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(54) POWER DEVICE WITH INSULATION COMPOSITION SHOWING THERMO-REVERSIBLE OIL-TO-GEL-TRANSITION

(57) An electrical power device is provided, which comprises an element producing heat during operation; and an enclosure holding an insulation composition, which is in thermal contact with the element, wherein the insulation composition comprises: an ester oil, and a polymer. Further, a method of treating a leak in a power device having an enclosure holding such an insulation composition is provided.

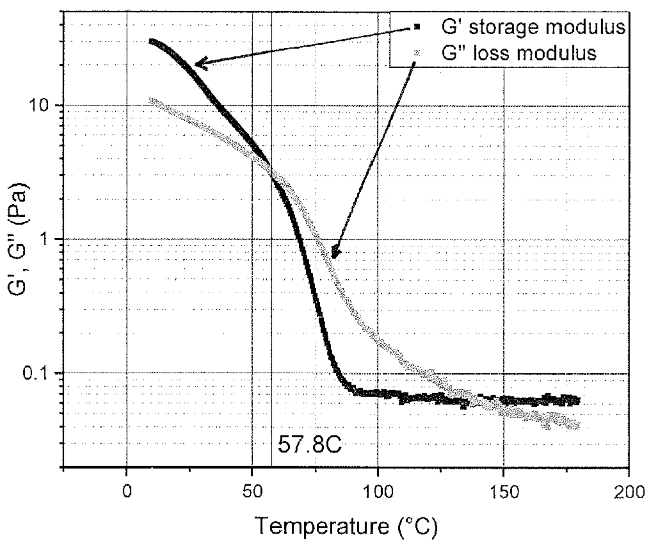

FIG. 2

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Description

Field

[0001] Aspects of the present disclosure relate to electric power conversion and switching devices with a filling of an insulating medium, which typically also serves as a cooling medium for the device. More particularly, the disclosure relates to the insulating medium itself, its composition and use in such electric power devices, as well as to methods for handling or treating leaks in power devices by employing insulation compositions.

Technical background

[0002] Medium and large transformers are typically filled with an insulating liquid, also called transformer oil, that both cools and insulates the windings. This pertains also to traction transformers in railway vehicles. For cooling purposes, also semiconductor switching devices for medium and high voltage power applications are often liquid-cooled with an insulating liquid. The applied liquids may be derived from natural sources such as plants, be mineral oils, or be purely synthetic products. While not all such insulation liquids may be correctly described as oils, they are substantially based on hydrocarbons. While this was originally mainly a concern with respect to mineral-oil-based and synthetic insulation liquids, it has also to be avoided that insulation liquids from natural sources leave the confined cooling circuits of electric devices and contaminate the surroundings of these devices, lest get into the surrounding natural environment.

[0003] However, the described liquid-filled power devices are susceptible to leakage, which can be caused, e.g., by corrosion or faulty welds. This may result in environmental damage, product downtime and ongoing maintenance costs. In order to minimize the environmental damage in case of leakages, traction transformers are equipped with metallic oil reservoirs, which are typically able to host the full amount of the insulating liquid upon leakage and/or failure. This, however, results in increased weight and cost of the whole system.

[0004] In view of the above and for other reasons, there is a need for the present invention.

Summary of the invention

[0005] In view of the above, a power device according to claim 1, a use of claim 8, and a method for treating a leak according to claim 9 are provided.

[0006] According to a first aspect, a power device is provided. It comprises an element producing heat during operation; an enclosure holding an insulation composition, which is in thermal contact with the element, wherein the insulation composition comprises an ester oil and a polymer.

[0007] According to a second aspect, a use of an insulation composition in a power device is provided. The insulation composition comprises an ester oil and a polymer, wherein the insulation composition is configured to undergo a thermo-reversible oil-to-gel transition below a predefined temperature.

[0008] According to a third aspect, a method of treating a leak in a power device having an enclosure holding an insulation composition is provided. The method comprises providing a power device having an enclosure with an insulation composition, the insulation composition comprising an ester oil and a polymer, operating the power device and dissipating heat via the insulation composition, wherein the insulation composition is configured such that the insulation composition is in a liquid phase during standard operation of the power device, in case of a leak in the enclosure, spilling an amount of the insulation composition through the leak to an outside of the enclosure, wherein the spilled amount undergoes a thermo-reversible oil-to-gel transition during or after the spilling.

[0009] Aspects and embodiments described herein generally relate to an ester-oil-based insulation system or insulation composition, which exhibits a thermo-reversible oil-to-gel transition, meaning that the insulation composition (henceforth also simplified called "oil" for practical reasons) is configured to be in a liquid state at normal operational temperatures of the device(s), and gels when it cools down to a temperature of an environment of the respective device. This temperature is, what goes without saying, typically significantly lower than the operating temperature of a heat-dissipating electric power device, be it a transformer or a semiconductor switching device. The employed gelation process is of high usefulness for preventing environmental damage upon any type of leakage - since the gel stays, e.g., only on a surface of a contaminated area of soil, for example, and is not able to penetrate the soil. The gel can subsequently easily be removed from the contaminated soil or other area. Hence, an environmental friendly solution is provided. It can also lead to significant weight reduction and cost reduction when applied in, e.g., traction transformers or distribution transformers, as conventionally used underneath-placed metal oil reservoirs (fallback reservoir) may be omitted. Further, the overall life cycle may be improved, and maintenance costs can be reduced, as small leakages can be self-healed by the gel, or at least be retarded, such that the time until arrival of maintenance personnel on the reparation site may be prolonged, thereby increasing a respective planning flexibility.

[0010] The insulation compositions as described herein are based on synthetic or natural ester oils, or mixtures thereof, which are used for the electrical insulation in power products, e.g. transformers, traction transformers, and semiconductor switching devices. Relatively low amounts of additives, typically less than about 10 wt.%, may be comprised in the insulation composition in order to induce a thermo-reversible oil-to-gel transition. Thus, the oil remains in the liquid state at operational temperatures, which enables heat dissipation through convection, and gels below a certain temperature which may be selected to be a few degrees higher than the maximum environmental temperature, which the product experiences under standard operating conditions. In the event of a leakage, the insulation composition, being exposed to the lower environmental temperature, gels fast, and hence any environmental related hazard is avoided, respectively minimized, as was described above.

[0011] Further advantages, features, aspects and details that can be combined with embodiments described herein are evident from the dependent claims, claim combinations, the description and the drawings.

Brief description of the Figures

[0012] More details will be described in the following with reference to the figures, wherein

Fig. 1 shows a graph indicating a complex viscosity of insulation compositions according to embodiments in dependency of temperature, and a comparative example;

Fig. 2 shows a graph indicating a storage modulus G' and a loss modulus of an exemplary insulation composition according to embodiments, in dependency of temperature;

Fig. 3 shows an exemplary power device according to embodiments;

Fig. 4a-4d show the result of a spillage test on soil for an insulation composition according to embodiments, and for a comparative conventional insulation composition.

Detailed Description of Aspects of the Invention

[0013] In the following, some aspects of the invention are described in detail. Aspects and parts of aspects are independent of each other and can be combined in any manner. For example, any aspect or embodiment described in this document can be combined with any other aspect or embodiment, as long as the combinations achieved are technically feasible, or unless the contrary is mentioned.

[0014] According to an aspect, in a power device of the first aspect, the insulation composition has a thermoreversible gel point preferably in the range from about 30°C to about 90°C, wherein the gel point is defined as the temperature at which the storage modulus G' is equal to the loss modulus G" .

[0015] According to an aspect, the insulation composition has a complex viscosity (defined as frequency-dependent viscosity function determined for a viscoelastic fluid by subjecting it to oscillatory shear stress) of equal or greater than 0.01 Pa-s at a temperature below the gel point, and a complex viscosity at temperatures above the gel point which is substantially equal, with a difference of less than about 30%, to the complex viscosity of the ester oil itself.

[0016] According to an aspect, the polymer comprises a copolymer and/or a block copolymer, preferably a triblock copolymer and/or a di-block copolymer, and wherein the ester oil is a natural ester oil and/or a synthetic ester oil.

[0017] According to an aspect, the polymer has a concentration of 0.1 wt.% to 10 wt.% based on the total weight of the insulation composition, and/or wherein the insulation composition further comprises an antioxidant, preferably at a concentration of 0.1 wt.% to 1 wt.%, based on the total weight of the insulation composition.

[0018] According to an aspect, the polymer comprises a copolymer and/or a tri-block copolymer and/or a diblock copolymer, which are at least one of: PMMA-PnBA-PMMA, styrene-(ethylene-isopropylene)-styrene, ethylene-vinylacetate, ethylene-butyleneacrylate, styrene-ethylene-butylene-styrene, and/or wherein the polymer comprises ethylcellulose.

[0019] According to an aspect, the power device is a transformer, optionally a traction transformer, or a semiconductor-based power device.

[0020] According to aspects, the power device is a transformer, optionally a traction transformer, or a semiconductor-based power device, and the insulation composition is configured to undergo a thermo-reversible oil-to-gel transition below a defined temperature, which is chosen to be about 1°C to about 10°C higher than the maximum environmental temperature expected during operation of the power device. Thereby, an oil-to-gel transition of a leaked amount of insulation composition is fostered under all normal operating conditions of the power device.

Detailed Description of Exemplary Embodiments

[0021] In the following, detailed embodiments of the invention are described, which shall not be regarded to be limiting for the invention.

[0022] Generally, the terms "gel point", "transition point", and "transition temperature" may be used interchangeably herein. Further, the terms "gel formation", "gelation", and "gel transition" may be used interchangeably.

[0023] In embodiments, a heat-producing power device has at least one element producing heat during operation. An enclosure of the device comprises an insulation composition. The latter is in thermal contact with the heat-producing element. The heat from the element, which may for example be a winding of a transformer or a semiconductor switching element, is transferred to the insulation composition. Via active and/or passive convection, the insulation composition circulates in the enclosure and dissipates the thermal energy at an area being a heat-sink, such as an enclosure wall having thermal contact to an outside temperature, or the heat from the insulation composition is dissipated via a closed cooling circuit, of which the insulation composition may be a filling.

[0024] The insulation composition employed according to embodiments is configured to exhibit a thermo-reversible oil-to-gel transition below a certain predefined temperature, herein also called transition point. This means that the insulation composition (henceforth also simplified called "oil" for practical reasons) is configured to be in a liquid state at normal operational temperatures of the device(s) or at higher temperatures, and is configured to transform into a gel when it cools down below that transition point, and vice versa. The thermo-reversibility of the oil-to-gel-transition enables to cool down a device, e.g. during downtime, which leads to the insulation composition transforming into the gel state. When the device is put into operation again, the gel will thus re-transform into a liquid being a condition for proper operation of the device.

[0025] Hence, below the transition point, the complex viscosity increases significantly as the insulation composition is in a gel state or gelated state. According to embodiments, the insulation composition typically cools down to below the transition point in case of a leakage of the insulation composition, hence when a leaked amount reaches the temperature of an environment around the respective device. The transition may in embodiments already occur during the leaking process - for example, if the leak is very small, such as e.g. an irregularity in a welding that has expanded into a small leak by corrosion, the gelation process may already occur in the small cavity of the leak. This may happen, e.g., when the outside face of the enclosure at the position of the leak has a temperature lower than the transition point of the employed insulation composition.

[0026] The formed gel in the leak itself may, according to embodiments, block a leak entirely, which can be regarded as a self-healing process of a leak. Whether this process is sufficient to fully block a leak is dependent on, e.g., the size of the leak, in particular its diameter, its geometry, the hydrostatic pressure of the insulation composition in the enclosure at the position of the leak, the complex viscosity of the gel, and the temperature distribution along the "channel" of the leak leading from the inside of the enclosure to the outside face of the enclosure, which influences along which part of the length of the leak channel there is a gel formation.

[0027] Generally, for the application of an insulation composition in power devices, according to embodiments, a transition point of the insulation composition may be configured to be in the range from about 30°C to about 90°C, more preferably from about 50°C to about 70°C. Thereby, the insulation composition is in the liquid state above the transition point, which enables heat dissipation from the power device during operation, either via natural convection or via forced convection. Below this transition point, the insulation composition is in the gel state. Typically, according to embodiments, the insulation composition cools down in the event of a leakage of an enclosure, or a tubing etc., of the power device. Once the insulation composition has cooled down to a temperature below the transition point, it transforms into the gel state. This typically happens when the insulation composition drops down to an earth surface, and/or when it comes into contact with a surface, e.g. the earth surface, in particular soil. As was described above, the gelation may already happen during passage of the insulation composition through the leak in the enclosure. This may be used as a self-healing or self-sealing process of such a leak. Typically, as the gel has only limited mechanical stability, the former process is mainly applicable to rather small leaks, such as of a pinhole size. When the insulation composition is configured to have a sufficiently high complex viscosity, the self-healing process may be applied also to leaks having larger dimensions. Typically, the transition point may be chosen to be about 1°C to about 10°C higher than the maximum environmental temperature expected during operation of the power device.

[0028] Hence, an oil-to-gel transition of a leaked or spilled amount of insulation composition will be fostered under all normal operating conditions of the power device.

[0029] Generally, according to embodiments, the above described insulation composition comprises an ester oil. The ester oil may be a synthetic ester oil or a natural ester oil, or a mixture of these ester oil. Examples for applicable ester oils are, e.g., Nycodiel or vegetable-based oils like e.g. Biotemp.

[0030] Generally, in embodiments, the insulation composition comprises a polymer at a concentration of about 10 wt.% or lower, which is a main component for fostering the above-described thermo-reversible oil-to-gel formation process. Typically, the polymer comprises a copolymer, a block copolymer, or mixtures thereof. The block copolymer may be a tri-block copolymer or a di-block copolymer.

[0031] The exact mechanism of the thermo-reversible gelation is not fully understood. Without wishing to be bound by theory, a plausible explanation for the oil-to-gel transition with block copolymers (as a particular example) may be as follows: block copolymers consist of hard and soft segments. At low temperatures, the hard segments have the tendency to cluster together thereby creating ordered structures, which can be regarded as crystalline areas, which are acting as crosslinking points in a gel, which can be described as a 3D network formation. At higher temperatures, these crystalline areas melt and the formulation converts to the liquid state. Thus, the formation of the gel happened below a certain temperature. When the gel is subsequently heated above this temperature, the gel becomes liquid again. The gel process according to embodiments is hence thermo-reversible. Also some copolymers lead to the above behaviour of an insulation composition, which is described further below.

[0032] In embodiments, insulation compositions are configured to have a complex viscosity of equal or greater than 0.01 Pa-s at a temperature below the transition point (gel point). At temperatures above the gel point, the complex viscosity is substantially equal, with a difference of less than about 30%, more typically less than 15%, to the complex viscosity of the ester oil itself, thus without the added polymer and optionally present antioxidants.

[0033] In the following, some embodiments are discussed which include various block copolymers.

[0034] In a first example, the block copolymer PMMA-PnBA-PMMA is used. It is, e.g., available as Kurarity LA2250 from the producer Kuraray.

[0035] A further example is Styrene-(ethylene-isopropylene)-styrene, available as Septon SEPS 2004 and SEPS 2104 from Kuraray.

[0036] In yet further examples, ethylene-vinylacetate (e.g. TPEV 1112 from Byk), ethylene-butyleneacrylate (e.g. TSEB 2113 from Byk), styrene-ethylene-butylene-styrene (e.g. TSKD 9103 from Byk) are employed as block copolymers.

[0037] In a further example, Ethylcellulose is used as a polymer, which is for example, available as Ethocel Standard 4 and Standard 10 from Dow Chemical. Ethylcellulose is an example for a polymer which can be used according to embodiments, which is not a block copolymer, and also fosters the thermo-reversible oil-to-gel transition.

[0038] According to further embodiments, optionally, antioxidants at concentrations of about 1 wt.% and below are also comprised in the insulation composition.

[0039] The temperature of the transition point, at which the oil-to-gel transition takes place, depends mainly on the type of ester oil(s) used as the basis for the insulating composition, on the type of the polymer(s), and on the amount of the polymer in the insulation composition.

[0040] A characteristic example of the temperature dependence of the complex viscosity of an insulation composition according to embodiments is shown in Figure 1. Thereby, the complex viscosity is shown as a function of temperature, at a frequency of 1 Hz (amplitude of 0.5%), for pure Nycodiel oil (top graph), and for an oil-to-gel formulation containing 4 wt.% PMMA-PnBA-PMMA block copolymer (intermediate graph), and containing 6 wt.% PMMA-PnBA-PMMA block copolymer. As can be seen in Fig. 1, the complex viscosity between the three samples is quite similar at temperatures well above 100°, meaning that the insulation composition with the added block copolymer has a complex viscosity which hardly deviates from that of the ester oil (Nycodiel) itself without an added polymer. At significantly lower temperatures, e.g. 50°C and below, the difference in complex viscosity steadily increases. At about 30°C, the difference is larger than 1,5 orders of magnitude between the pure ester oil and the ester oil with 6wt.% polymer.

[0041] The above-described behaviour is also illustrated in Fig. 2. Therein, the storage modulus G' (the energy stored by elastic deformation) and the loss modulus G" (the loss of energy due to viscous flow) are shown as a function of temperature, at a frequency of 1 Hz (amplitude of 0.5%). The employed sample is identical to the one as employed resulting in the top graph in Fig. 1, Nycodiel as ester oil with an additive of 6 wt.% PMMA-PnBA-PMMA block copolymer. The crossover point, where the storage modulus G' is identical to the loss modulus G" corresponds to the gel point (here 57.8°C).

[0042] In Fig. 3, a power device 1, exemplarily being a transformer, according to embodiments is shown. The power device 1 has an enclosure 10 holding an insulation composition 20 which has an ester oil as a main component. Symbolically, an added polymer 25 in the insulation composition 20 is shown. The device comprises a heat-producing element 15, which in this case includes the windings and the core of the transformer. The element 15 is in thermal contact with the insulation composition 20. The power device 1 may in particular be a traction transformer for railway vehicles, or a distribution transformer for use in energy distribution grids or the like. Further, the power device may in embodiments be a semiconductor switching device. The insulation composition is configured to undergo a thermo-reversible oil-to-gel transition below a predefined temperature, also described herein as the transition point or gel point, as was extensively described above.

[0043] When the power device 1 suffers a leakage during operation, in particular when there is a leak in the enclosure 10, an amount of the insulation composition is spilled through the leak to an outside of the enclosure 10. Thereby, the spilled amount undergoes a thermo-reversible oil-to-gel transition during or after the spilling. This leads either to a closing of the leak, or to an immediate gelation of the insulation composition when it comes into contact with a surface having a temperature of the environment, which may for example be from about 10°C to about 30°C.

[0044] Figs. 4a - 4d show the result of a spillage experiment. The two images on the left (Fig. 4a, 4b) show the result of the insertion of pure ester oil (Nycodiel) at 120°C onto a soil sample with ambient temperature. As can be seen due to the homogeneous colour profile of the soil in the image below/left (Fig. 4b), the oil penetrated the soil entirely, which is equivalent to a well-known spilling event with conventional insulation oils. On the right (Fig. 4c, 4d), an insulation composition according to the example in Fig. 2 (Nycodiel with 6 wt.% polymer being PMMA-PnBA-PMMA block copolymer) was used instead at the same temperature levels as described above. With this oil-to-gel formulation according to embodiments, only a thin layer of gel is formed on the soil's surface (Fig. 4d). This layer can easily be removed, thus leaving behind clean, non-contaminated soil.

[0045] The electrical and dielectric characterization of the insulation composition according to embodiments, as well as long term ageing experiments, showed that the good insulating performance of the ester oil is not compromised by the presence of the additives.

[0046] It also has been demonstrated that in case of large spillages, which may typically happen due to an overpressure valve release, a rapid transition to the gel state can be achieved, which reduces both fire and safety hazards.

Claims

1. A power device, comprising:

- an element producing heat during operation;
- an enclosure holding an insulation composition, which is in thermal contact with the element,

wherein the insulation composition comprises:

- an ester oil, and
- a polymer.

2. The power device of claim 1, wherein the insulation composition has a thermo-reversible gel point, preferably in the range from about 30°C to about 90°C, wherein the gel point is defined as the temperature at which a storage modulus G' of the insulation composition is equal to a loss modulus G" of the insulation composition.

3. The power device of claim 2, wherein the insulation composition has a complex viscosity of equal or greater than 0.01 Pa-s at a temperature below the gel point, and a complex viscosity at temperatures above the gel point which is substantially equal, with a difference of less than about 30%, to the complex viscosity of the ester oil itself.

4. The power device of any preceding claim, wherein the polymer comprises a copolymer and/or a block copolymer, preferably a tri-block copolymer and/or a di-block copolymer, and wherein the ester oil is a natural ester oil and/or a synthetic ester oil.

5. The power device of any preceding claim, wherein the polymer has a concentration of 0.1 wt.% to 10 wt.% based on the total weight of the insulation composition, and/or wherein the insulation composition further comprises an antioxidant, preferably at a concentration of 0.1 wt.% to 1 wt.%, based on the total weight of the insulation composition.

6. The power device of any preceding claim, wherein the polymer comprises a copolymer and/or a tri-block copolymer and/or a di-block copolymer, which are at least one of: PMMA-PnBA-PMMA, styrene-(ethylene-isopropylene)-styrene, ethylene-vinylacetate, ethylene-butyleneacrylate, styrene-ethylene-butylene-styrene, and/or wherein the polymer comprises ethylcellulose.

7. The power device of any preceding claim, wherein the power device is an electrical power device, in particular is a transformer, optionally a traction transformer, or a semiconductor-based power device.

8. Use of an insulation composition in a power device, in particular in a power device according to any one of the preceding claims, wherein the insulation composition comprises

- an ester oil, and
- a polymer,

wherein the insulation composition is configured to undergo a thermo-reversible oil-to-gel transition below a predefined temperature.

9. Method of treating a leak in a power device, in particular in a power device according to any one of the preceding claims, having an enclosure holding an insulation composition, comprising:

- providing a power device having an enclosure with an insulation composition, the insulation composition comprising an ester oil and a polymer,
- operating the power device and dissipating heat via the insulation composition, wherein the insulation composition is configured such that the insulation composition is in a liquid phase during standard operation of the power device,
- in case of a leak in the enclosure, spilling an amount of the insulation composition through the leak to an outside of the enclosure,

wherein the spilled amount undergoes a thermo-reversible oil-to-gel transition during or after the spilling.

10. The use of claim 8 or the method of claim 9, wherein the insulation composition has a thermo-reversible gel point from about 30°C to about 90°C, the gel point being defined as the temperature at which the storage modulus G' of the insulation composition is equal to the loss modulus G" of the insulation composition.

11. The use of claim 10 or the method of claim 10, wherein the insulation composition has a complex viscosity of 0.01 Pa-s or higher at a temperature below the gel point, and a complex viscosity at temperatures above the gel point which is substantially equal, with a difference of less than about 30%, to the complex viscosity of the ester oil itself.

12. The use of claims 8 to 11 or the method of claims 9 to 11, wherein the insulation composition comprises a copolymer and/or a block copolymer, preferably a tri-block copolymer and/or a di-block copolymer, and wherein the ester oil is a natural ester oil and/or a synthetic ester oil.

13. The use of claims 8 to 12 or the method of claims 9 to 12, wherein the polymer has a concentration of 0.1 wt.% to 10 wt.% based on the total weight of the insulation composition, and/or wherein the insulation composition further comprises an antioxidant, preferably at a concentration of 0.1 wt.% to 1 wt.%, based on the total weight of the insulation composition.

14. The use of claims 8 to 13 or the method of claim 9 to 13, wherein the polymer comprises a copolymer and/or a tri-block copolymer and/or a di-block copolymer, which are at least one of: PMMA-PnBA-PMMA, styrene-(ethylene-isopropylene)-styrene, ethylene-vinylacetate, ethylene-butyleneacrylate, styrene-ethylene-butylene-styrene, and/or wherein the polymer comprises ethylcellulose.

15. The use of claims 8 to 14 or the method of claim 9 to 14, wherein the power device is a transformer, optionally a traction transformer, or a semiconductor-based power device, and wherein the insulation composition is configured to undergo a thermo-reversible oil-to-gel transition below a defined temperature, which is chosen to be about 1°C to about 10°C higher than the maximum environmental temperature expected during operation of the power device, in order to foster an oil-to-gel transition of a leaked amount of insulation composition under all normal operating conditions of the power device.

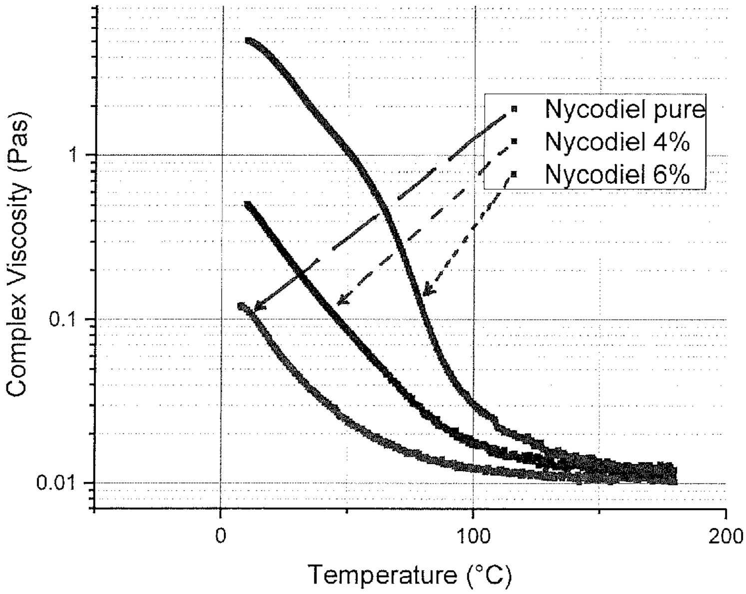
Complex Viscosity (Pas)
Temperature (°C)
Nycodiel pure
Nycodiel 4%
Nycodiel 6%
0.01
0.1
1
0
100
200

FIG. 1

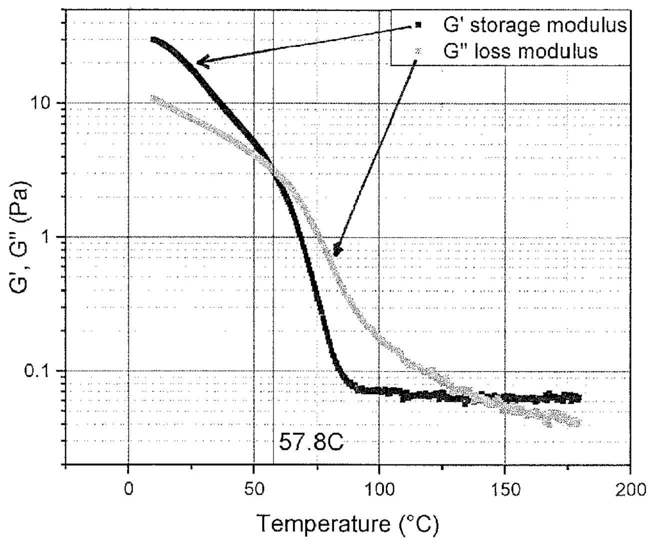
G', G'' (Pa)
Temperature (°C)
G' storage modulus
G'' loss modulus
57.8C
0.1
1
10
0
50
100
150
200

FIG. 2

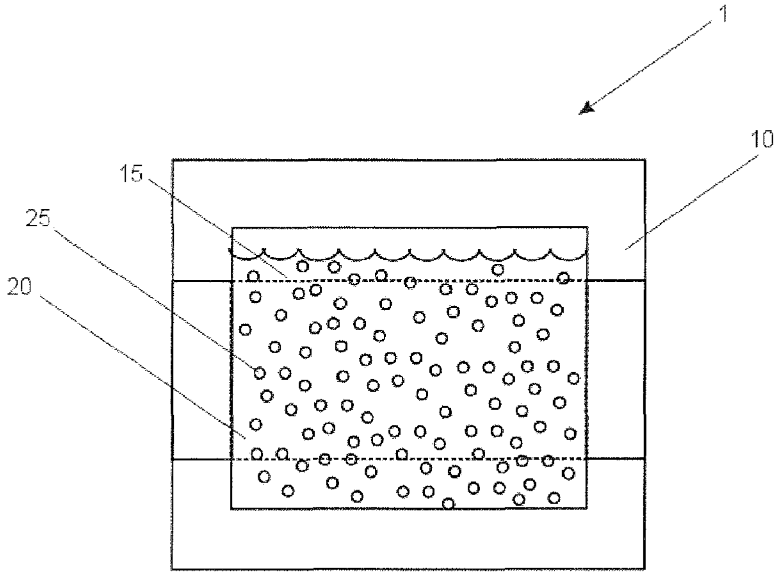

FIG. 3

Fig. 4a

Fig 4c

Nycodiel oil (reference)

Nycodiel + 6 wt.% LA2250 (oil-to-gel)

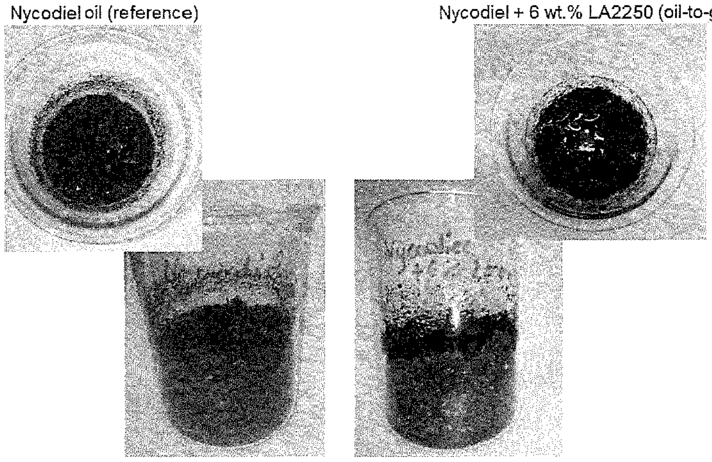

Fig. 4b

Fig. 4d

Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 2464

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	US 5 736 915 A (GOEDDE GARY L [US] ET AL) 7 April 1998 (1998-04-07) * abstract; table 3 * * column 5, line 13 - line 23 * * column 16, line 50 - line 60 * * column 20, line 7 - column 24, line 39 * -----	1-8	INV. H01F27/12 H01B3/20 H01F27/32
X	US 2017/009119 A1 (HAHN HYEOK [US] ET AL) 12 January 2017 (2017-01-12) * paragraph [0001] - paragraph [0004] * * paragraph [0012] - paragraph [0020] * * paragraph [0041] * -----	1,5,7	
A	US 9 260 645 B2 (BRUZDA KAREN J [US]; LAIRD TECHNOLOGIES INC [US]) 16 February 2016 (2016-02-16) * abstract * * column 1, line 14 - line 47 * * column 3, line 23 - column 4, line 14 * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01F H01B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	27 September 2018	Tano, Valeria

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 16 2464

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