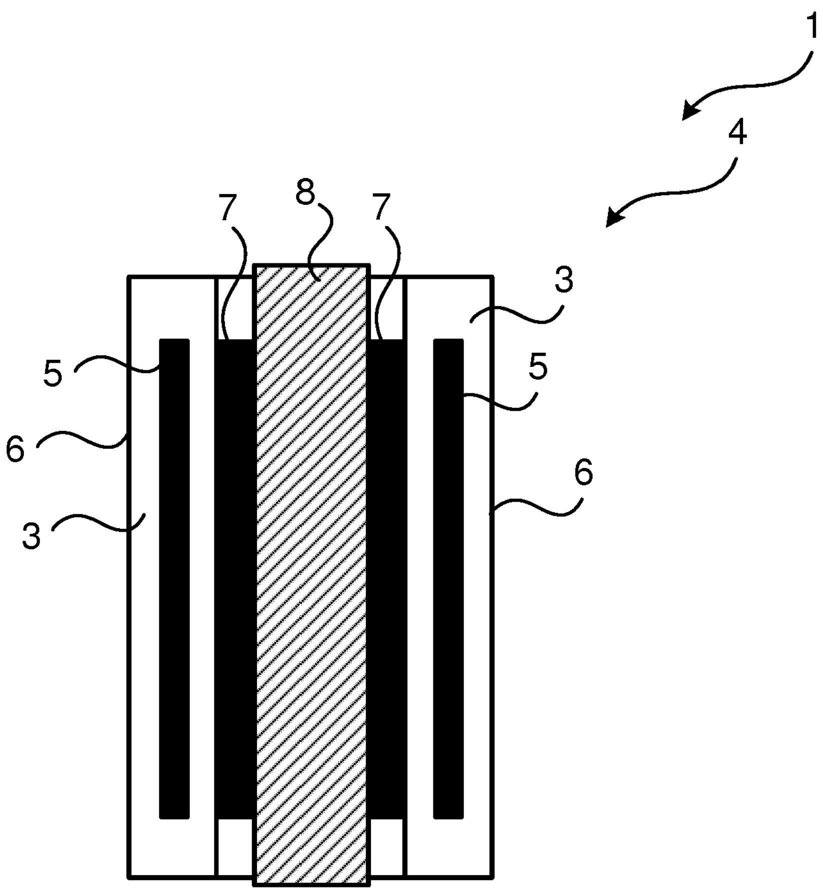

Fig. 1b

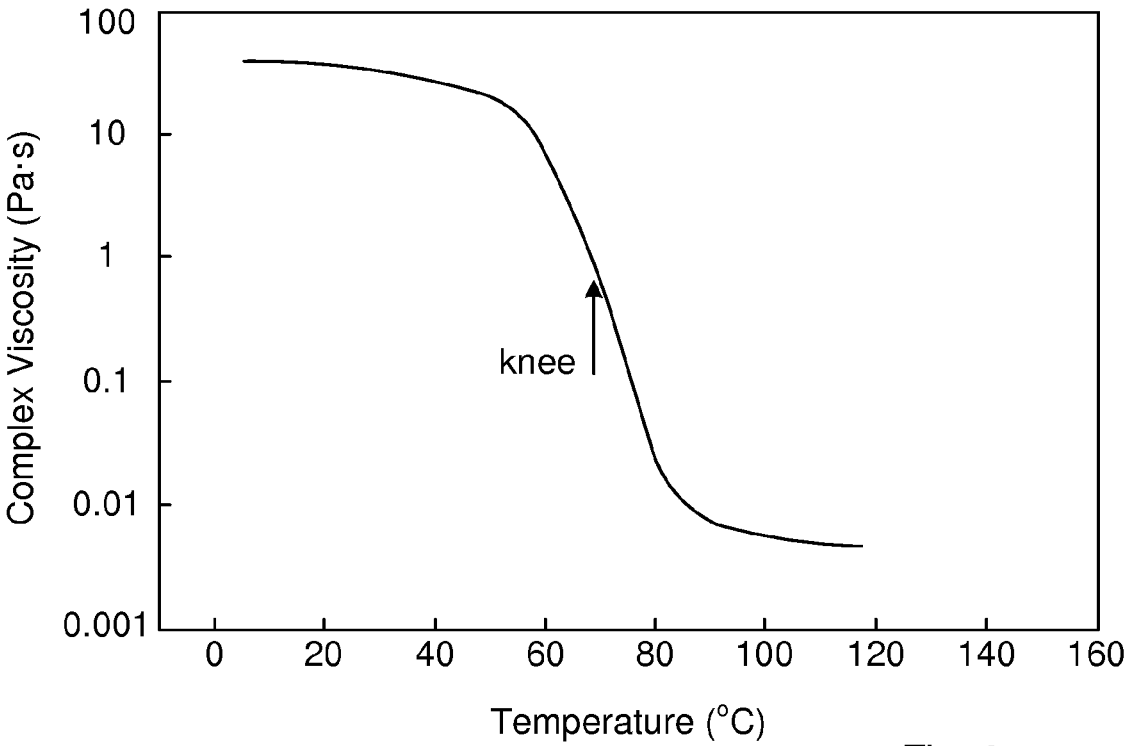
100
10
1
0.1
0.01
0.001
Complex Viscosity (Pa·s)
knee
0
20
40
60
80
100
120
140
160
Temperature (°C)

Fig. 2

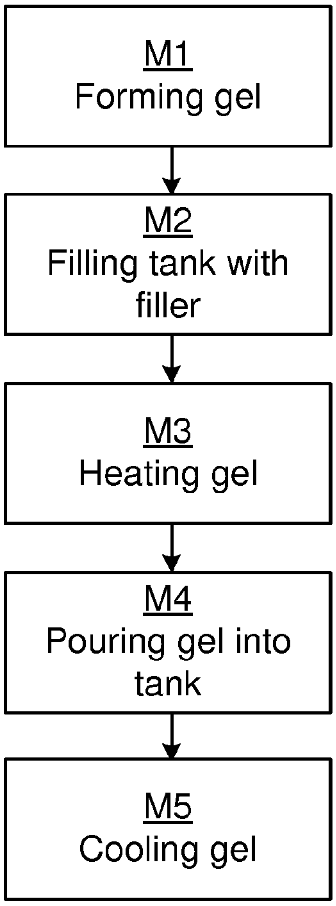
M1
Forming gel
M2
Filling tank with filler
M3
Heating gel
M4
Pouring gel into tank
M5
Cooling gel

Fig. 3

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 16 2517

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	EP 0 736 215 A1 (RAYCHEM LTD [GB]) 9 October 1996 (1996-10-09) * pages 2-4; figure 1 *	1-4,6,9 5	INV. H01F27/32 H01F27/02 H01F41/12 H01F41/00 H01B3/20
X Y	US 6 383 634 B1 (KORNFELDT ANNA [SE] ET AL) 7 May 2002 (2002-05-07) * column 1, lines 40-43 * * column 6, line 45 - column 9, line 62 * * column 11, line 40 - column 12, line 39 * * figure 1 *	1-4,6-13 1-13	
X Y	US 6 391 447 B1 (KORNFELDT ANNA [SE] ET AL) 21 May 2002 (2002-05-21) * column 1, lines 15-23 * * column 2, lines 45-67 * * column 6, line 30 - column 14, line 47 * * figure 1 *	1,3,4, 6-13 1-13	
X Y	WO 99/33066 A1 (ASEA BROWN BOVERI [SE]; KORNFELDT ANNA [SE]; FELIX JOHAN [SE]; BERGKVI) 1 July 1999 (1999-07-01) * page 1, last paragraph * * pages 9-16; claim 28 * * figure 1 *	1-4,6-13 5	TECHNICAL FIELDS SEARCHED (IPC) H01F H01B
Y	US 2011/287226 A1 (ROSEEN PATRIK [SE]) 24 November 2011 (2011-11-24) * paragraphs [0014], [0024]; figure 1 *	1-13	
Y	DE 101 10 062 A1 (ABB RESEARCH LTD [CH]) 5 September 2002 (2002-09-05) * paragraphs [0001] - [0013]; figure 1 *	1-13	
X Y	US 8 134 089 B2 (ABB) 13 March 2012 (2012-03-13) * column 3, line 60 - column 4, line 17 * * column 6, line 6 - column 7, line 3; figure 1 *	1,2,5,6, 9 5	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 September 2018	Weisser, Wolfgang

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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