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(54) COMPOSITE MAGNETIC INDUCTOR ELEMENT AND FABRICATION METHOD THEREOF

(57) Method of manufacturing a composite magnetic inductor element, the method comprising obtaining powdered magnetic charges by a grinding process of at least soft-ferrite magnetic elements; obtaining a magnetic polymer by mixing a first polymer with the powdered magnetic charges, the powdered magnetic charges being in a percentage selected, between 70% and 85% by weight of the total weight of the magnetic polymer, to provide a given magnetic inductance; and obtaining the magnetic inductor element by melting and injecting the magnetic polymer into a core mold or through a die, the magnetic inductor element being a magnetic core for an inductor device or a magnetic inductor pellet.

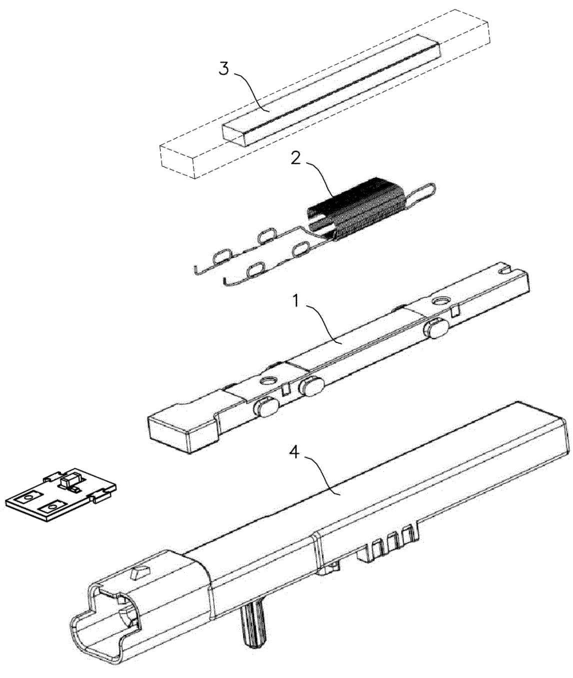

Fig. 1

EP 4 369 359 A1

Description

Technical field

[0001] The present invention is directed to a composite magnetic inductor element, such a magnetic core for an inductor device, or a magnetic pellet for the later fabrication of a magnetic core. The proposed composite magnetic inductor element is made of a mixture of a polymer and powdered magnetic charges the latter being obtained from recycled magnetic cores or parts thereof properly grinded.

Background of the Invention

[0002] EP3089176B1 discloses an elongated flexible inductor suitable for an antenna comprising a core and a winding made from a conductive element arranged around the core formed by at least two rigid magnetic cores made from ferromagnetic material. The EP3089176B1 further relates to a flexible polymer casing that surrounds the core and the polymer casing includes magnetic charges that work together to prevent magnetic flux dispersion in the coupling areas or interstices between said at least two magnetic cores, said flexible polymer casing including microfibers, microparticles and/or nanoparticles of a soft ferromagnetic material present alone or in any combination thereof inside the polymer matrix of said polymer casing, providing said magnetic charges.

[0003] EP3192084B1 refers to a soft magnetic core, including a ferromagnetic material arranged to form parallel magnetic paths within a core body that is made of a cured polymeric medium, said parallel magnetic paths being electrically insulated from each other by said polymeric medium, wherein said ferromagnetic material comprises a plurality of parallel, continuous, ferromagnetic elements embedded in said core body made of said polymeric medium, wherein said continuous ferromagnetic elements are spaced apart from each other.

[0004] The proposal of this invention is different to the quoted prior art.

[0005] Those prior art documents do not anticipate the fabrication of magnetic pellets which can be later used for the fabrication of composite magnetic cores, improving the logistic operations, nor the partial insertion of an electric component within the magnetic core for the connection of the electrically conductive coils, among other improvements provided by the present invention.

[0006] Also, the present invention proposed to obtain a composite magnetic core, or magnetic pellets for the later fabrication of a composite magnetic core, in which a large part of the raw material is the result of the recycling of magnetic cores that have finished their useful life.

[0007] The inventors have found that the new composite magnetic core can be obtained by a method providing that the magnetic core achieves magnetic properties (quality factor, etc.) similar to those of a virgin or composite core as already disclosed.

Description of the Invention

[0008] To that end, the present invention concerns to a fabrication method of a composite magnetic inductor element, as defined in claim 1.

[0009] The proposed method comprises the following steps:

- obtaining powdered magnetic charges by a grinding process of at least soft-ferrite magnetic elements;
- obtaining a magnetic polymer by mixing a first polymer with the powdered magnetic charges, the powdered magnetic charges being in a percentage selected, between 70% and 85% by weight of the total weight of the magnetic polymer, to provide a given magnetic inductance; and
- obtaining the magnetic inductor element by melting and injecting the magnetic polymer into a core mold or through a die, the magnetic inductor element being a magnetic core for an inductor device or a magnetic inductor pellet.

[0010] Preferably the powdered magnetic charges are ferrite particles or Mn-Zn ferrite particles.

[0011] The fabrication of a sintered ceramic magnetic core is one of the more energetic intensive processes involved in the fabrication of an inductive device, therefore the reduction in the energy required to obtain a magnetic core greatly contributes to reduce the overall carbon footprint of an inductor device.

[0012] Typically, the obtention of the magnetic polymer is achieved by mixing plastic pellets made of the first polymer with the powdered magnetic charges, for example in a hopper, and the later fusion of the plastic pellets, for example in a worm screw, producing the mixture with the powdered magnetic charges producing the magnetic polymer. In this example, the worm screw will push the melted magnetic polymer through nozzles into the core mold, preferably an array of core molds in the form of a plastic blisters, to produce magnetic cores or through a die to produce extruded composite magnetic inductor elements such magnetic pellets.

[0013] Preferably, the percentage of powdered magnetic charges is selected to obtain a composite magnetic inductive element not electrically conductive.

[0014] The composite magnetic inductor element requires much less energy to be produced than a sintered ceramic magnetic element such a sintered ceramic magnetic core.

[0015] A composite magnetic inductor element in the shape of a magnetic core can be used to fully, or partially, substitute a sintered ceramic magnetic core with minor losses in performance which can be compensated with a small increase in size of the magnetic core, but greatly reducing the carbon footprint produced.

[0016] Also, a composite magnetic inductor element in the shape of a magnetic pellet can be used as a precursor for the later production of a magnetic core. The fabrication of the magnetic pellets, and the later conversion of the magnetic pellets into a magnetic core slightly increases the energy consumption compared with the direct fabrication of the magnetic core from a mixture of plastic pellets and the powdered magnetic charges, but still requiring much less energy than the fabrication of a sintered ceramic magnetic core.

[0017] The use of magnetic pellets in the fabrication of magnetic cores greatly facilitates the logistic operations, the quality control and other aspects leading to a price reduction, which compensate the slight increase in the energy consumption.

[0018] According to that, the powdered magnetic charges is mostly or completely a soft-ferrite powder.

[0019] According to a preferred embodiment, the method further comprises separating, from functional sintered ceramic magnetic cores produced in a sintered ceramic magnetic core production line, defective sintered ceramic magnetic cores, for example broken or incomplete magnetic cores, and/or sintered ceramic magnetic scrap, and grinding in one or several stages said defective sintered ceramic magnetic cores and/or sintered ceramic magnetic scrap to obtain the powdered magnetic charges.

[0020] In the sintered ceramic magnetic cores production lines, certain percentage of the produced sintered ceramic magnetic cores are defective, are broken, or are incomplete and sintered ceramic scrap is produced. In accordance with the concept of the present invention those defective magnetic cores and/or sintered ceramic scrap, which has required a lot of energy to be produced, are the source material for the obtention of the powdered magnetic charges.

[0021] Additionally, or alternatively, the method comprises recycling discarded inductor devices by separating the sintered ceramic magnetic cores or parts thereof from other components of said inductor devices, such the electrically conductive coil, or the enclosure, and grinding said magnetic cores or parts thereof to obtain the powdered magnetic charges. Said separation can be produced by physical or chemical means, for example by a manual disassembly thereof, by crushing the inductive devices into small pieces, by melting or solving some components of the inductor device, etc., and by selecting from the portions of the inductor device those portions completely or mostly made of soft-ferrite material, for example by density separation, by magnetic separation, by optic separation, by melting temperature differences, etc. As a result of this recycling operation, soft-ferrite magnetic elements will be obtained. Some percentage of other materials, for example up to 5% in weight, could be mixed with the soft-ferrite magnetic elements obtained from this recycling operations. Those other materials will be also grinded and included as part of the powdered magnetic charges without jeopardizing the performance of the resulting composite magnetic element.

[0022] Preferably, the defective sintered ceramic magnetic cores and/or the sintered ceramic scrap and/or the recycled sintered ceramic magnetic cores or parts thereof are first crushed to sizes smaller than 10mm, and later further grinded into the powdered magnetic charges.

[0023] Preferably, the powdered magnetic charges have a size smaller than 400 μm, or smaller than 100 μm, or smaller than 20 μm. This fine grinding can be obtained, for example, using a planetary ball mill.

[0024] According to that, the powdered magnetic charges are recycled magnetic charges, greatly reducing the carbon footprint of the obtained composite magnetic element. Also, the first plastic can be recycled plastic to further reduce the carbon footprint.

[0025] According to an embodiment, before the injection of the melted magnetic polymer into the core mold, a solid soft-ferrite block can be inserted within the core mold, so that the melted magnetic polymer is overmolded around the solid soft-ferrite block. As a result, a hybrid magnetic core will be obtained. Preferably the solid soft-ferrite block is made of a Mn-Zn ferrite.

[0026] The hybrid magnetic core will have a better performance than a magnetic core of the same size and shape completely made of magnetic polymer but with a higher carbon footprint but will have a reduced carbon footprint than a magnetic core of the same size and shape completely made of solid soft-ferrite.

[0027] In practice it has been proven that, for example, a solid soft-ferrite block made of sintered ceramic soft-ferrite, constitutive of up to 50% or up to 40% of the volume of the magnetic core, the rest of the magnetic core being made of the magnetic polymer, provides a magnetic performance similar to, or merely slightly smaller (-1 to -2 dB) than, that of a magnetic core of the same size and shape but completely made of sintered ceramic soft-ferrite, but with a much lower carbon footprint.

[0028] The small reduction in magnetic performance can be compensated by a small increase in the general size of the magnetic core.

[0029] The magnetic core, with or without the solid soft-ferrite block therein, can be winded by at least one electrically conductive coil wound there around, providing an inductive device.

[0030] The at least one electrically conductive coil can be one or several independent coils wound around one X axis, and/or two or three independent coils wound around two or three orthogonal X and Y axis or X and Y and Z axis.

[0031] Preferably, the magnetic core includes winding channels formed on its external surface for guiding the winding of the electrically conductive coils.

[0032] After winding the at least one conductive coil around the magnetic core, the inductive device can be overmolding with a polymeric enclosure by inserting the inductive device in an enclosure mold and by melting and injecting a second polymer in the enclosure mold around the inductive device. The second polymer can be a mere isolating polymer made of plastic, or can be also magnetic polymer, increasing the performance of the resulting inductor device.

[0033] The second polymer can be the same magnetic polymer described above, so that the enclosure is part of the magnetic core, the electrically conductive coil being contained therein. Optionally, the second polymer is another magnetic polymer similar to the magnetic polymer described above but with powdered magnetic charges in a percentage lower than the percentage of powdered magnetic charges of the previously described magnetic polymer.

[0034] Also, the second polymer is preferably the same type of polymer as the first polymer to facilitate the recycling of the resulting inductor device.

[0035] The obtention of the magnetic polymer can further include mixing dispersant additives and/or flame retardant additives with the first polymer and the powdered magnetic charges.

[0036] Before the injection of the melted magnetic polymer in the core mold, an electric component, for example a circuit board or an electric connector, can be partially inserted in the core mold so that after the injection of the magnetic polymer said electric component is partially embedded in the magnetic core, attached thereto and partially projecting therefrom, and later the at least one electrically conductive coil is connected to said electric component.

[0037] According to a second aspect, the present invention is directed to a composite magnetic inductor element wherein the magnetic inductor element is a magnetic core for an inductor device, or a magnetic pellet, made of magnetic polymer comprising a mixture of a first polymer and powdered magnetic charges, the powdered magnetic charges being in a percentage selected, between 70% and 85% by weight of the total weight of the magnetic polymer, to provide a given magnetic inductance.

[0038] Preferably, the powdered magnetic charges have a size smaller than 400 μm, or smaller than 100 μm, or smaller than 20 μm, and/or the first polymer is selected among polyvinyl, polyethylene, polyimide, and polypropylene.

[0039] The magnetic core can further include an electrically conductive coil wound there around, forming an inductor device.

[0040] The composite magnetic inductor element described above will be preferably obtained by the previously described fabrication method.

[0041] It will also be understood that any range of values given may not be optimal in extreme values and may require adaptations of the invention to these extreme values are applicable, such adaptations being within reach of a skilled person.

Brief description of the Figures

[0042] The foregoing and other advantages and features will be more fully understood from the following detailed description of an embodiment with reference to the accompanying drawings, to be taken in an illustrative and non-limitative manner, in which:

Fig. 1 shows an exploded view of an inductor device including a parallelepiped solid soft-ferrite block overmolded with magnetic polymer forming a magnetic core winded with an electrically conductive coil, forming an inductor device, which is later overmolded with an plastic enclosure. This figure includes, drawn in a dashed line around the solid soft-ferrite block, the size that a magnetic core entirely made of sintered ceramic ferrite with magnetic properties equivalent to those of the hybrid magnetic core shown in this figure would have.

Detailed Description of the Invention and of particular embodiments

[0043] According to a preferred embodiment, the proposed fabrication method comprises separating, from functional sintered ceramic magnetic cores produced in a sintered ceramic magnetic core production line, defective sintered ceramic magnetic cores, for example broken or incomplete magnetic cores, and/or sintered ceramic magnetic scrap, and grinding said defective magnetic cores and/or sintered ceramic magnetic scrap to obtain the powdered magnetic charges.

[0044] Preferably, the powdered magnetic charges are grinded to a size smaller than 400 μm, or smaller than 100 μm, or smaller than 20 μm.

[0045] Additionally, or alternatively, the method comprises recycling discarded inductor devices by separating the sintered ceramic magnetic cores of said inductive devices, or parts thereof, from other components of said inductor devices, such the electrically conductive coil or the enclosure, and grinding said sintered ceramic magnetic cores or parts thereof to obtain the powdered magnetic charges.

[0046] The defective sintered ceramic magnetic cores and/or the sintered ceramic scrap and/or the recycled sintered ceramic magnetic cores or parts thereof are preferably first crushed to sizes smaller than 10mm, and later further grinded into the powdered magnetic charges.

[0047] The obtained powdered magnetic charges are then mixed with plastic pellets made of a first polymer, preferably polyvinyl, polyethylene, polyimide or polypropylene.

[0048] The plastic pellets mixed with the powdered magnetic charges are melted, typically in a worm screw, producing a melted magnetic polymer.

[0049] The powdered magnetic charges are mixed in a percentage selected between 70% and 85% by weight of the total weight of the magnetic polymer, to provide a given magnetic inductance to any composite magnetic induction element produced with the resulting magnetic polymer.

[0050] According to a first embodiment, the melted magnetic polymer is then injected, typically by said worm screw, into a plurality of core molds formed in a plastic blister to form a plurality of composite magnetic inductor elements in the form of magnetic cores 1.

[0051] According to a second embodiment, the melted magnetic polymer is then injected, typically by said worm screw, through a die to produce a rod which can be later cut into magnetic pellets. Those magnetic pellets can be later melted and injected into core molds for the production of magnetic cores 1.

[0052] The obtained magnetic core 1 can be wound by an electrically conductive coil 2 such a recycled cooper wire, forming an inductor device.

[0053] Such inductor device can be later inserted in an enclosure mold and overmolded with a second polymer to form an enclosure 4 there around, as can be seen in Fig. 1.

[0054] As can be seen drawn in Fig. 1, the size of the solid soft-ferrite block required to obtain a composite magnetic inductor element is much smaller than the size of a magnetic core entirely made of sintered ceramic ferrite, drawn in dashed line around the solid soft-ferrite block, with equivalent magnetic properties.

[0055] As this comparison shows, for an elongated inductor device with one electrically conductive coil wound there around, the solid soft-ferrite block contained inside the magnetic core can be up to 30% or 40% shorter than the overall length of the magnetic core.

[0056] According to an optional embodiment, the magnetic polymer is injected in the core mold with a solid soft-ferrite block 3 inserted therein, typically made of sintered ceramic Mn-Zn ferrite, the magnetic polymer being overmolded around the solid soft-ferrite block 3 forming the magnetic core 1. Preferably the solid soft-ferrite block 3 represents up to 50% of the volume of magnetic core 1, or up to 40%.

Claims

1. Method of manufacturing a composite magnetic inductor element, the method comprising:

obtaining powdered magnetic charges by a grinding process of at least soft-ferrite magnetic elements;

obtaining a magnetic polymer by mixing a first polymer with the powdered magnetic charges, the powdered magnetic charges being in a percentage selected, between 70% and 85% by weight of the total weight of the magnetic polymer, to provide a given magnetic inductance; and

obtaining the magnetic inductor element by melting and injecting the magnetic polymer into a core mold or through a die, the magnetic inductor element being a magnetic core (1) for an inductor device or a magnetic inductor pellet.

2. The manufacturing method according to claim 1 wherein the method comprises

separating, from functional sintered ceramic magnetic cores produced in a sintered ceramic magnetic core production line, defective sintered ceramic magnetic cores and/or sintered ceramic magnetic scrap, and grinding said defective magnetic cores and/or sintered ceramic magnetic scrap to obtain the powdered magnetic charges; and/or

recycling discarded inductor devices by separating sintered ceramic magnetic cores, or parts thereof, of said inductor devices from other components thereof and grinding said sintered ceramic magnetic cores or parts thereof to obtain the powdered magnetic charges.

3. The manufacturing method according to claim 1 or 2 wherein the defective sintered ceramic magnetic cores and/or the sintered ceramic scrap and/or the recycled sintered ceramic magnetic cores or parts thereof are first crushed to sizes smaller than 10mm, and later further grinded into the powdered magnetic charges.

4. The manufacturing method according to any one of the preceding claims wherein the powdered magnetic charges have a size smaller than 400 μm, or smaller than 100 μm, or smaller than 20 μm.

5. The manufacturing method according to any one of the preceding claims wherein the method comprises using the magnetic inductor pellets to further obtain a magnetic core (1) for an inductor device by melting the magnetic inductor pellets and injecting the resulting melted magnetic polymer into a core mold.

6. The manufacturing method according to any one of the preceding claims wherein the method comprises, before the injection of the melted magnetic polymer into the core mold, the insertion of a solid soft-ferrite block (3) within the core mold, the melted magnetic polymer being overmolded around the solid soft-ferrite block (3).

7. The manufacturing method according to any one of the preceding claims wherein the method comprises winding at least one electrically conductive coil (2) around the magnetic core (1), providing an inductive device.

8. The manufacturing method according to claim 7 wherein the method further comprises, after winding the at least one conductive coil (2) around the magnetic core (1), overmolding the inductive device with a polymeric enclosure (4) by inserting the inductive device in an enclosure mold and by melting and injecting a second polymer in the enclosure mold around the inductive device.

9. The manufacturing method according to claim 8 wherein the second polymer is the magnetic polymer or is another magnetic polymer with powdered magnetic charges in a percentage lower than the percentage of powdered magnetic charges of the magnetic polymer or is the same type of polymer as the first polymer to facilitate the recycling of the inductor device.

10. The manufacturing method according to any one of the preceding claims wherein the step of obtaining the magnetic polymer further includes mixing dispersant additives and/or flame retardant additives.

11. The manufacturing method according to any preceding claim wherein the method further comprises, before the injection of the melted magnetic polymer in the core mold, the partial insertion of an electric component, or of an electric component selected among circuit board or electric connector, so that after the injection of the magnetic polymer said electric component is partially embedded in the magnetic core, and later the at least one electrically conductive coil is connected to said electric component.

12. A composite magnetic inductor element wherein the magnetic inductor element is a magnetic core (1) for an inductor device, or a magnetic pellet, made of magnetic polymer comprising a mixture of a first polymer and powdered magnetic charges, the powdered magnetic charges being in a percentage selected, between 70% and 85% by weight of the total weight of the magnetic polymer, to provide a given magnetic inductance.

13. The magnetic inductor element according to claim 12 wherein the powdered magnetic charges have a size smaller than 400 μm, or smaller than 100 μm, or smaller than 20 μm.

14. The magnetic inductor element according to claim 12 or 13 wherein the first polymer is selected among polyvinyl, polyethylene, polyimide, and polypropylene.

15. The magnetic inductor element according to claim 12, 13 or 14 wherein the magnetic core (1) further includes an electrically conductive coil (2) wound there around, forming an inductor device.

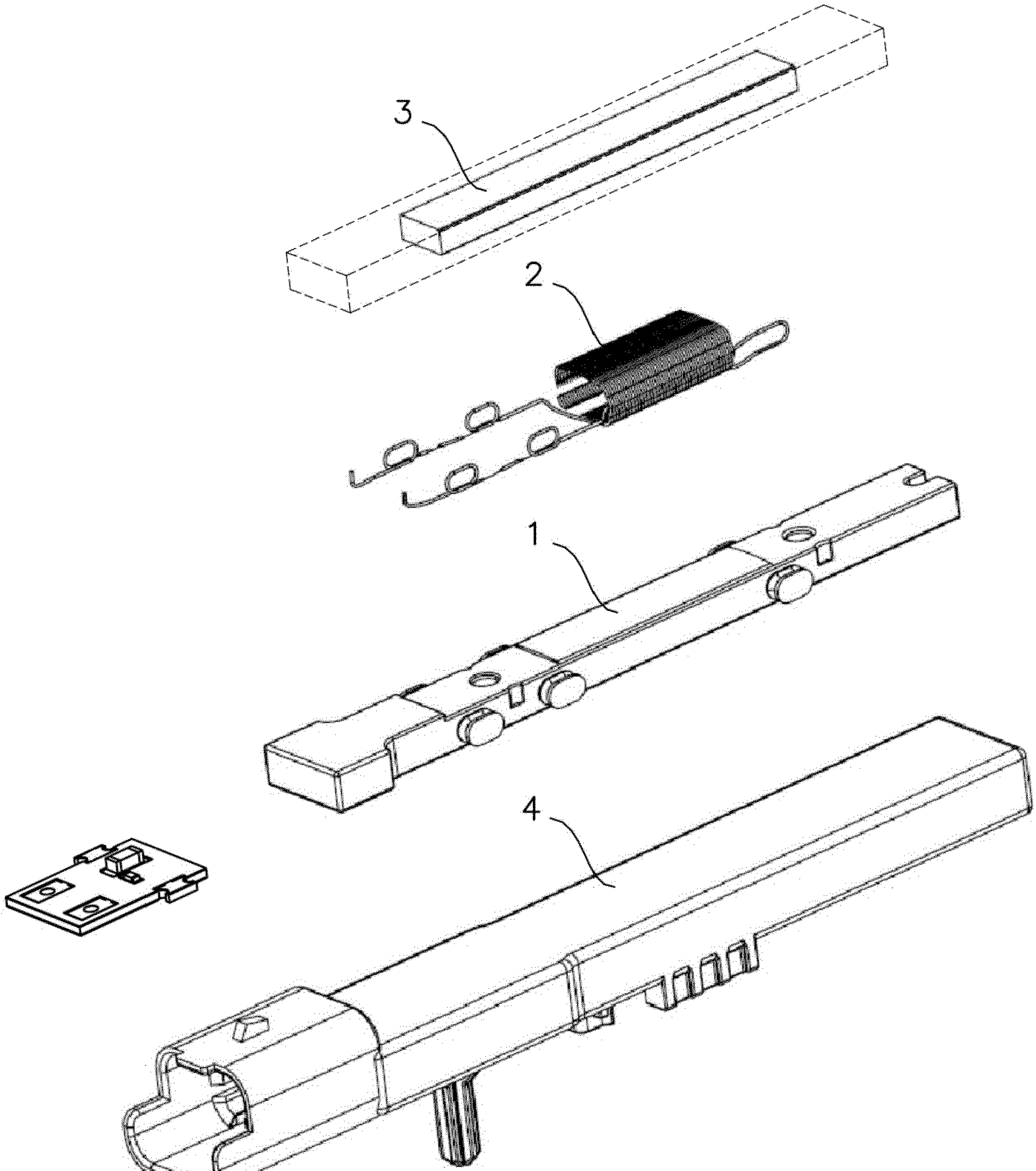

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 22 38 3092

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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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			H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	2 May 2023	Primus, Jean-Louis

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CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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