Abstract: The present invention relates to the shielding of coils of transformers, in particular, to a coil for a transformer and a transformer with the coil. A coil (100) for a transformer with a coil body (102) is provided. The coil body (102) comprises a wound conductor (201). The coil (100) further comprises an insulation material (203) attached to the wound conductor (201), and a field control layer arrangement (200) for reducing the maximum field strength of an electric field generated in the coil (100). Further, a supporting device (202) in a U-shape in the form of a ring (205) with sidewalls for supporting the wound conductor (201) is provided. At least one first field control layer (301) of the field control layer arrangement (200) is applied at edges (205) of the wound conductor (201). At least one second field control layer (204) of the field control layer arrangement (200) is provided, wherein the supporting device (202) comprises at least one of the second field control layers (204).

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DESCRIPTION

TRANSFORMER WITH FIELD CONTROL LAYER ARRANGEMENT

FIELD OF THE INVENTION

The invention relates to the shielding of coil transformers. In particular, the invention relates to a coil for a transformer, a transformer with the coil, and to a method of manufacturing the coil.

BACKGROUND OF THE INVENTION

In the field of medium and high voltage applications transformers are widely used.

Transformers are generally insulated by an insulation material comprising a thermoset such as epoxy and may further comprise glass reinforcement such as a glass filler. Small transformers from 50 VA up to 3 kVA are encapsulated by a thermoplastic.

SUMMARY OF THE INVENTION

It may be seen as an object of the invention to provide an improved, flexible and efficient shielding for a coil of a transformer.

This object is achieved by a coil for a transformer, by a transformer comprising the coil, and by a method of manufacturing the coil according to the independent claims. Further embodiments are evident from the dependent claims.

According to one embodiment of the invention a coil for a magnetic component with at least one coil body with a wound conductor is provided. The coil comprises an insulation material attached to the wound conductor, and a field control layer arrangement for reducing the maximum field strength of an electric field generated in the coil.

The insulation material may be moulded to the wound conductor. The field control layer arrangement may have a high permittivity material with a permittivity of about 10, and the insulation material may have a low permittivity. The field control layer arrangement may
be injection-moulded around the wound conductor. The field control layer arrangement may reduce the maximum field strength of the coil by 50% compared to a coil without a field control layer arrangement and refractive field control may be provided by the field control layer arrangement. The field control layer arrangement may comprise a material selected from the group consisting of a composite material comprising doped ZnO varistor powder with a filler, in particular with Ti03 or BaTi03 filler. Due to the difference in permittivity between the grading layer and the insulation material, the electric field concentrates in the insulation material and is reduced at the with high permittivity layer coated coil corners or coil edges. The field control layer arrangement may comprise a first field control layer which is applied at edges of the wound conductor and may comprise at least one second field control layer. The coil further comprises a supporting device for supporting the wound conductor, wherein the supporting device comprises at least one of the first and/or second field control layers.

The insulation material may be a thermoplastic material instead of a thermosetting material which may make a curing cycle unnecessary when manufacturing the magnetic component, thus decreasing the production time of the magnetic component.

According to another embodiment of the invention the permittivity ratio of the insulation material to the field control layer arrangement is 1 to x, wherein x is 1.5 to 20, in particular 2 to 5 thereby controlling the electric field.

Such a refractive field control or control of the electric field may be achieved by a specific arrangement of materials with different permittivity; for example materials or devices with a permittivity ratio of 1 to 1.5-20, particularly 1 to 2-5, may be arranged adjacent to each other or over one another thereby enabling the refractive field control or control of the electric field generated in the coil.

According to another embodiment of the invention the magnetic component is a transformer.
According to another embodiment of the invention the magnetic component is a reactor. The coil may thus be a reactor coil.

The reactor may be a cooling reactor with voltage levels up to 36 kV or higher, may have a single or three phases, and may be either air cored, iron cored, or of a shell type.

The first field control layer may be applied at the inner edges of the wound conductor facing another conductor, such as a LV conductor, for example, and/or at the outer edges of the conductor. The first field control layer may comprise rounded edges and may have the same features as the above mentioned features of the field control layer arrangement.

According to another embodiment of the invention the wound conductor is in form of a foil and may be wound around the supporting device enabling a faster manufacturing of the coil compared to a manufacturing of the coil wherein the conductor is in form of a wire possibly wound around the supporting device being a further embodiment of the invention.

The first field control layer may be part of the supporting device, and a second field control layer may also be part of the supporting device, possibly applied at the first field control layer. More than one first field control layer may be part of the supporting device, possibly arranged or applied next to each other, and more than one second field control layer may be part of the supporting device, possibly arranged or applied next to each other. First and second field control layers may be applied in an alternating way to each other being part of the supporting device.

The at least one second field control layer may be a high epsilon layer. The at least one second field control layer may have the same features as the above mentioned features of the field control layer arrangement.

According to another embodiment of the invention the coil further comprises a plurality of coil bodies. Each coil body of the plurality of coil bodies is electrically connected to another coil body of the plurality of coil bodies forming a coil body stack, the stack defining a stack axis, or the coil. The uniform cross-section of each of the plurality of coil
bodies may be a non-circular cross-section and the cross-section is in a plane perpendicular to the stack axis.

Such a coil may provide for considerable cost-savings, especially, for example, for transformers with low ratings. These cost-savings may be provided mainly from faster production cycles compared to a production of a single non-modular coil or in other words one coil body. The coil as described above may provide a high degree of standardization concerning the manufacturing of the coil enabling variable sizing of the coil and thus time and cost savings compared to a manufacturing of a non-modular coil which is generally designed for manufacturing a defined size of a transformer. The coil with the non-circular cross-section may further enable a reduction of the core steel, as the distance between phases of a transformer may be reduced and thereby less core steel may be used, also if the cores are stacked, for example of cut metal sheets. A coil with coil bodies with a uniform non-circular cross-section as described above may enable a faster manufacturing of the core of the transformer. Manufacturing a non-circular core by conventional stacking of cut metal sheets may be more efficient than manufacturing a circular core since all metal sheets may have the same width. Furthermore the transformer with a non-circular cross-section may be built more compact compared to a core with a circular cross-section. The coil may be a modular coil and the transformer may be a dry transformer or a dry distribution transformer. The coil body may be a modular disk or a disk. The disk or modular disk may comprise a supporting device with a thereto wound conductor, wherein an insulation material may be attached to the supporting device and the conductor for insulating the supporting device and the conductor.

The electrical connecting of the coil bodies to each other may comprise the steps of removing enamel of the connecting means at each coil body of the plurality of coil bodies and crimping the connecting means of each coil body of the plurality of coil bodies to a connecting means of an adjacent coil body of the plurality of coil bodies.

According to another embodiment of the invention the coil body comprises at least one high voltage (HV) coil body.

According to another embodiment of the invention the coil body comprises at least one low voltage (LV) coil body.
The terms high voltage and low voltage may be understood in such a way that high voltage is higher than low voltage according to another embodiment of the invention without limiting high voltage and low voltage to specific voltage levels.

A coil with coil bodies of a modular type or in other words a coil of a modular type means that HV and/or LV windings may be adapted as disc windings which may be moulded and which may have two connections or terminals such that the disc windings are stackable.

High voltage and low voltage coils may be combined in one coil body according to another embodiment of the invention.

Furthermore only high voltage coils may be in one coil body and only low voltage coils may be in one coil body.

The high voltage coil may be arranged at a secondary possibly low voltage coil comprising a secondary or low voltage coil conductor in insulating material.

According to another embodiment of the invention the non-circular cross-section of the coil is a cross-section selected from the group consisting of a rectangular, a hexagonal, an oval, and a polygonal cross-section.

Such a coil with a non-circular cross-section or an oval cross-section may provide for a compact modular arrangement of the cores of the transformer and the transformer itself.

According to another embodiment of the invention the coil may further comprise a locking means for preventing rotation of adjacent coil bodies of the plurality of coil bodies. By locking means a locking system or locking arrangement is meant that may comprise more than one locking devices.

According to another embodiment of the invention the locking means comprises a through-hole in each of the plurality of coil bodies and a rod being adapted to pass through the through-hole of each of the plurality of coil bodies.
The rod may be a threaded rod fitting to threads in the through-holes. Two through-holes may be arranged on opposite sides of the coil bodies and two rods may each pass through one of the two through-holes preventing the coil bodies from rotating among each other.

According to another embodiment of the invention the locking means comprises a latch arranged at each of the plurality of coil bodies in a recess arranged at each of the plurality of coil bodies such that the latch of the coil bodies of the plurality of coil bodies is adapted to fit to the recess of an adjacent coil body of the plurality of coil bodies.

Such a latch-recess locking mechanism may prevent the rotation of the coil bodies among each other efficiently, wherein each coil body may be easily stacked to another coil body. There may be more than one recess and more than one latch arranged at each of the coil bodies. Eight latches and eight recesses may be arranged equispaced at each of the coil bodies. The recess and the latch may be part of the coil body and both may have one of a circular, a rectangular, a polygonal, a non-circular, a hexagonal, and a triangular form. Furthermore the latch may be pin-like and the recess may be hole-like.

According to another embodiment of the invention the locking means comprises a snap-fit connection arranged at adjacent coil bodies of the plurality of coil bodies. The snap-fit connection may comprise a clamp and a matching counterpart being arranged at each of the plurality of coil bodies. There may be a plurality of clamps and counterparts arranged at each of the plurality of coil bodies, for example three clamps and three counterparts per coil body.

According to another embodiment of the invention the coil further comprises a guiding element for the electrical connection, e.g. in form of a clamp connecting or crimp connecting the plurality of coil bodies and for clamp or crimp connecting the coil bodies to a further coil of a transformer. The guiding element may be arranged at each of the conductors of the plurality of coil bodies.
According to another embodiment of the invention the wound conductor is a high voltage conductor and an insulation material is attached to a low voltage conductor. The attached high voltage conductor is combined with the attached low voltage conductor surrounding a core of the transformer, and the magnetic component, respectively. At least one of the first and second field control layers is applied at least at one edge of the high voltage conductor opposite of the low voltage conductor.

The first and/or second field control layers may be applied at the inner edges of the high voltage conductor facing the low voltage conductor, and/or at the outer edges of the high voltage conductor not facing the low voltage conductor. The insulation material may be moulded to the low voltage conductor.

According to another embodiment of the invention the plurality of coil bodies is a plurality of high voltage coil bodies, forming a high voltage coil body stack, and the insulation material is attached to the high voltage coil body stack instead of being attached to the wound conductor of each high voltage coil body of the plurality of high voltage coil bodies separately. An insulation material is attached to a low voltage conductor. The high voltage coil body stack is combined with the attached low voltage conductor surrounding a core of the transformer, and the magnetic component, respectively. At least one of the first and second field control layers is applied at least at one edge of the high voltage conductor opposite of the low voltage conductor.

The first and/or second field control layers may be applied at the inner edges of the high voltage conductor facing the low voltage conductor, and/or at the outer edges of the high voltage conductor not facing the low voltage conductor. The insulation material may be moulded to the high voltage coil body stack. The insulation material may be moulded to the low voltage conductor.

According to another embodiment of the invention the plurality of coil bodies is a plurality of high voltage coil bodies, forming a high voltage coil body stack, and the high voltage coil body stack may be combined with a low voltage conductor using centring elements at the front and back ends of the high voltage coil body stack and the low voltage conductor assuring a constant distance between the high voltage coil body stack and the
low voltage conductor. The insulation material is attached to the high voltage coil body stack and the low voltage conductor together instead of being attached to the wound conductor of each high voltage coil body of the plurality of high voltage coil bodies separately. The high voltage coil body stack and low voltage conductor surround a core of the transformer, and the magnetic component, respectively. At least one of the first and second field control layers is applied at least at one edge of the high voltage conductor opposite of the low voltage conductor.

The first and/or second field control layers may be applied at the inner edges of the high voltage conductor facing the low voltage conductor, and/or at the outer edges of the high voltage conductor not facing the low voltage conductor. The insulation material may be moulded to the high voltage coil body stack and the low voltage conductor.

According to another embodiment of the invention a transformer with a coil of anyone of the above mentioned embodiments is provided. The core of the transformer may have a cross-section corresponding to the cross-section of the coil. The core may be an amorphous core.

The core may be built from thin sheets which are insulated against each other for minimizing the losses from Eddy currents. Concerning the material of the sheets the following steel qualities for the sheets may be used: Standard core steel (usually low C content of less than 0.1% and alloyed with Si of usually less than 3%); grain oriented core steel, wherein the cold rolling of steel orients the magnetic domains which leads to good loss properties in the rolling direction; amorphous core steel. The core of the transformer may be stacked or wound, wherein the core may be wound around the mandrel in a first step, cut at one position in a second step, spread/open up for placing the low voltage and high voltage of the transformer in a third step, and the low voltage and high voltage coils may be placed at the core in a fourth step. Four equal wound cores of a transformer may be arranged next to each other being combined by three high voltage and low voltage coils forming the transformer. Two equal wound small cores and one large wound core could be combined by three high voltage and low voltage coils forming a transformer according to a further embodiment.
According to another embodiment of the invention the transformer further comprises a second coil of anyone of the above-mentioned embodiments and a third coil of anyone of the above-mentioned embodiments, wherein each of the first, second and third coils surrounds the core. The first, second and third coils are arranged in a triangular way next to each other forming a compact transformer.

Due to the minimal distance of the transformer axes to each other and due to the non-circular cross-sections of the coils in a plane perpendicular to the transformer axes the transformer with triangular arrangement of the coils may provide a greater mechanical stability and a more compact design compared to transformers with coils with a circular cross-section, and also compared to a linear arrangement of the coils. A triangular arrangement of coils with a circular cross-section may provide for a minimized distance of the coil axes to each other and thus a better mechanical stability and space-saving compared to a linear arrangement of coils with a non-circular cross-section.

According to another embodiment of the invention the transformer further comprises a second coil of anyone of the above-mentioned embodiments and a third coil of anyone of the above-mentioned embodiments, wherein each of the first, second and third coils surrounds the core. The first, second and third coils are arranged in a linear way next to each other forming a compact transformer.

Such a transformer with a linear arrangement of coils with non-circular cross-sections in a plane perpendicular to the transformer axes or to the core limbs may be built more compact due to a possible more room saving arrangement of the non-circular cross-section coils, for example at edges of the coils, compared to a linear arrangement of coils with circular cross-sections.

A transformer with a plurality of coils according to anyone of the above mentioned embodiments may be arranged next to each other in the most compact room-saving way depending on the non-circular shape of the cross-section of each of the plurality of coil bodies of the plurality of coils such as a triangular way for a hexagonal, and for an oval-cross section or for a cross-section comprising a combination of a non-circular and a circular cross-section. The plurality of coils may be arranged in line, for example three
coils next to each other, forming a transformer, wherein each coil body of the plurality of coil bodies of the plurality of coils of the transformer may have one of a rectangular, hexagonal, oval, non-circular, and polygonal form, or a combination of a circular and a non-circular form. Each core may be surrounded by a low voltage coil which is surrounded by a high voltage coil.

According to another embodiment of the invention a method of manufacturing a coil for a transformer is provided, with the steps of winding a conductor of a coil body around a supporting device of the coil body, applying at least one of a first and second field control layer of a field control layer arrangement at edges of the wound conductor, attaching an insulation material to the conductor and the supporting device. The field control layer arrangement is adapted for reducing the maximum field strength of an electric field generated in the coil. The insulation material may be moulded to the conductor and the supporting device.

According to another embodiment of the invention the method of manufacturing a coil for a transformer is provided, wherein the permittivity ratio of the insulation material to the field control layer arrangement is 1 to x, wherein x is 1.5 to 20, in particular 2 to 5, thereby controlling the electric field.

According to another embodiment of the invention the method further comprises the steps of stacking each of the conductors and supporting devices to a coil and electrically connecting each coil body of a plurality of coil bodies to another coil body of the plurality of coil bodies.

According to another embodiment of the invention the method further comprises the step of moulding the supporting device. The moulding may comprise of an injection moulding of the supporting device by a two component injection moulding process using a first component comprising a second field control layer of the field control layer arrangement and a second component.
These and other aspects of the present invention will become apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject-matter of the invention will be explained in more detail in the following text with reference to exemplary embodiments which are illustrated in the attached drawings.

Fig. 1A schematically shows a cross-sectional view of a coil for a transformer according to an embodiment of the invention.

Fig. 1B schematically shows a cross-sectional view of a coil for a transformer according to another embodiment of the invention.

Fig. 2 schematically shows a cross-sectional view of a coil for a transformer according to another embodiment of the invention.

Fig. 3 schematically shows a cross-sectional view of a coil body according to another embodiment of the invention.

Fig. 4 schematically shows a cross-sectional view of one phase of a transformer with a coil according to another embodiment of the invention.

Fig. 5 schematically shows a cross-sectional view of one phase of a transformer with a coil according to another embodiment of the invention.

Fig. 6 schematically shows a cross-sectional view of one phase of a transformer with a coil according to another embodiment of the invention.

Fig. 7 schematically shows a flow chart of a method of manufacturing a coil for a transformer according to another embodiment of the invention.
Reference signs used in the drawings, and their meanings, are listed in summary form as a list of reference signs. In principle, identical parts are provided with the same reference signs in the figures.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Fig. 1A schematically shows a cross-sectional view of a part of one phase of a transformer (instead of the transformer a reactor or generally a magnetic component may be provided according to embodiments of the invention) with a coil 100 and a core 104 of the transformer and a middle axis A separating the core 104 of the transformer. The coil 100 has a coil body 102 which comprises a supporting device 202 for supporting a wound conductor 201 being wound around the supporting device 202. The supporting device 202 may be omitted according to another embodiment of the invention. An insulation material 203 is attached or moulded to the wound conductor 201 and the supporting device 202. Fig. 1A depicts a field control layer arrangement 200 for reducing the maximum field strength of the electric field generated in the coil 100. A first field control layer 301 of the field control layer arrangement 200 is applied at edges 205 of the conductor 201. One first field control layer 301 may be applied at inner edges 205 facing another conductor, such as a low voltage conductor 403 attached or moulded by an insulation material 203 to an attached or moulded low voltage conductor 402, and an additional first field control layer 301 may be applied at outer edges 205 not-facing the adjacent attached or moulded low voltage conductor 402. The first field control layer 301 may also be arranged circumferentially around the conductor 201 covering all the edges 205 of the conductor 201. At least one second field control layer 204 of the field control layer arrangement 200 is provided. The supporting device 202 may comprise at least one of the at least one second field control layer 204 and/or the first field control layer of the field control layer arrangement 200. The field control layer arrangement 200 may either comprise the first field control layer 204 or the at least one second field control layer 301 or both, the first and the second field control layers 204, 301, and may comprises a plurality of field control layers 204, 301 according to exemplary embodiments of the invention. The permittivity ratio of the insulation material 203 to the field control layer arrangement 200 may be 1 to x, wherein x is 1.5 to 20, in particular 2 to 5 thereby controlling the electric field. Refractive field control or control of the electric field may be achieved by a specific
arrangement of materials or devices such as the conductor 201, the supporting device 202, the insulation material 203, the field control layer arrangement 200, and ambient air with different permittivity; for example materials or devices with a permittivity ratio of 1 to 1.5-20, particularly 1 to 2-5, which may be arranged adjacent to each other or over one another thereby enabling the refractive field control or control of the electric field generated in the coil 100.

Fig. 1B schematically shows a coil 100 with a plurality of coil bodies 102, wherein a first field control layer 301 is applied at edges 205 of each wound conductor 201 of each of the plurality of coil bodies 102. Insulation material 203 is attached or moulded to the wound conductors 201, and the coil bodies 102, respectively, forming one single body. As mentioned above, one first field control layer 301 may be applied at inner edges 205 and another first field control layer 301 may be applied at outer edges 205 of each conductor 201 or one first field control layer 301 may be applied at the inner and outer edges 205 of each conductor 201.

The following features and embodiments of descriptions may be applicable to all figures, in particular to Fig. 1A, IB, 2, and 3.

The transformer may be a dry transformer and cast coils may be used for the dry transformer 101. The cast coils 201 may be made of a wound foil conductor 201 cast in an insulation media. Mechanical reinforcing structures may be in contact with the coil bodies 102. The insulation material 203 close to the edges of the conductors 201 may be submitted to increase electrical stress. To avoid electrical failure of the transformer sufficient insulation distances between coil bodies 102 and other metallic parts must be kept, especially when the electric strength of the insulation system is reduced due to the presence of interfaces. An electrical field control layer arrangement in form of the first field control layer 301 comprising a high permittivity material at the critical location, such as the edges 205 of the conductors and/or coil bodies, may provide for refractive field control and thereby reducing the electric field enhancements, which allows to reduce the dimension of the conductors 201 or to increase the voltage rating of a given geometry. The main insulation between primary and secondary coil or high voltage and low voltage coils of the dry-type transformer may be air. The transformers may have high voltage, especially a voltage of 10 kV and higher.
The transformer may also be a dry transformer with no air gap between primary and secondary coils, but solid insulation only.

The high permittivity of the material may be an intrinsic characteristic of the field control layer material or may be realized by using a filler in a matrix, e.g. high permittivity particles in a polymer. If, for example, a first field control layer 301 with epsilon equal to 10 is used, the maximum field strength at the coil body edge 205 is reduced to 50%. An even better result may be achieved, if the first high permittivity field control layer 301 has rounded corners.

The insulation material 203 may have a permittivity of 2 to 10. The first and second field control layer 301, 204 may have an epsilon 1.5 to 20 times higher than the insulation material 203, in particular 2 to 5 times higher.

Fig. 2 depicts a cross-sectional view of one phase of a transformer 101 with a coil 100. The coil 100 comprises a plurality of coil bodies 102 of a modular type, each of the plurality of coil bodies 102 having a uniform cross-section. Each coil body 102 of the plurality of coil bodies 102 is electrically connected to another coil body 102 of the plurality of coil bodies 102 forming a coil body stack 100, the stack 100 defining a stack axis A, or in other words the coil 100. Electrical connections or guiding elements 103 for clamp connecting the plurality of coil bodies 102 and for clamp connecting the coil body stack 100 to a further core of another transformer are provided and may ensure the electrical connection of the coil bodies 102 to each other. A non-circular part of a core 104 of the transformer 101 is surrounded by the coil 100. The uniform cross section of each of the plurality of coil bodies 102 is a non-circular cross-section and the cross-section is in a plane perpendicular to the stack axis A.

Fig. 3 shows a non-circular cross-section of a coil body 102 of Fig. 2, the cross-section being in a plane perpendicular to the stack axis A. The coil body 102 comprises a wound conductor 201 which is supported by supporting device 202, wherein the wound conductor 201 may be wound around the supporting device 202. An insulation material 203 is surrounding the wound conductor 201 and the supporting device 202 and may be used for an electrical insulation of the conductor 201. The supporting device 202 has a U-shape in the form of a ring 205 with sidewalls.

The supporting device 202 may be moulded by a two compound injection moulding process allowing to have one field grading compound, smoothing the electrical field
around the conductor 201 and thereby allowing for a distance between high voltage and low voltage coils to be reduced and a second compound of a material selected form the group consisting of a thermoset and a thermoplastic.

In addition to a first field control layer (not shown, see Fig. 1A), the supporting device 202 may comprise a second field control layer 204 for reducing the maximum field strength of the electric field generated in the coil 100. The wound conductor 201 may form a winding 201 wherein a second field control layer may be applied directly at edges 205 of the coil body 102. The supporting device 202 may comprise high permittivity thermoplastic. The insulation material 203 may be attached or impregnated or moulded to the wound conductor 201 and the supporting device 202 by first over-moulding or attaching the wound conductor 201, then over-moulding or attaching the sidewalls of the supporting device 202 in form of a ring 202, and third by over-moulding or attaching an inner wall of the ring 202 with the insulation material 203.

Fig. 4 schematically shows a cross-section of one phase of a transformer with a middle axis A (the stack axis according to Fig. 1A and Fig. 2) separating a core 104 of the transformer 101. The core 104 is coaxially surrounded by a low voltage conductor 403 which is moulded or attached by an insulation material 203 forming an attached low voltage conductor 402. The attached low voltage conductor 402 is surrounded by two high voltage coil bodies 102. Each high voltage coil body 102 has a supporting device 202 which may comprise a second field control layer 204 supporting the conductor 201 which may be wound around the supporting device 202. A first field control layer may be applied at edges of each conductor as depicted in Fig. 1B. Each conductor 201 and supporting device 202 is moulded or attached by an insulation material 203. The high voltage coil bodies 102 form a high voltage coil body stack 401 which is arranged around the attached low voltage conductor 402 surrounding the core 104 of the transformer.

The transformer of Fig. 4 may be manufactured by moulding or attaching the supporting device 202, winding a conductor 201 around the supporting device 202, moulding or attaching the conductor 201 and the supporting device 202 with an insulation material 203, wherein the supporting device 202 and the conductor 201 may be inserted into a mould and over-moulded by the insulation material 203 forming a high voltage coil body 102. The high voltage coil bodies 102 are stacked to a high voltage coil body stack 401 and the high voltage coil bodies 102 are electrically connected to each other. The insulation material
203 may comprise a thermoplastic material moulded by injection moulding, or a thermosetting material, processed by vacuum casting or automatic pressure gelation.

The high voltage coil body stack 401 is then arranged around the attached low voltage conductor 402 which is arranged around the core 104 of the transformer. At least one of the first and second field control layers may be applied at least at one edge of the high voltage conductors 201 opposite of the low voltage conductor 403. The first and/or second field control layers may be applied at the inner edges of the high voltage conductors 201 facing the low voltage conductor 403, and/or at the outer edges of the high voltage conductors 201 not facing the low voltage conductor 403.

Fig. 5 schematically shows a cross-section of one phase of a transformer 101 with a middle axis A separating a core 104 of the transformer 101. An insulation material 203 is attached to a low voltage conductor 403 forming an attached low voltage conductor 402 being arranged or wound around the core 104 according to Fig. 4. A high voltage coil body stack 401 comprising two high voltage coil bodies 102 moulded or attached together by an insulation material 203 is arranged around the attached low voltage conductor 402. The high voltage coil bodies 102 are not separated, as depicted according to Fig. 4, but form one part being moulded or attached together by the insulation material 203.

The transformer 101 of Fig. 5 may be manufactured by moulding or attaching the supporting devices 202, mounting the supporting devices 202 to a mandrel with space in between the supporting devices 202, winding a conductor 201 around each supporting device 202 or both supporting devices 202 at once, electrically connecting each conductor 201 of each high voltage coil body 102 to an adjacent conductor 201, e.g. by crimping, and over-moulding or attaching all supporting devices 202 with electrically connected conductors 201 by the insulation material 203, e.g. by vacuum casting or automatic pressure gelation, thus forming the one body high voltage coil body stack 401. The insulation material 203 may be a low permittivity material. The mandrel is taken out, the low voltage coil body 402 is arranged at the inside of the high voltage coil body stack 401, and the core 104 of the transformer is placed in the low voltage coil body 402. According to an embodiment of the invention a plurality of attached low voltage conductors 402 may be used. At least one of first and second field control layers may be applied at least at one edge of the high voltage conductors 201 opposite of the low voltage conductor 403. The first and/or second field control layers may be applied at the inner edges of the high
voltage conductors 201 facing the low voltage conductor 403, and/or at the outer edges of the high voltage conductors 201 not facing the low voltage conductor 403.

Fig. 6 schematically shows a cross-sectional view of one phase of a transformer with a low voltage conductor 403 and two high voltage coil bodies 102 with conductors being moulded or attached by an insulation material 203 forming a high voltage coil body and low voltage coil unit 601.

The transformer 101 of Fig. 6 may be manufactured by moulding or attaching all high voltage coil bodies 102 and the low voltage conductor 403 by the insulation material 203 together, wherein the high voltage coil body stack 401 may be inserted into a mould together with a low voltage conductor 403 and over-moulded or attached with low permittivity insulation material 203. To assure a constant distance between low voltage and high voltage coils, the low voltage conductor 403 and the high voltage coil bodies 102 may be fixed into the mould by having centric elements at the front and backend of the high voltage coil body stack 401 and the low voltage conductor 403 positioning them into the mould. The low voltage conductor 403 may be used as a mandrel for the high voltage coil bodies by inserting spacing elements between the outer side of the low voltage winding and the inner surface of the high permittivity supporting devices 202 of the high voltage coil bodies 102, the conductors of the high voltage coil bodies 102 being wound into each supporting device 202 separately or onto a stack of high voltage supporting devices 202. At least one of first and second field control layers may be applied at least at one edge of the high voltage conductors opposite of the low voltage conductor 403. The first and/or second field control layers may be applied at the inner edges of the high voltage conductors facing the low voltage conductor 403, and/or at the outer edges of the high voltage conductors not facing the low voltage conductor 403.

Fig. 7 schematically shows a flow-chart of a method 2600 of manufacturing a coil for a transformer with the steps of moulding a supporting device 2601, the moulding comprising the steps of injection-moulding the supporting device by a two-component injection moulding process using a first component comprising a second field control layer and a second component, winding a conductor of a coil body around a supporting device of the coil body 2602, applying at least one of a first and second field control layer of a field
control layer arrangement at the edges of the wound conductor 2603; attaching an insulation material to the conductor and the supporting device 2604, wherein the field control layer arrangement is adapted for reducing the maximum field strength of an electric field generated in the coil, stacking each of the conductors and supporting devices to a coil body stack or the coil 2605, and electrically connecting each coil body or coil body of the plurality of coil bodies to another coil body of the plurality of coil bodies 2606. The insulation material may be attached to the conductor and the supporting device.

While the invention has been illustrated and described in detail in the drawings and the foregoing description, such illustration and description are to be considered illustrative or exemplary and not restricted; the invention is not limited to the disclosed embodiments.

Other variations of the disclosed embodiments may be understood and effected by those skilled in the art and practising the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single coil or a single transformer may fulfil the function of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures may not be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.
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<tr>
<th>Reference Symbol</th>
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<tr>
<td>102</td>
<td>Coil body(s), high voltage coil body(s)</td>
</tr>
<tr>
<td>103</td>
<td>Guiding elements</td>
</tr>
<tr>
<td>104</td>
<td>Core</td>
</tr>
<tr>
<td>200</td>
<td>Field control layer arrangement</td>
</tr>
<tr>
<td>201</td>
<td>Conductor</td>
</tr>
<tr>
<td>202</td>
<td>Supporting device</td>
</tr>
<tr>
<td>203</td>
<td>Insulation material</td>
</tr>
<tr>
<td>204</td>
<td>First field control layer</td>
</tr>
<tr>
<td>205</td>
<td>Edges of conductor(s)</td>
</tr>
<tr>
<td>301</td>
<td>Second field control layer</td>
</tr>
<tr>
<td>401</td>
<td>High voltage coil body stack</td>
</tr>
<tr>
<td>402</td>
<td>Attached low voltage conductor</td>
</tr>
<tr>
<td>403</td>
<td>Low voltage conductor(s)</td>
</tr>
<tr>
<td>601</td>
<td>High voltage &amp; low voltage coil(s)</td>
</tr>
</tbody>
</table>
1. A coil (100) for a magnetic component (101), the coil (100) comprising at least one coil body (102), the at least one coil body (102) comprising:

- a wound conductor (201);

the coil (100) further comprising:

- an insulation material (203) attached to the wound conductor (201);

- a field control layer arrangement (200) for reducing the maximum field strength of an electric field generated in the coil (100);

- a supporting device (202) in a U-shape in the form of a ring (205) with sidewalls for supporting the wound conductor (201);

- at least one first field control layer (301) of the field control layer arrangement (200) is applied at edges (205) of the wound conductor (201);

- at least one second field control layer (204) of the field control layer arrangement (200);

wherein the supporting device (202) comprises at least one of the second field control layers (204).

2. The coil (100) of claim 1,

wherein the permittivity ratio of the insulation material (203) to the field control layer arrangement (200) is 1 to x, wherein x is 1.5 to 20, in particular 2 to 5, thereby controlling the electric field.

3. The coil (100) of claim 1 or 2,

wherein the magnetic component (101) is a transformer (101) or a reactor.

4. The coil (100) of anyone of claims 1 to 2,

wherein at least one of the first field control layers (301) is arranged circumferentially around the conductor 201 covering all the edges (205) of the conductor (201).
5. The coil (100) of anyone of claims 1 to 4,
wherein the field control layer arrangement (200) comprises a material selected from
the group consisting of a composite material comprising doped ZnO varistor powder
with a filler, in particular with Ti03 or BaTi03 filler.

6. The coil (100) of anyone of the preceding claims,
wherein the wound conductor (201) is in form of a foil.

7. The coil (100) of anyone of the preceding claims.,
wherein the supporting device (202) comprises at least one of the first and second field
control layers (301, 204).

8. The coil (100) of anyone of the preceding claims, further comprising:
a plurality of coil bodies (102);
wherein each coil body (102) of the plurality of coil bodies (102) is electrically
connected to another coil body (102) of the plurality of coil bodies (102) forming a coil
body stack (100).

9. The coil (100) of anyone of claims 1 to 8,
wherein the wound conductor (201) is a high voltage conductor (201);
wherein an insulation material is attached to a low voltage conductor (403);
wherein the attached high voltage conductor (201) is combined with the attached low
voltage conductor (402) surrounding a core (104) of the transformer (101),
wherein at least one of the first and second field control layers (301, 204) is applied at
least at one edge (205) of the high voltage conductor (201) opposite of the low voltage
conductor (403).

10. The coil (100) of claim 7,
wherein the plurality of coil bodies (102) is a plurality of high voltage coil bodies (102)
forming a high voltage coil body stack (401);
wherein the insulation material is attached to the high voltage coil body stack (401) instead of being attached to the wound conductor (201) of each high voltage coil body (102) of the plurality of high voltage coil bodies (102) separately;
wherein an insulation material is attached to a low voltage conductor (403);
wherein the attached high voltage coil body stack (401) is combined with the attached low voltage coil conductor (402) surrounding a core (104) of the transformer (101);
wherein at least one of the first and second field control layers (301, 204) is applied at least at one edge (205) of the high voltage conductor (201) opposite of the low voltage conductor (403).

11. The coil (100) of claim 8,
wherein the plurality of coil bodies (102) is a plurality of high voltage coil bodies (102) forming a high voltage coil body stack (401);
wherein the insulation material (203) is moulded to the high voltage coil body stack (401) and the low voltage conductor (403) together instead of being moulded to the wound conductor (201) of each high voltage coil body (102) of the plurality of high voltage coil bodies (102) separately;
wherein the high voltage coil body stack (401) and low voltage conductor (403) surround a core (104) of the transformer (101);
wherein at least one of the first and second field control layers (301, 204) is applied at least at one edge (205) of the high voltage conductor (201) opposite of the low voltage conductor (403).

12. A dry-transformer (101) comprising:
a coil (100) of anyone of claims 1 to 11.

13. Method (2600) of manufacturing a coil (100) for a transformer (101), the method (2600) comprising the steps of:
winding a conductor (201) of a coil body (102) around a supporting device (202) of the coil body (102, 2602);
applying at least one of a first and second field control layer (301, 204) of a field control layer arrangement (200) at the edges (205) of the wound conductor (201, 2603);
attaching an insulation material (203) to the conductor (201) and the supporting device (202, 2604);
wherein the field control layer arrangement (200) is adapted for reducing the maximum field strength of an electric field generated in the coil (100).

14. The method of claim 14,
wherein the permittivity ratio of the insulation material (203) to the field control layer arrangement (200) is 1 to x, wherein x is 1.5 to 20, in particular 2 to 5, thereby controlling the electric field.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01F27/32 H01F27/36 H01F41/12

ADD.

According to International Patent Classification (IPC) and both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>X</td>
<td>US 3 265 998 A (PARK CHARLES W) 9 August 1966 (1966-08-09) claims 1-4,7,9 col u mn 1, line 25 - line 72 col u mn 3, line 26 - line 57 figures -----</td>
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<td>US 2008/211611 Al (HANOV RUDOLF [DE]) 4 September 2008 (2008-09-04) claims 13,16,18-20 paragraphs [0011], [0019], [0021] figures 1,3 -----</td>
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<td>A</td>
<td>US 4 663 603 A (VAN RI EMSDIJK GERARDUS A [NL] ET AL) 5 May 1987 (1987-05-05) claims 1,6,10 col u mn 5, line 26 - line 31 figures 1,2,6,24 -----</td>
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  "K" document member of the same patent family

Date of the actual completion of the international search
10 October 2011

Date of mailing of the international search report
18/10/2011

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016

Authorized officer
Sti chauer, Li bor

Form PCT/ISA2110 (second sheet) (April 2005)
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<td>A</td>
<td>US 3 708 875 A (MARTINCIC P ET AL) 9 January 1973 (1973-01-09) claims 1,2 column 6, line 47 - line 60 figure 1</td>
<td>1,3, 6-10,12</td>
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