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(54) **A TOROIDAL MAGNETIC CORE WITH WINDINGS**

(57) The subject of the invention is a toroidal magnetic core with windings and a method of manufacturing such core. The invention has an application as a transformer or an inductor in the electrical field, especially for high voltage application. A toroidal magnetic core with windings characterised in that it comprises a metal ring (1) which is covered with insulating coating (2) on which a conductive layer (3) of a metal material is disposed around the core (1) for making at least one conductive

winding (5) helically disposed around the core (1) on the insulating coating (2). The windings (5) have singular turns (3') and between each turn (3') of the winding (5) a helical groove (4) is placed for insulating the neighbouring turns (3') one from of the other and the groves (4) have a depth equal to a thickness of a conductive layer (3) from which the winding (5) is made during a process of etching the layer (3).

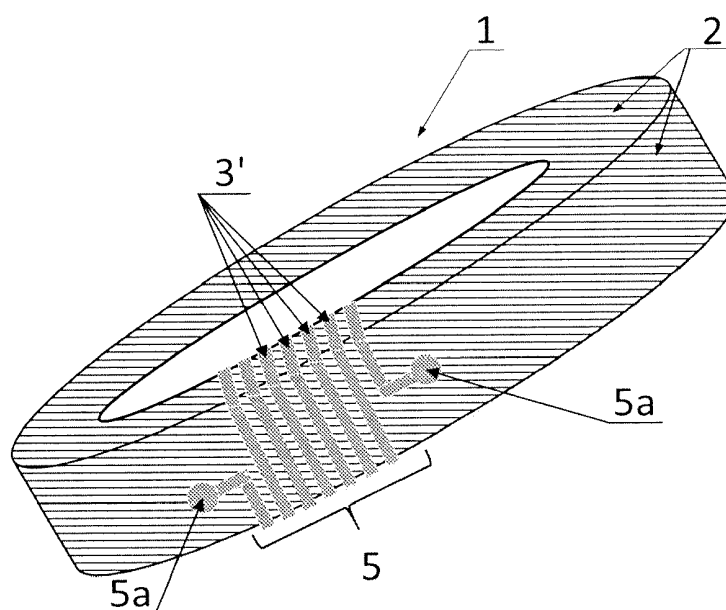


Fig. 1

## Description

**[0001]** The subject of the invention is a toroidal magnetic core with windings and a method of manufacturing such core. The invention has an application as a transformer or an inductor in the electrical field, especially for high voltage application.

**[0002]** Toroidal transformers or inductors are becoming ever more popular. Their windings are usually done using toroidal winding machines and magnet wire. There are however certain applications where winding on a toroidal core becomes a bit cumbersome. Traditional winding may cause some issues related to the insulation quality when applied to the high insulation voltage transformer, as the geometry of the winding influences the field distribution, moreover the repeatability of the geometry of winding is not that easy to keep with the normal winding method. The traditional toroidal winding when applied to the high insulation voltage transformer may cause some tissues when trying to achieve high voltage insulation between the windings which are relatively close to each other. The issues are related mostly to uneven field distribution caused by the geometry of the winding as well as difficulty to properly fill the space between the windings with the dielectric material. High insulation voltage between two separate electrical networks which are residing in close proximity to each other is achievable by the use of dielectric material with high dielectric strength. To assure the long term reliability of such insulation the dielectric material between the two networks must be free of any voids which may cause partial discharges leading to the degradation of the insulating barrier. As an insulating medium, epoxy, polyurethane or silicone potting is used in the electronic equipment whose electronic networks must be insulated from each other. The insulation degradation is related mostly to uneven field distribution caused by the geometry of the winding as well as difficulty to properly fill the space between the windings with the dielectric material. Often the potting applied to the traditionally wound transformer does not penetrate the winding living small air pockets which become a source of the partial discharges. In order to omit deficiencies of the prior art there is a need for design of an improved magnetic core with windings.

**[0003]** US patent application US 2005/0156703 describes a toroidal winding whose aim is to filter unwanted noise from electrical connectors and devices. Here the toroid comprises a metal ring surrounded by a plate-able and non-plate-able plastic cast, and a conductive layer deposited onto the plate-able cast. The toroid is manufactured by first molding the non-plate-able plastic, having helically patterned grooves, around the metal ring. The plate-able plastic is then molded into the grooves of the non-plate-able plastic. A conductive plating is then electrodeposited onto the plate-able plastic to form a helically patterned winding around the metal ring. The method according to this solution allows for manufacturing a toroid in automatic process easier than in comparison

with the traditional winding conductors. This solution although feasible, seems quite expensive and difficult to manufacture, moreover it does not address the issues mentioned above. Even though the geometry of the windings is repeatable here, hence the manufacturing issues related to geometry field distortion are resolved, the method calls for casts associated with windings and casts are known for having air voids inside. It also seems that the spacing between the turns are relatively large due to the necessity of having two kinds of casts. This implies field distortion.

**[0004]** The essence of a toroidal magnetic core with windings according to the invention is that the core comprises a metal ring which is covered with insulating coating, on which a conductive layer of a metal material is disposed around the core. The conductive layer is disposed for making at least one conductive winding helically placed around the core on the insulating coating. The windings have singular turns and between each turn a helical groove is placed for insulating the neighbouring turns one from of the other. The grooves have a depth equal to a thickness of a conductive layer from which the winding is made during a process of etching the layer. Preferably the widths of each turn are bigger than the width of each groove.

Preferably the conductive winding has their ends adapted as terminals for electrical connection with any electrical conductors.

Preferably the insulating coating is made from an epoxy resin.

Preferably the conductive layer is made of copper.

**[0005]** An essence of the method of manufacturing a toroidal magnetic core with windings where the windings are helically disposed around a toroidal ring depends on the following steps:

- manufacturing the toroidal ring from the ferromagnetic material,
- covering a whole surface of the ring with an insulating coating,
- disposing on the entire surface of the coating a conductive layer,
- choosing at least one part of the ring with the conductive layer for etching in the layer some grooves helically disposed on the ring,
- etching grooves in the layer by one of the known method of etching until receiving a clear surface of insulating layer of the ring,
- leaving the unetched parts of conductive layer as electrical conductive winding disposed between the helical grooves and having a singular turns helically disposed around the chosen part of the ring.

**[0006]** Preferably the method comprises an additional step of adapting ends of the conductive windings as electrical terminals of the windings.

Preferably the step of etching grooves in the conductive layer is carried out on two parts of the ring forming two windings disposed an opposite each other.

Preferably the step of etching grooves in the conductive layer is carried out by classical etching like for etching the printed circuit boards or by laser burning.

Preferably the conductive layer is made of cooper.

Preferably the insulating layer made of epoxy resin.

A toroidal transformer characterized in that it has a ring with windings according to claims 1-5.

A toroidal inductor characterized in that it has a ring with windings according to claims 1-5.

**[0007]** The main advantage of the invention is to provide a transformer core for high voltage application which has a simple construction and forms more reliable unit being a transformer or inductor. The core has the windings placed very tight, which is important for high voltage application as this allows linearization of the field between the low and the high voltage windings, reducing the stress on the insulating material. The winding together with the core create relatively flat equipotential surface, hence the deficiency of the traditional winding where the geometry can vary, are eliminated. The new process of manufacturing the core according to the invention improves the geometrical repeatability of windings allowing to create uniform flat equipotential surface of the winding, which will promote a better field distribution between the primary and the secondary windings. Due to this fact the assembly of the transformer or inductor allows to eliminate issues related to potting, helping to achieve good coherent layer of the insulation between the windings.

**[0008]** A toroidal core according to the invention is presented in the drawing where: Fig.1 shows a toroidal magnetic core with one singular winding on the core in an axonometric view, and Fig.2 shows the toroidal magnetic core with the singular winding in the cross-section of the core.

**[0009]** A toroidal magnetic core comprises a ring 1 covered by a layer of an insulating coating 2. The ring 1 is made of a ferromagnetic material. The insulating coating is an epoxy coating or other type of insulating material. The thickness of the insulating layer 2 should be selected according to the technical requirement of a transformer or inductor for which the core is designed. On the insulating layer 2, a plate-able conductive layer 3 is disposed which is indicated in the drawing by a dashed lines. The plate-able layer 3 is made of conductive metal, preferably copper. The plate-able layer 3 becomes a material for etching in it or laser burning the grooves 4 which are helically disposed on at least one part of the ring 1 coated with the insulating layer 2. The grooves have a thickness equal of the thickness of the plate-able conductive layer 3. The unetched surfaces of the layer 3 create a helical electrical winding 5 of a toroidal core. The widths of the unetched surfaces of the layers 3 forming turns 3' preferably

are bigger than the width of the grooves 4 what has a practical meaning in creating very tight winding 5. The winding 5 are ended by terminals 5a to which supply leads are attached by soldering or welding. The leads are not presented on the drawing. The winding 5 are disposed on the core in as many places as practical however in the drawing presents only one singular windings.

**[0010]** The method of manufacturing the core according to the invention comprises the following steps:

- manufacturing the toroidal ring 1 from the ferromagnetic material,
- covering the whole surface of the ring 1 with an insulating coating 2,
- disposing on the entire surface of ring coating 2 a conductive layer 3,
- choosing a part of the ring 1 with the conductive 3 layer for etching in the layer 3 some grooves 4 helically disposed on the ring 1,
- etching grooves 4 in the layer 3 by one of the known method of etching until receiving the clear surface of insulating layer 2 of the ring 1,
- leaving the unetched parts of layer 3 as electrical conductive winding 5 disposed between the helical grooves 4 and having a singular turns 3' helically disposed around the chosen part of the ring 1.

**[0011]** Additionally the method comprises the step of adapting the ends of the conductive windings 5 for terminals 5a of the windings.

**[0012]** After the process of etching grooves the in the conductive layer 3, creating a helically disposed grooves 4 down to the insulating layer 2, the remaining part of the conductive layer 3 creates a winding 5 of a transformer or an inductor. The conductive surface of the winding 5 could be etched in many different ways, depending on the required properties of transformer or the inductor. One of the options is to leave a conductive layer covering almost all toroidal ring and creating etched traces. This is practical for some specific application create an equipotential surface. The windings 5 are etched by the process similar to the one used for etching the printed circuit boards. Alternatively the windings could be etched by laser burning the narrow gaps in the conductive layer 3. This process allows to create very tight winding 5. At the same time the winding together with the core create relatively flat "equipotential" surface, hence the deficiencies of the traditional winding should be eliminated. This allows for equalization of the field between the low and high voltage windings, hence improve partial discharge situation. The winding would create one coherent block together with the core, which would create a uniform surface The preparation of the terminals 5a of the winding

5 is performed by the known way for making electrical connection by welding or soldering. The step of etching groves 4 in the conductive layer 3 is carried out on at least one part of the ring 1 but it is provided in many part of the ring 1 what is not presented in the drawing. Preferably the step of etching groves 4 in the conductive layer 3 is carried out in two parts of the ring forming two windings 5 disposed an opposite each other.

## Claims

1. A toroidal magnetic core with windings **characterised in that** it comprises a metal ring (1) which is covered with insulating coating (2) on which a conductive layer (3) of a metal material is disposed around the core (1) for making at least one conductive winding (5) helically disposed around the core (1) on the insulating coating (2); the windings (5) have singular turns (3') and between each turn (3') of the winding (5) a helical groove (4) is placed for insulating the neighbouring turns (3') one from of the other and the groves (4) have a depth equal to a thickness of a conductive layer (3) from which the winding (5) is made during a process of etching the layer (3).
2. A core according to claim 1, **characterised in that** the widths of the turn (3') are bigger than the width of the groove (4).
3. A core according to claims 1-2, **characterised in that** the conductive winding (5) has their ends (5a) adapted as terminals for electrical connection with any electrical conductors.
4. A core according to claim 1, **characterised in that** the insulating coating (2) is made from an epoxy resin.
5. A core according to claim 1, **characterised in that** the conductive layer (3) is made of copper.
6. A method of manufacturing a toroidal magnetic core with windings (5) where the windings are helically disposed around a toroidal ring (1) comprising the steps of:

- manufacturing the toroidal ring (1) from the ferromagnetic material,
- covering a whole surface of the ring (1) with an insulating coating (2),
- disposing on the entire surface of the coating (2) a conductive layer (3),
- choosing at least one part of the ring (1) with the conductive layer (3) for etching in the layer (3) some groves (4) helically disposed on the ring (1),

- etching groves (4) in the layer (3) by one of the known method of etching until receiving a clear surface of insulating layer (2) of the ring (1),
- leaving the unetched parts of layer (3) as electrical conductive winding (5) disposed between the helical groves (4) and having a singular turns (3') helically disposed around the chosen part of the ring (1).

7. A method according to claim 6, **characterized in that** it comprising additional step of adapting ends of the conductive windings (5) for electrical terminals (5a) of the windings.
8. A method according to claim 6, **characterized in that** the step of etching groves (4) in the layer (3) is carried out on two parts of the ring (1) forming two windings (5) disposed an opposite each other.
9. A method according to claim 6, **characterized in that** the step of etching groves (4) in the layer (3) is carried out by classical etching like for etching the printed circuit boards or by lase burning.
10. A method according to claim 6, **characterized in that** the conductive platable layer (3) is carried out from cooper.
11. A method according to claim 6, **characterized in that** the insulating layer (2) is carried out from epoxy resin.
12. A toroidal transformer **characterized in that** it has a ring (1) with windings (5) according to claims 1-5.
13. A toroidal inductor **characterized in that** it has a ring (1) with windings (5) according to claims 1-5.

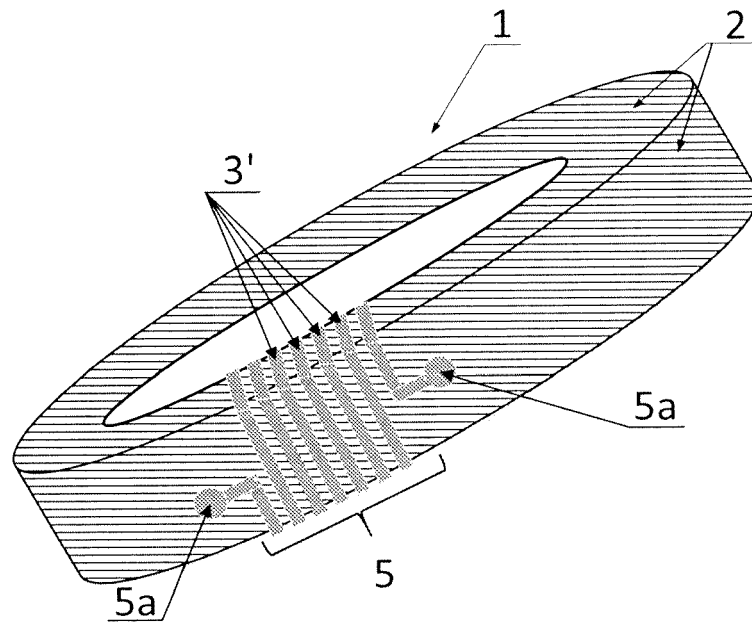


Fig. 1

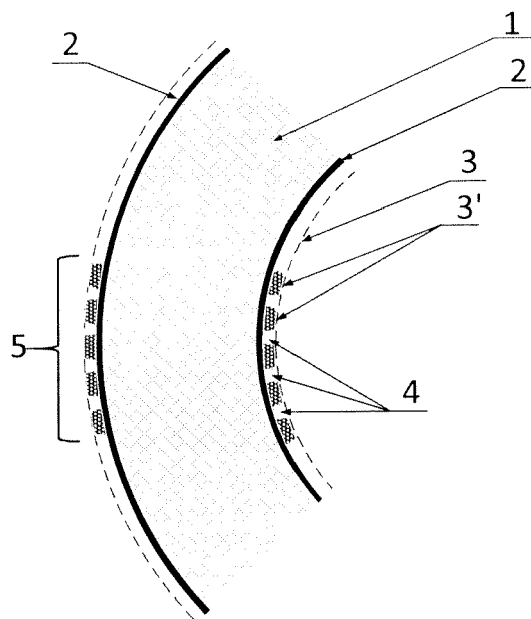


Fig. 2



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Application Number  
EP 16 46 0063

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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                    |                                                                                                                                                 |                                                                                                                                                                                                                                                                              |                                             |
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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<br><b>Munich</b>                                                                                                                                                                                                                       |                                                                                                                                                 | Date of completion of the search<br><b>3 February 2017</b>                                                                                                                                                                                                                   | Examiner<br><b>Weisser, Wolfgang</b>        |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |                                                                                                                                                 | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                             |

EPO FORM 1503 03.82 (P04C01)

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