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(54) A METHOD FOR PRODUCING A TRANSFORMER

(57) A method for producing a transformer (1), in particular a medium voltage instrument transformer, comprising the steps of winding (101) a coil of a transformer (1) with an insulation material (2) comprising capsules (3) with a chemical initiator (4), preparing (102) an active part of the transformer (1), wherein the active part comprises the wound coil, casting (103) the active part of the transformer (1) with an impregnation material (7), wherein the impregnation material (7) is an epoxy resin or a silicone; increasing (105) a temperature of the active part of the transformer (1) to release chemical initiator (4) from the capsules (3) to allow cross-linking, while the cross-linking is carried out until curing of the impregnation material (7); and cooling (106) the transformer (1). Further, after the step of casting (103) the active part of the transformer (1) and before the step of increasing (105) the temperature of said active part to allow cross-linking, a temperature of the active part of the transformer (1) is increased (104) to reduce the viscosity of the impregnation material (7), and said cross-linking is initiated by a temperature higher than the activation temperature of the chemical initiator (4) to release the chemical initiator (4) from the capsules (3). Furthermore, the insulation material (2) is poly(ethylene terephthalate) non-woven porous fabric, polypropylene non-woven fabric, fiberglass or crepe paper. The insulation material (2) has distributed on its surface the chemical initiator (4) encapsulated in capsules (3). The capsules (3) are adapted to release the chemical initiator (4) in a temperature higher than an activation temperature of the chemical initiator (4).

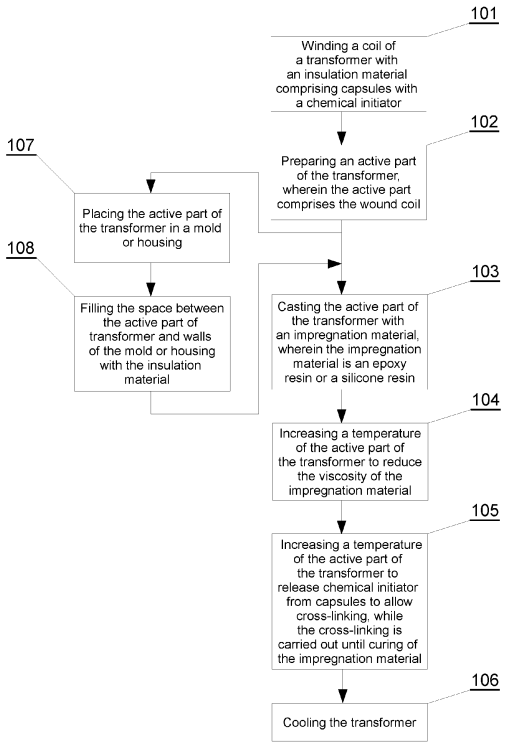


Fig. 1

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Description

Technical field

[0001] The present invention relates to a method for producing a transformer, in particular a medium voltage instrument transformer.

Background of the invention

[0002] From Chinese patent application CN105047256A there is known a mica tape comprising from the top to the bottom a mica paper layer, an adhesive layer and an alkali-free glass cloth layer, where both the mica paper layer and the adhesive layer contain microcapsule curing accelerators. Said microcapsule curing accelerators are suitable for a two-component epoxy anhydride impregnating resin. The microcapsule wall is made of a urea formaldehyde resin, urea resin or polyester resin. In turn, the microcapsule core is an imidazole curing accelerator, an amine curing accelerator or acetylacetone. The mica tape might be used for insulation treatment of electrical coil windings e.g. in transformers.

[0003] PCT patent application WO2017012735A1 discloses a solid, particularly strip-shape insulation material, which can be used in vacuum impregnation process to produce insulation that can be applied in electric industry. The solid insulation material comprises a support, a barrier material, a first curing catalyst and a tape adhesive, wherein said tape adhesive is inert to the first curing catalyst under the conditions of the vacuum impregnation with the cycloaliphatic epoxy groups of a cycloaliphatic epoxy resin. Furthermore, the solid insulation material contains a carrier in the form of fabric, nonwoven fabric, paper and/or in the form of a film.

[0004] Therefore, there is a need to provide a method for producing a transformer, in particular a medium voltage instrument transformer, with a single casting step that prevents the occurrence of partial discharges in a transformer.

The Essence of the Invention

[0005] The object of the invention is a method for producing a transformer, in particular a medium voltage instrument transformer, comprising the steps of:

(i) winding a coil of a transformer with an insulation material comprising capsules with a chemical initiator,
(ii) preparing an active part of the transformer, wherein the active part comprises the wound coil,
(iii) casting the active part of the transformer with an impregnation material, wherein the impregnation material is an epoxy resin or a silicone resin;
(iv) increasing a temperature of the active part of the transformer to release chemical initiator from capsules to allow cross-linking, while the cross-linking is carried out until curing of the impregnation material;
(v) cooling the transformer.

[0006] The essence of the invention is that after the step of casting the active part of the transformer and before the step of increasing the temperature of said active part to allow cross-linking, a temperature of the active part of the transformer is increased to reduce the viscosity of the impregnation material, and cross-linking is initiated by a temperature higher than the activation temperature of the chemical initiator to release the chemical initiator from the capsules. Furthermore, the essence of the invention is that the insulation material is poly(ethylene terephthalate) non-woven porous fabric, polypropylene non-woven fabric, fiberglass or crepe paper, and the insulation material has distributed on its surface the chemical initiator encapsulated in capsules, and the capsules are adapted to release the chemical initiator in a temperature higher than an activation temperature of the chemical initiator.

[0007] The presence of the two disclosed steps of increasing temperature in combination with the application of the poly(ethylene terephthalate) non-woven porous fabric, polypropylene non-woven fabric, fiberglass or crepe paper as the insulation material comprising the capsules with the chemical initiator as disclosed above provides a method for producing a transformer with a single casting step, thus leading to its simplification, while still preventing the occurrence of partial discharges in said transformer. This is due to the fact that the disclosed adaptation of the capsules distributed on the surface of the disclosed insulation material causes the impregnation of said insulation material and cross-linking of the impregnation material to occur separately. Thus, in the method according to the invention, the impregnation is carried out without starting the cross-linking. The impregnation temperature is raised and the viscosity of the impregnation material is reduced, thereby the impregnation of the disclosed insulation material is more precise than in the solutions known in the prior art and the resulting transformer is less prone to formation of cracks and voids leading to the patrial discharges than the solution known in the prior art.

[0008] Furthermore, the application of the silicone resin as the impregnation material, which after cross-linking has a form of a silicone gel, minimizes the risk of skin irritation when in contact with said silicone gel, which can lead to toxic eczema or allergic skin reactions. In turn, the application of the epoxy resin improves mechanical and dielectric properties of the insulation material.

[0009] Preferably, the chemical initiator is distributed uniformly on the surface of the insulation material.

[0010] Uniform distribution of the encapsulated chemical initiator on the surface of the disclosed insulation material prevents undesirable agglomeration of said chemical initiator in the impregnation material leading to non-uniform cross-linking and thus even more prevents

from the occurrence of partial discharges in the transformer.

[0011] Preferably, after the step of preparing the active part of the transformer and before the step of casting said active part with the impregnation material, the active part of the transformer is placed in a mold or housing and the space between the active part of the transformer and walls of the mold or housing is filled with the insulation material as disclosed.

[0012] Preferably, the space between the active part of the transformer and walls of the mold or housing is filled with pieces of the insulation material as disclosed.

[0013] Filling the space between the active part of the transformer and walls of the mold or housing with the disclosed insulation material, in particular pieces of said insulation material, improves mechanical properties, especially durability and mechanical strength, of the impregnation material outside the coil structure and reduces the usage of said impregnation material. This is due to the fact that said filling leads to reduction of chemical and thermal shrinkage of the impregnation material, in particular epoxy resin or silicone resin, and resulting stresses in the impregnation material. As a result of said step of filling, the impregnation material and the insulation material form the same composite, free of cracks and/or voids, both outside and inside the coil structure. Furthermore, it extends the lifespan of the transformer comparing to the solution known from the prior art.

[0014] Preferably, the epoxy resin is a low-viscosity epoxy-resin.

[0015] The application of the low-viscosity epoxy resin leads to a further improvement in impregnation of the insulation material, as said low-viscosity resin spreads more easily over the impregnated surfaces.

[0016] Preferably, the chemical initiator is a hardener, cross-linking agent, catalyst, or an accelerator.

[0017] Preferably, the impregnation material is the silicone resin and the chemical initiator is catalyst for addition cured silicones on the basis of precious metal.

[0018] The application of the catalyst for addition cured silicones on the basis of precious metal eliminates formation of by-products that negatively affect insulating properties of the insulation material.

[0019] Preferably, the precious metal is platinum.

[0020] Preferably, the catalyst is selected from platinum-carbonyl cyclovinylmethylsiloxane complex, platinum-divinyltetramethyldisiloxane complex or platinum-cyclovinylmethylsiloxane complex.

[0021] The application of said catalysts ensures a moderate cross-linking speed.

[0022] Preferably, the impregnation material is the silicone resin and the chemical initiator is a cross-linking agent for condensation curing silicones.

[0023] Preferably, the cross-linking agent is selected from ethyltriacetoxysilane, methyltriacetoxysilane, di-n-butylbis(2-ethylhexylmaleate)tin.

[0024] Preferably, the impregnation material is a low-viscosity epoxy resin and the chemical initiator is a hardener in a form of an anhydrite.

[0025] Preferably, the catalyst is selected from HexaHydroPhthalic Anhydride (HHPA), Methylhexahydrophthalic Anhydride (MHHPA) or Methyltetrahydrophthalic Anhydride (MTHPA).

Advantages of the invention

[0026] The method for producing a transformer according to the invention is a cost efficient production process as it is a single casting step method.

[0027] The method for producing a transformer according to the invention ensures high quality, void-free and crack free structure of the transformer.

[0028] The method for producing a transformer according to the invention leads to a reduction of scrap rate and costs associated with scrapping the manufactured transformers.

[0029] The method for producing a transformer according to the invention ensures matching of the coefficient of thermal expansion between a coil of a transformer and its outer insulation.

Description of the drawings

[0030] The subject of the invention is shown in the embodiments in a drawing, in which:

Fig.1 presents a flowchart of a method for producing a transformer according to the invention;

Fig.2 presents schematically an insulation material used in the method according to the invention in a top view;

Fig.3 presents schematically an active part of a transformer placed in a mold filled with an insulation material during production by the method according to the invention.

Detailed description of the invention

The first embodiment of the invention

[0031] In a method for producing a transformer 1 according to the invention in the first step a coil of a transformer 1 is wound 101 with an insulation material 2 comprising capsules 3 with a chemical initiator 4. Next, there is prepared 102 an active part of the transformer 1, wherein the active part comprises the wound coil with a winding terminal 5 and a core 6.

[0032] In the further step, the active part of the transformer 1 is casted 103 with an impregnation material 7, wherein the impregnation material 7 is a silicone resin. As a result, a GND screen 8 is also covered with the impregnation material 7. The application of the silicone resin as the impregnation material 7, which has a form of a silicone gel after cross-linking, minimizes the risk of

skin irritation when in contact with said silicone gel, which can lead to toxic eczema or allergic skin reactions.

[0033] When the impregnation material 7 is the silicone resin, the chemical initiator 4 can be a catalyst for addition cured silicones on the basis of precious metal, for example platinum-carbonyl cyclovinylmethylsiloxane complex, platinum-divinyltetramethyldisiloxane complex or platinum-cyclovinylmethylsiloxane complex. The application of the catalyst for addition cured silicones on the basis of precious metal eliminates formation of by-products that negatively affect insulating properties of the insulation material 2. Further, the application of said catalysts ensures a moderate cross-linking speed.

[0034] In the other embodiments, when the impregnation material 7 is the silicone resin, the chemical initiator 4 can be a cross-linking agent for condensation curing silicones, for example ethyltriacetoxysilane, methyltriacetoxysilane, di-n-butylbis(2-ethylhexylmaleate)tin.

[0035] In still other embodiments, the impregnation material 7 can be an epoxy resin, in particular low-viscosity epoxy resin, and the chemical initiator 4 can be a hardener in a form of an anhydrite, for example HexaHydroPhthalic Anhydride (HHPA), Methylhexahydrophthalic Anhydride (MHHPA) or Methyltetrahydrophthalic Anhydride (MTHPA). The application of the epoxy resin as the impregnation material 7 improves mechanical and dielectric properties of the insulation material 2. In turn, the application of the low-viscosity epoxy resin leads to a further improvement in impregnation of the insulation material 2, as said low-viscosity resin spreads more easily over the impregnated surfaces. In the further embodiments the chemical initiator 4 can be also an accelerator.

[0036] Next, a temperature of the active part of the transformer 1 is increased 104 to reduce the viscosity of the impregnation material 7, for example said active part is increased to the temperature of 50-70°C. The viscosity of the impregnation material 7 can be from 1 to 1000 $\times$ 10^{-3} Pa·s at room temperature.

[0037] Thus, it is possible to reach the maximum impregnation temperature before the crosslinking of the impregnation material 7 occurs. Impregnation may last up to several hours, for example 8 hours. Casting and the impregnation are carried out under vacuum conditions.

[0038] In the following step, the temperature of the active part of the transformer 1 is increased 105 again to release the chemical initiator 4 from the capsules 3 to allow cross-linking of the impregnation material 7, wherein said cross-linking is initiated by a temperature higher than the activation temperature of the chemical initiator 4. For example said active part is increased to the temperature of 80-120°C. The cross-linking is carried out until curing of said impregnation material 7. Finally the transformer 1 is cooled 106.

[0039] The insulation material 2 is poly(ethylene terephthalate) non-woven porous fabric with uniformly distributed on its surface the chemical initiator 4 encapsulated in the capsules 3, and the capsules 3 are adapted to release the chemical initiator 4 in a temperature higher than an activation temperature of the chemical initiator 4. Thus, said capsules 3 are adapted to withstand a temperature higher than the activation temperature of the chemical initiator 4. The capsules 3 may be in a form of polymeric microspheres and they may be applied by spraying on the poly(ethylene terephthalate) non-woven porous fabric. In the other embodiments, the insulation material 2 can be polypropylene non-woven fabric, fiberglass or crepe paper.

[0040] The presence of the two disclosed steps of increasing temperature in combination with the application of the poly(ethylene terephthalate) non-woven porous fabric or polypropylene non-woven fabric, fiberglass or crepe paper as in the other embodiments as the insulation material 2 comprising the capsules 3 with the chemical initiator 4 as disclosed above provides a method for producing a transformer 1 with a single casting step, thus leading to its simplification, while still preventing the occurrence of partial discharges in said transformer 1. This is due to the fact that the disclosed adaptation of the capsules 3 distributed on the surface of the disclosed insulation material 2 causes the impregnation of the disclosed insulation material 2 and cross-linking of the impregnation material 7 to occur separately. Thus, in the method according to the invention, the impregnation is carried out without starting the cross-linking. The impregnation temperature is raised and the viscosity of the impregnation material 7 is reduced, thereby the impregnation of the disclosed insulation material 2 is more precise than in the solutions known in the prior art and the resulting transformer 1 is less prone to formation of cracks and voids leading to the patrial discharges than the solution known in the prior art. Furthermore, uniform distribution of the encapsulated chemical initiator on the surface of the disclosed insulation material 2 prevents undesirable agglomeration of said chemical initiator in the impregnation material leading to non-uniform cross-linking and thus even more prevents from the occurrence of partial discharges in the transformer.

The second embodiment of the invention

[0041] The second embodiment of the method for producing a transformer 1 is as in the first embodiment, with the difference that after the step of preparing 102 the active part of the transformer 1 and before the step of casting 103 said active part with the impregnation material 7, the active part of the transformer 1 is placed 107 in a mold 9 or housing and the space between the active part of the transformer 1 and walls of the mold 9 or housing is filled 108 with the insulation material 2, in particular pieces of the insulation material 2.

[0042] Filling the space between the active part of the transformer 1 and walls of the mold 9 or housing with the disclosed insulation material 2, in particular pieces of said insulation material 2, improves mechanical properties, especially durability and mechanical strength, of the impregnation material 7 outside the coil structure and re-

duces the usage of said impregnation material 7. This is due to the fact that said filling leads to reduction of chemical and thermal shrinkage of the impregnation material, in particular epoxy resin or silicone resin, and resulting stresses in the impregnation material. As a result of said step of filling, the impregnation material 7 and the insulation material 2 form the same composite, free of cracks and/or voids, both outside and inside the coil structure. Furthermore, it extends the lifespan of the transformer 1 comparing to the solution known from the prior art.

Claims

1. A method for producing a transformer, in particular a medium voltage instrument transformer, comprising the steps of:

   (i) winding (101) a coil of a transformer (1) with an insulation material (2) comprising capsules (3) with a chemical initiator (4),
   (ii) preparing (102) an active part of the transformer (1), wherein the active part comprises the wound coil,
   (iii) casting (103) the active part of the transformer (1) with an impregnation material (7), wherein the impregnation material (7) is an epoxy resin or a silicone resin;
   (iv) increasing (105) a temperature of the active part of the transformer (1) to release chemical initiator (4) from the capsules (3) to allow cross-linking, while the cross-linking is carried out until curing of the impregnation material (7);
   (v) cooling (106) the transformer (1),
   characterized in that
   (vi) after the step of casting (103) the active part of the transformer (1) and before the step of increasing (105) the temperature of said active part to allow cross-linking, a temperature of the active part of the transformer (1) is increased (104) to reduce the viscosity of the impregnation material (7), and
   (vii) said cross-linking is initiated by a temperature higher than the activation temperature of the chemical initiator (4) to release the chemical initiator (4) from the capsules (3),

   wherein

   the insulation material (2) is poly(ethylene terephthalate) non-woven porous fabric, polypropylene non-woven fabric, fiberglass or crepe paper, and
   the insulation material (2) has distributed on its surface the chemical initiator (4) encapsulated in capsules (3), and
   the capsules (3) are adapted to release the chemical initiator (4) in a temperature higher than an activation temperature of the chemical initiator (4).

2. The method according to claim 1, wherein the chemical initiator (4) is distributed uniformly on the surface of the insulation material (2).

3. The method according to claim 1 or 2, wherein after the step of preparing (102) the active part of the transformer (1) and before the step of casting (103) said active part with the impregnation material (7), the active part of the transformer (1) is placed (107) in a mold (10) or housing and the space between the active part of the transformer (1) and walls of the mold (9) or housing is filled (108) with the insulation material (2).

4. The mold according to claim 3, wherein the space between the active part of the transformer (1) and walls of the mold (9) or housing is filled (107) with pieces of the insulation material (2).

5. The method according to any of the preceding claims, wherein the epoxy resin is a low-viscosity epoxy-resin.

6. The method according to any of the preceding claims, wherein the chemical initiator (4) is a hardener, cross-linking agent, catalyst, or an accelerator.

7. The method according to claim 6, wherein the impregnation material (7) is the silicone resin and the chemical initiator (4) is catalyst for addition cured silicones on the basis of precious metal.

8. The method according to claim 7, wherein the precious metal is platinum.

9. The method according to claim 8, wherein the catalyst is selected from platinum-carbonyl cyclovinylmethylsiloxane complex, platinum-divinyltetramethyldisiloxane complex or platinum-cyclovinylmethylsiloxane complex.

10. The method according to claim 6, wherein the impregnation material (7) is the silicone resin and the chemical initiator (4) is a cross-linking agent for condensation curing silicones.

11. The method according to claim 10, wherein the cross-linking agent is selected from ethyltriacetoxysilane, methyltriacetoxysilane, di-n-butylbis(2-ethylhexylmaleate)tin.

12. The method according to claim 6, wherein the impregnation material (7) is a low-viscosity epoxy resin and the chemical initiator (4) is a hardener in a form of an anhydrite.

13. The method according to claim 12, wherein the anhydrite is selected from HexaHydroPhthalic Anhydride (HHPA), Methylhexahydrophthalic Anhydride (MHHPA) or Methyltetrahydrophthalic Anhydride (MTHPA).

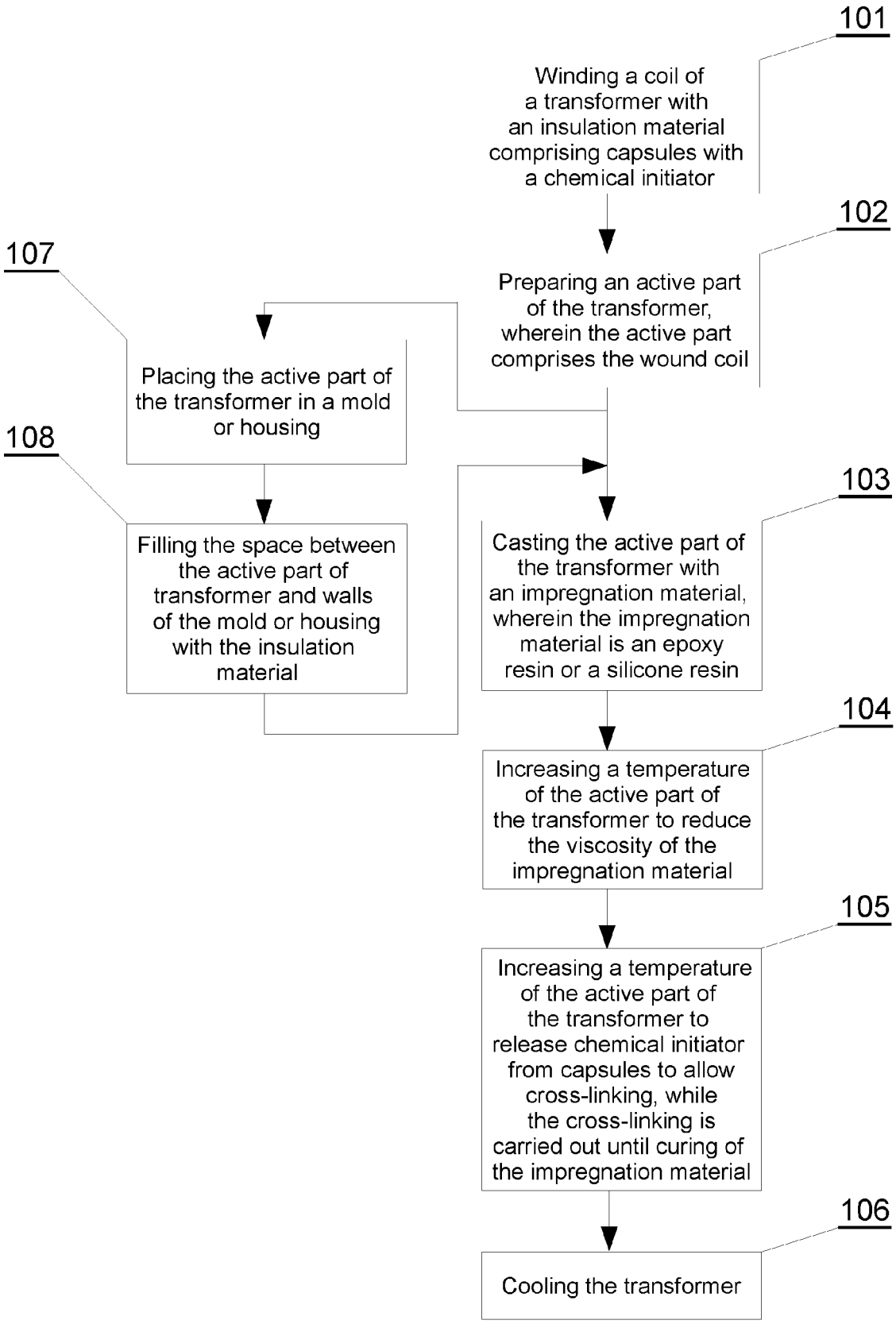

101
Winding a coil of a transformer with an insulation material comprising capsules with a chemical initiator
102
Preparing an active part of the transformer, wherein the active part comprises the wound coil
107
Placing the active part of the transformer in a mold or housing
108
Filling the space between the active part of transformer and walls of the mold or housing with the insulation material
103
Casting the active part of the transformer with an impregnation material, wherein the impregnation material is an epoxy resin or a silicone resin
104
Increasing a temperature of the active part of the transformer to reduce the viscosity of the impregnation material
105
Increasing a temperature of the active part of the transformer to release chemical initiator from capsules to allow cross-linking, while the cross-linking is carried out until curing of the impregnation material
106
Cooling the transformer

Fig. 1

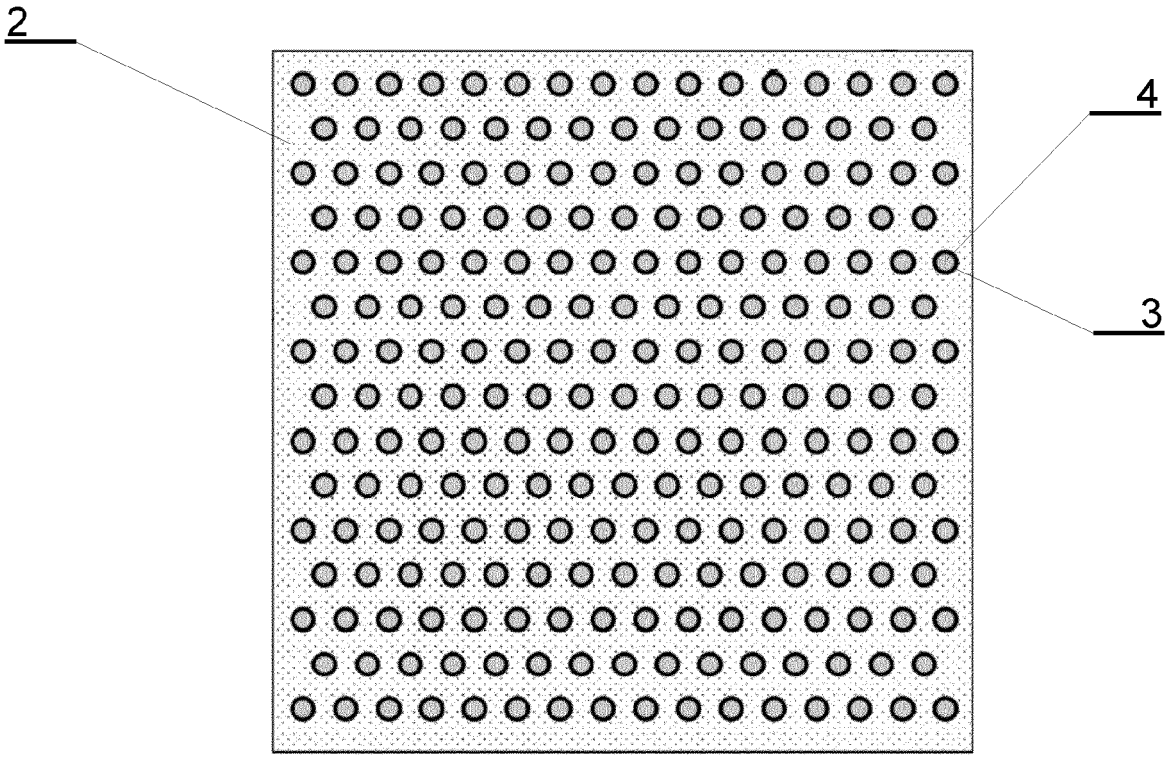


Fig. 2

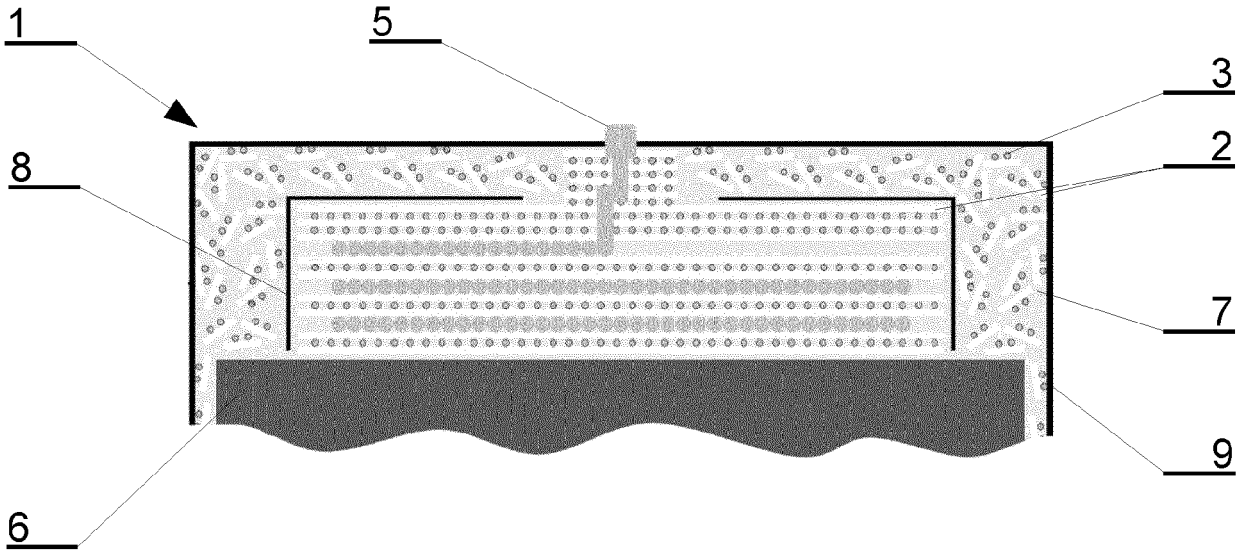


Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 22 20 8680

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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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 May 2023	Reder, Michael

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