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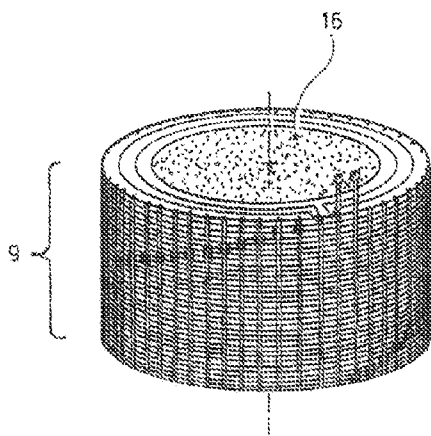


fig. 3

(57) Abstract: The invention relates to an electrical device comprising a stack of electrical elements, wherein: a central axis is defined in the stack; each element comprises an electrically insulating carrier; the carrier carries an electrically conductive loop-shaped track; both end zones of the track are located in the edge zone of the carrier; the loop-shaped tracks each form a turn and are arranged around the central axis in the stack; the end zones are connected to each other in electrically conductive manner such that the turns form one winding in at least groupwise manner; the carriers are congruent and each have a form such that they can be rotated from a starting position through an angle α around the central axis to a rotated position in which they take up the same space as in the starting position; adjacent elements with tracks which together form a winding are disposed rotated through an angle α relative to each other, and the mutually registered end zones are mutually connected by an electrical conductor extending transversely of the elements; the free end zones of the tracks of the outermost elements of the stack of elements form the externally accessible terminals of the or each winding; the elements are connected non-releasably to each other, and the stack has a peripheral surface with a form which is prismatic at least in its central zone, i.e. has the same cross-sectional form at any axial position.

ELECTRICAL DEVICE, IN PARTICULAR A COIL OR A TRANSFORMER

The invention relates to an electrical device, in particular a coil or a transformer.

Such a device is generally known in different embodiments. A coil comprises one
5 electrically conductive winding, in particular of insulated copper wire, the ends of which are externally accessible for the purpose of transmitting electric current, in particular alternating current. Such a coil can be a coreless coil or an air coil but can also comprise a ferromagnetic core, optionally with an external yoke forming a closed magnetic circuit with the core. The self-inductance of the coil is hereby increased substantially.

10 Such a device can also be embodied as transformer. A transformer comprises a minimum of two windings, in particular a primary winding and one or more secondary windings. It is for instance possible to envisage a transformer for transforming down from the mains voltage of for instance 115 V or 230 V AC, which is transformed down by the transformer to a voltage of for instance several volts. For this purpose the transformer comprises a primary winding with a
15 relatively large number of turns and one or more secondary windings with a smaller number of turns. It is usual for such a transformer to comprise a ferromagnetic core with an external yoke.

The drawback of such a known device is that it is heavy, expensive due to the nature of the production technique and takes up much space.

20 It is an object of the invention to embody a device of the described type such that the device is suitable for mass production, can be manufactured at relatively low cost and can be given a very light form.

With a view to the above the invention provides an electrical device, in particular a coil or a transformer, comprising a stack of electrical elements, wherein:

25 in the stack a central axis is defined which extends perpendicularly of the electrical elements;

each element comprises an electrically insulating flat carrier;

the carrier carries at least one electrically conductive loop-shaped track;

both end zones of the or each track are located in the edge zone of the carrier;

30 the loop-shaped tracks each form a turn and are arranged around the central axis in the stack;

the end zones are connected to each other in electrically conductive manner such that the turns form one winding in at least groupwise manner and that the electric currents conducted through the turns during operation of the device generate summing magnetic fields in the zone enclosed by the turns;

35 the carriers are congruent and each have a form such that they can be rotated from a starting position through an angle α around the central axis to a rotated position in which they take

up the same space as in the starting position;

adjacent elements with tracks which together form a winding are disposed rotated through an angle relative to each other such that only one end zone of the track of the one element is in register position relative to only one end zone of the track of the adjacent element, and these
5 mutually registered end zones are mutually connected by an electrical conductor extending transversely of the elements;

the free end zones of the tracks of the outermost elements of the stack of elements, or at least that part of the stack with tracks which together form one winding, form the externally accessible terminals of the or each winding;

10 the elements are connected non-releasably to each other, and
the stack has a peripheral surface with a form which is prismatic at least in its central zone, i.e. has the same cross-sectional form at any axial position.

According to an important aspect of the invention, the device has the special feature that each track is located some distance from the peripheral edge of the carrier;

15 the end zones of the track are located close to the peripheral edge of the carrier in the edge zone thereof; and

situated on the outer side of the stack and extending over the full height thereof are electrical conductors which each connect two mutually registered end zones of the tracks of adjacent elements electrically to each other.

20 The adjacent elements with tracks which together form a winding cover an overall angle of rotation of $n \cdot \alpha$, wherein $n \cdot \alpha$ must be less than 360° .

In respect of the foregoing the device can advantageously have the special feature that each carrier is round.

25 The device can alternatively be embodied such that each carrier has the form of a regular polygon. The polygon comprises a number of sides which equal $360^\circ/\alpha$.

The device preferably has the special feature that a ferromagnetic core is located in the space of the stack enclosed by the turn. A greatly increased self-inductance is hereby achieved for a coil and achieved for a transformer is that the windings have a substantially stronger mutual electromagnetic coupling.

30 In a further practical embodiment the device has the special feature that
a ferromagnetic zone is located in the space enclosed by the turn of each electrical element;
each flat carrier comprises a plastic substrate; and

the ferromagnetic zone comprises a magnetic material in powder form which is mixed through the substrate material and is thus embedded therein in substantially homogenous
35 distribution.

Such an embodiment can particularly be mass-produced in very simple manner on large

industrial scale with a limited number of production steps.

A device of the latter type preferably has the feature that the end zones of the core are coupled at least magnetically to each other by a ferromagnetic yoke extending outside the stack such that the core and the yoke together form a closed magnetic circuit. Stray fields are hereby prevented and the effectiveness of the operation of the ferromagnetic core is substantially enhanced.

A further improvement is achieved with an embodiment in which the yoke comprises two yoke parts extending on either side of the stack.

A preferred embodiment has a special feature that the yoke comprises two ferromagnetic plates at least magnetically coupled to the end zones of the core and a ferromagnetic jacket at least magnetically coupled to these plates; and situated in the jacket and/or in at least one of the plates is a passage for allowing through electrical conductors connected to both terminals of the or each winding.

In an important variant the device has the special feature that the ferromagnetic yoke comprises a plastic substrate into which magnetic material in powder form is mixed and is thus embedded therein in substantially homogenous distribution; and the yoke is manufactured by injection moulding.

According to yet another aspect of the invention, the device has the feature that respective electrically conductive pins are connected to both terminals of the or each winding, which pins extend outside the peripheral surface of the device.

According to an important aspect of the invention, the device can have the special feature that the pins are located in a zone forming part of a flat part of the peripheral surface of the device extending in longitudinal direction, and the pins extend perpendicularly of this flat part.

A device designed as transformer, for instance power supply transformer, can have the feature that

the tracks of the elements of the stack together form at least two windings, wherein a primary winding is configured to receive a relatively high alternating voltage and the or each other secondary winding is configured to generate a relatively low alternating voltage; and

the pins connected to the primary windings are located at the one axial end zone of the device, and the pins connected to the or each secondary winding are located at the other axial end zone of the device.

According to an important aspect, the above specified device according to the invention serving as transformer has the special feature that the pins are located in a zone forming part of a flat part of the peripheral surface of the device extending in axial direction, and the pins extend perpendicularly of this flat part. Such a transformer can be easily arranged on a printed circuit board or other carrier, the carrier being provided beforehand with for instance through-holes or

other connecting provisions for correct positioning and electrical connection of the transformer and the electric connecting pins.

According to a further practical aspect of the invention, the device can have the special feature that the tracks of the or each secondary winding have a larger cross-section than the tracks of the primary winding. In such an embodiment the generation of heat per volume unit in the tracks of the primary winding or in the or each secondary winding can be substantially the same during operation, whereby temperature differences can be reduced to negligible proportions.

It is known that for instance power supply transformers for electronic units which convert the available mains voltage to a lower voltage must generally have a large mass because of the relatively low mains frequency, in particular 50 or 60 Hz. With a view to a still further miniaturization according to the invention an embodiment is recommended in which a frequency converter is added to the device embodied as transformer which converts the frequency of the alternating current to be supplied to the primary winding from a relatively low value, for instance 50 or 60 Hz, to a relatively high value of a minimum of 100 kHz.

The device still more preferably has the special feature that the relatively high value of the frequency amounts to a minimum of 1 MHz.

According to an important aspect of the invention, the device can have the special feature that thermally conductive protrusions are situated on the outer side of the device, for instance pins, wires or fins, which at least partially relinquish heat generated in the device to the surrounding area.

Such protrusions can be embodied in per se known manner in a suitable thermally conductive material, for instance a metal such as copper, aluminium, silver.

As practical alternative the device can be embodied such that the protrusions consist together or in groups of a plastic substrate through which thermally conductive material in powder form, for instance aluminium powder, copper powder, silver powder, carbon powder, diamond powder, is mixed and thus embedded therein in substantially homogenous distribution; and the protrusions are manufactured together or in groups by injection moulding or extrusion.

According to yet another aspect of the invention, the device has the special feature that each flat carrier consists of film material with a thickness of a maximum of about 100 μm .

It is particularly possible to envisage film thicknesses of 50 μm or less, and even to the order of 10 μm .

A practical choice in the context of the invention is that where the film material is PI (polyimide) or PEI (polyetherimide).

Polyimide and polyetherimide are materials with an extremely good temperature loadability. Melting of the materials and degeneration due to heating occur only at extremely high temperatures, i.e. above 400°C.

The device according to the invention is highly suitable for miniaturization. It is thus possible to envisage an embodiment in which the maximum linear dimension of the device, for instance the diameter of a cylindrical device, transversely of the central axis amounts to 10 mm, preferably 8 mm, still more preferably 6 mm.

5

The invention will now be elucidated with reference to the accompanying drawings. In the drawings:

figure 1 is a perspective, partially exploded view of a stack of electrical elements in the preliminary phase of the manufacture of a coil based thereon,

10 figure 2 shows the finished stack according to figure 1 in which the end terminals of the coil have been formed and protrude outward;

figure 3 is a perspective view corresponding to figure 2 of a coil in which a ferromagnetic core is present in the space enclosed by the copper tracks;

figure 4 is a top view of a square film-like flat carrier with a copper track;

15 figure 5 is a view corresponding to figure 4 of a flat film-like carrier having the form of a regular octagon;

figure 6 is a top view corresponding to figures 4 and 5 of an embodiment in which the carrier has the form of a regular dodecagon;

figure 7 is a top view corresponding to figures 4, 5 and 6 of a carrier with a circular form;

20 figure 8 is a cut-away, partially exploded perspective view of a transformer with a ferromagnetic core and a ferromagnetic yoke;

figure 9 is an exploded view of a variant of the transformer according to figure 8;

figure 10 is an exploded view of a variant of the transformer according to figure 9 which is provided with cooling fins;

25 figure 11 shows an electronic unit with a carrier, an electronic processor present thereon and a number of micro-transformers according to the invention;

figure 12 is a partially cut-away perspective view on enlarged scale of the elongate transformer designated XII in figure 11;

30 figure 13 is a perspective view corresponding to figure 12 of an alternative transformer provided with vertically disposed cooling fins;

figure 14 shows a cross-section through the transformer according to figure 13 at the stage where the aluminium injection-moulded parts carrying the cooling fins are placed and fixed in close-fitting manner around the transformer;

35 figure 15 is a perspective, partially exploded view corresponding to figure 1 of a stack of multiple, not yet mutually connected and cured carriers with loop-shaped copper tracks, wherein the end zones of the copper tracks of adjacent carriers are rotated in each case through an angle α ,

the angle α corresponding to the angular distance between the end zones of the copper tracks, such that only one end zone of each copper track is placed in register with only one end zone of an adjacent copper track;

figure 16 is a schematic view of the manner in which a number of stacks of electrical elements are cut out of the stack according to figure 15 by means of a laser;

figure 17 is a schematic perspective view of a subsequent process wherein longitudinal angularly equidistant (α) grooves are arranged by means of a laser in the peripheral surface of the cylinder in the areas of the end zones of the copper tracks;

figure 18 is a view corresponding to figure 17 of the subsequent phase in which, by stepwise rotation through in each case the angle α and diagonal winding, copper wires with a solder sheath are placed in the grooves obtained according to figure 17 over the whole effective surface of the stack;

figure 19 shows a stack of electrical elements provided with a complete set of connecting wires, which stack is heated in a schematically designated oven or magnetron device such that the carrier-film material cures and the end zones, which are provided with a layer of soldering material, are connected at the position of the longitudinal grooves in electrically conductive manner by soldering to the wires provided with a layer of soldering material;

figure 20 is a schematic view of the finished and cured stack according to figure 19, wherein a coaxial cylindrical through-hole is arranged by means of a laser for the purpose of arranging a ferromagnetic core and removing the central zones around the central axis of the connecting wires;

figure 21 is an exploded view of a complete transformer with ferromagnetic core and yoke and external connecting pins on the basis of the stack of electrical elements according to figure 20;

figure 22 shows a vertical section on enlarged scale of the connection between the end zones of a winding and the associated external electrical connecting pins, in combination with closing of the ferromagnetic yoke;

figure 23 shows a round, flat, membrane-like plastic carrier with a substantially circular loop-shaped copper track and a ferromagnetic zone which is present in the central zone thereof and in which ferromagnetic powder material is incorporated in fine distribution in the plastic substrate of the flat carrier in order to form a continuous ferromagnetic core inside the space, enclosed by the turns of a winding, of a stack of electrical elements; and

figure 24 is a perspective view of a stack of electrical elements prior to curing of the plastic at the stage where a number of longitudinal through-holes are arranged in the plastic substrate material by means of a schematically designated laser for the purpose of accelerating evaporation of solvent from the starting plastic material.

Figure 1 shows a perspective view of a partial stack 1 of electrical elements 2 to be described below.

As shown particularly clearly in the top view of figure 7, each electrical element 2, which in this embodiment has a circular form, comprises a film-like plastic carrier, in particular of PI or PEI, on which a loop-shaped electrically conductive track 3 of copper is present. The end zones of track 3, which are designated 4, 5, extend as far as the peripheral edge of plastic carrier 6. At the position of this peripheral edge 7 the end zones 4, 5 have a mutual angular distance relative to central axis 8 (see figure 1) of a value α . Particular reference is made in this respect to figure 1.

The adjacent elements 2 of the complete stack 9 are placed such that each end zone 4, 5 of an element is registered with only one end zone of the adjacent element 2. The registered zones of the complete stack, which are all designated with the reference numeral 10, thus acquire the linear helical form shown clearly in, among others, figure 1. Once stack 9 has been thus formed and the electrical elements are connected non-releasably to each other in the manner to be described below, the registered zones must be connected to each other for electrical conduction. For this purpose end zones 4, 5 are provided beforehand with soldering material, for instance an eutectic mixture of lead and tin. According to figure 1, end zone 4 of each upper-lying element is connected to each end zone 5 of each element lying thereunder. The mutually offset relation is thus obtained with the drawn helical form as result.

Realized with the described coupling in each case of an end zone 4 to the subsequent end zone 5 is that the windings of a coil and of a winding of a transformer are respectively connected in series to each other.

Figure 17 shows the manner in which the longitudinal grooves are arranged in the peripheral surface of stack 9 using laser 11. The angular distance between these grooves amounts to α , as will be apparent from the foregoing description.

Positioned in grooves 12 in a manner to be described below with reference to figures 18, 19, 20 are copper wires which are provided with a cover layer of soldering material, in particular an eutectic mixture of lead and tin.

Figure 2 shows the situation in which wires 13 are positioned in the grooves. In this or at least a technically equivalent situation heating of stack 9 takes place with the thus placed wires 13. Curing of the plastic material of carriers 6 hereby takes place, while due to the presence of the wires the registered zones are also individually connected to each other by realizing a sufficiently high temperature, i.e. a temperature above the melting temperature of the soldering material, without the danger of any form of further undesired contact between such zones.

As shown in figure 2, two wires designated 14 protrude on the upper side above stack 9. These are terminals of the complete coil. It will be apparent herefrom that, in accordance with the present concept, the described helical form of the registered zones 10 can extend through an angle

of less than 360° .

The coil according to figure 2 manufactured in the above described manner is designated with reference numeral 15.

Coil 15 is of the type which does not have a ferromagnetic core. Only the plastic of carriers 6 is located in the space present defined by the tracks 3 operating as turns.

Figure 3 shows a variant in which a ferromagnetic core 16 is located in the space enclosed by tracks 3. This can in principle be arranged in two ways. A first manner of arrangement consists of a cylindrical part of the plastic material being removed, for instance by making use of a laser, and a pre-manufactured core, for instance of ferrite material, being placed into the thus created cylindrical space.

As alternative the carriers 6 can be embodied in their central zone, i.e. in the zone within the conductive tracks 3, such that ferromagnetic material in powder form is embedded in the plastic of the usually film-like carriers 3. By assembling and curing stack 9 under high temperature and optionally pressure a non-releasable unit is thus formed which is provided with a ferromagnetic core.

Figure 4 shows by way of example another form of a carrier, i.e. a square shape. Such a shape could be used as element for a stack in which end zones 4 are all connected to each other and end zones 5 are all connected to each other. The turns, consisting of tracks 3, of such a coil are not in series in such an embodiment but connected in parallel. Such a coil can also be manufactured by means of the process drawn in and described with reference to the foregoing figures.

Figure 5 shows a variant with a flat film-like plastic carrier in the form of a regular octagon.

Figure 6 shows an embodiment in which the film-like plastic carrier, for instance of PE or PEI, takes the form of a regular dodecagon.

Figure 7 shows the carrier 2 already described in the foregoing which has a circular form.

Figure 8 is a cut-away perspective view, with removed upper yoke part or cover, of a transformer with a ferromagnetic core and a ferromagnetic yoke. The manner in which a transformer with an internal cylindrical through-cavity can be manufactured will be apparent on the basis of the above description. This transformer is designated in stricter sense with reference numeral 17. It comprises a stack of carriers, the upper part 18 of which forms the primary winding and the lower part 19 forms the secondary winding. The end terminals of the primary winding and those of the secondary winding are carried to the outside and are designated with reference numeral 20.

The electromagnetic coupling between the primary winding and secondary winding is substantially improved in this embodiment in that a core and a yoke co-acting therewith are added to the transformer. Ferromagnetic core 16 is formed as monolithic unit with a ferromagnetic

bottom plate 22 and a ferromagnetic jacket 23. The thus resulting magnetic circuit is closed on the upper side after placing of a ferromagnetic cover 24 which has an edge recess 25 through which the terminals of the primary winding and those of the secondary winding extend. Edge recess 25 co-acts for positioning purposes with a correspondingly formed elevation 37 which protrudes from end surface 26.

The coupling between end surface 26 of the jacket and end surface 27 of the core and the lower surface of cover 24 can be realized by making use of a very thin adhesive layer.

Attention is drawn to the fact that copper tracks 3 of primary winding 18 have a smaller cross-sectional area than those of secondary winding 19. As is after all generally known from transformer technology, the cross-sectional area of a turn must be selected in the light of the current to be transmitted. For a secondary winding which generates a voltage of for instance 1 V, this is substantially greater than is the case for the primary winding, which is for instance intended for an alternating voltage of for instance 230 V.

Figure 9 is an exploded view of a variant of the transformer according to figure 8.

Transformer 28 according to figure 9 comprises primary winding 18 and two secondary windings which are jointly designated with reference numeral 19.

The terminals of the primary winding are designated with reference numeral 128, while the terminals of the three secondary windings are jointly designated with reference numeral 29.

Figure 9 shows that the two connecting wires of the primary winding, which are designated with 128, extend upward while the six wires forming the terminals of the three secondary windings extend downward.

A ferromagnetic core with yoke is constructed symmetrically and via a thin electrically insulating jacket 30 can be arranged from both sides over the ends of stack 9 and subsequently fixed with for instance a small quantity of adhesive.

It is important to note that the two ferromagnetic yoke parts 31, 32 together define on their outer side a flat surface 33, 34 perpendicularly of which the connecting pins 35 of the primary winding extend at the one axial end zone, while connecting pins 36 of the three secondary windings extend perpendicularly thereof on the other axial side. As a result of the presence of this flat surface and the fact that pins 35, 36 extend perpendicularly thereof, transformer 28 can be easily positioned on a carrier of an electronic unit, after which pins 35, 36 are fixed, for instance with a welding or soldering process, to electrically conductive tracks.

Figure 10 shows a transformer 28 which has a flat placing surface 38 and comprises a ferromagnetic core 16. The ferromagnetic core co-acts with a likewise ferromagnetic bottom plate 39 and a ferromagnetic cover 40, the end zones of which are coupled magnetically to each other by means of a more or less cylindrical element 41 comprising an aluminium cylinder 42 formed by extrusion and having cooling fins 43 extending in longitudinal direction, wherein a more or less

cylindrical discrete element 44 of ferromagnetic material is situated in the space between aluminium cylinder 42 and cooling fins 43, which element 44 extends between the bottom plate and the cover and so closes the magnetic circuit. The monolithically formed aluminium cylinder 42 and cooling fins 43 can advantageously be formed together with the discrete ferromagnetic element 44 by co-extrusion. Ferromagnetic element 44 can be embodied as a for instance thermoplastic plastic which functions as substrate in which ferromagnetic material in powder form is embedded.

Figure 11 shows an electronic unit 45 with a carrier, for instance of the printed circuit board type, on which is situated an electronic processor 47 which is powered with low direct voltages. Power supply transformers are also provided for this purpose on the carrier. The eight vertically disposed, substantially cylindrical transformers are all designated 48, while two elongate horizontal transformers are designated respectively 49 and 50.

For purposes of comparison a match 51 is placed next to electronic unit 45. This has the particular purpose of indicating the small dimensions of transformers 48, 49, 50.

All transformers are provided with cooling fins. Transformers 48 can be by and large of type as according to figure 10, with the proviso that the connecting pins are located on the lower end surface of the transformers. Transformers 49 and 50 can be of the type of transformer 28 as according to figure 10, albeit that transformers 49 and 50 take a more elongate form.

It will be apparent from figure 11 that the space still available on carrier 46 can be utilized very effectively for the placing of the transformers. This is a great advantage of the principles of the invention. The transformers can after all be manufactured very small and, due to the presence of the cooling fins in co-action with a forced airflow as is usual in computer and in particular server environments, bring about a highly effective cooling.

Figure 12 shows transformer 50, which for the sake of completeness is designated with the reference XII in figure 11, on larger scale and partially cut-away.

Situated on the underside of transformer 50 is a flat placing surface with which in the mounted situation as according to figure 11 the transformer is in stable contact with the upper surface of the plate-like, for instance plastic carrier 46. Pins 35, 36 protrude perpendicularly from this surface 38 and in the mounted state extend through through-holes in carrier 46. Situated on the underside thereof are conductive tracks, wherein connecting pins 35, 36 are connected for electrical conduction.

As a result of the usual application of a forced cooling airflow along an electronic unit of the type according to figure 11 it makes little difference in practice in which direction the thermally conductive, for instance aluminium cooling fins 43 extend. The cooling fins of transformers 49 and 50 extend in horizontal direction, while the cooling fins of transformers 48 extend vertically.

Figure 13 shows a variant in which an elongate transformer 52 is provided with a divided aluminium sleeve 53 which is assembled following mounting and both parts of which are provided

with vertical cooling fins 54. Each sleeve part with cooling fins can be embodied as aluminium injection-moulded part.

Figure 14 shows that the aluminium sleeve parts 53 are placed via an electrically insulating jacket 55 over stack 9. This electrically insulating jacket is for instance of a suitable plastic with a small thickness such that its heat resistance is negligible. An electrically insulating plate 58, 59 is located on the underside and on the upper side of stack 57.

Figure 16 shows on enlarged scale the manner in which a number of stacks of electrical elements, for instance of the type according to figure 7, are cut out of the stack 57 according to figure 15 by means of a schematically designated laser 60. The cutting contours of the laser are designated with reference numeral 61. Attention is drawn to the fact that the cutting contour of the laser is circular and extends through end zones 4, 5 of copper track 3. This ensures that the end zones, which are provided with a layer of soldering material, always extend all the way to the outer surface or the peripheral surface of the associated stack as according to for instance figure 1.

Figure 17 has already been discussed in the foregoing. With a stepwise rotation of stack 9 as according to arrow 62 the stack is rotated successively further through an angle α each time such that laser 11 is able to arrange the grooves 12 in the jacket zone of cylindrical stack 9.

Figure 18 shows the subsequent phase in which, once again by successive stepwise rotation as according to arrow 62, each time through an angle α , and by diagonal winding, the wires are positioned in the indicated desired manner. After a central cylindrical hole has been arranged in stack 9 using laser 11, by heating the stack the device 9 can be completed by curing of the plastic carriers. The heating takes place to a temperature at which the soldering material melts and wires 13 are soldered fixedly at the end zones, and wherein the material of the plastic carriers cures. This temperature must be selected under all conditions so as to be substantially lower than the value at which degeneration of the plastic material could occur.

Figure 20 is a schematic view of the finished and cured stack according to figure 19, wherein a coaxial cylindrical through-hole 64 is arranged by means of laser 11 for the purpose of arranging a ferromagnetic core and removing the connecting wires at the position of the two central zones around the central axis.

Figure 21 is an exploded view of a transformer 65 with a basic transformer consisting of a unit of windings obtained following the operation with a laser 11 as according to figure 20, a ferromagnetic core 67, a ferromagnetic jacket 68, a ferromagnetic bottom plate 69 and a ferromagnetic cover 70. An electrically insulating film-like sleeve 71 extends between the outer surface of unit 66, where the voltage-carrying wires 13 lie unprotected, and jacket 68. This insulates the wires 13 from the inner surface of ferromagnetic jacket 68. Situated on the upper side is an insulating plate 72 which has through-holes for passage of the connecting wires to connecting pins 35 for the primary winding. Situated on the underside is a functionally corresponding

insulating plate 73 with a passage for allowing through the connections of the secondary windings to connecting pins 36 for these secondary windings.

Figure 22 shows a vertical section on enlarged scale of the connection between the end zones of a winding and the associated external connecting pins 35, which connecting pins 35 extend through a filler block 76 of electrically insulating material received in a recess in ferromagnetic cover 70.

Ferromagnetic cover 70 with filler block 76 and coupling surfaces 75 on the underside of connecting pins 35 takes place via the electrically insulating plate 72, which can for instance be embodied as film. Attention is drawn to the fact that, with a view to good positioning and a reliable electrically conductive connection between pins 35 and end zones 74, the coupling surfaces are provided with shallow grooves lying in the direction of the roughly radially extending upper parts of wires 13.

Figure 23 shows a round, flat, membrane-like plastic carrier 78 with a substantially circular, loop-shaped copper track 3 and a ferromagnetic zone 77 present in the central zone thereof, in which zone ferromagnetic powder material is incorporated in finely distributed manner in the plastic substrate of the flat carrier for the purpose of forming a continuous ferromagnetic core inside the space, enclosed by the turns or electrically conductive tracks 3 of a winding, of a stack of electrical elements 79 of the type according to figure 23.

Figure 24 shows a stack of electrical elements as according to figure 2 prior to the curing of the plastic at the stage where by means of a schematically designated laser 80 a number of longitudinal through-holes 81 are arranged in the as yet not cured plastic substrate material for the purpose of enhancing rapid evaporation of solvent from the starting plastic material. It will be apparent that this variant is only worthwhile in the case where a solvent has been added to the substrate material.

Claims

1. Electrical device, in particular a coil or a transformer, comprising a stack of electrical elements, wherein:

5 in the stack a central axis is defined which extends perpendicularly of the electrical elements;

each element comprises an electrically insulating flat carrier;

the carrier carries at least one electrically conductive loop-shaped track;

both end zones of the or each track are located in the edge zone of the carrier;

10 the loop-shaped tracks each form a turn and are arranged around the central axis in the stack;

the end zones are connected to each other in electrically conductive manner such that the turns form one winding in at least groupwise manner and that the electric currents conducted through the turns during operation of the device generate summing magnetic fields in the zone
15 enclosed by the turns;

the carriers are congruent and each have a form such that they can be rotated from a starting position through an angle α around the central axis to a rotated position in which they take up the same space as in the starting position;

adjacent elements with tracks which together form a winding are disposed rotated through
20 an angle α relative to each other such that only one end zone of the track of the one element is in register position relative to only one end zone of the track of the adjacent element, and these mutually registered end zones are mutually connected by an electrical conductor extending transversely of the elements;

the free end zones of the tracks of the outermost elements of the stack of elements, or at
25 least that part of the stack with tracks which together form one winding, form the externally accessible terminals of the or each winding;

the elements are connected non-releasably to each other, and

the stack has a peripheral surface with a form which is prismatic at least in its central zone,
i.e. has the same cross-sectional form at any axial position.

30 2. Device as claimed in claim 1, wherein

each track is located some distance from the peripheral edge of the carrier;

the end zones of the track are located close to the peripheral edge of the carrier in the edge zone thereof; and

35 situated on the outer side of the stack and extending over the full height thereof are electrical conductors which each connect two mutually registered end zones of the tracks of

adjacent elements electrically to each other.

3. Device as claimed in either of the claims 1-2, wherein each carrier is round.

5 4. Device as claimed in either of the claims 1-2, wherein each carrier has the form of a regular polygon.

5. Device as claimed in any of the foregoing claims, wherein a ferromagnetic core is located in the space of the stack enclosed by the turns.

10 6. Device as claimed in claim 5, wherein
a ferromagnetic zone is present in the space enclosed by the turn of each electrical element;
each flat carrier comprises a plastic substrate; and
the ferromagnetic zone comprises a magnetic material in powder form which is mixed
15 through the substrate material and is thus embedded therein in substantially homogenous distribution.

7. Device as claimed in claim 5 or 6, wherein the end zones of the core are coupled at least magnetically to each other by a ferromagnetic yoke extending outside the stack such that the core
20 and the yoke together form a closed magnetic circuit.

8. Device as claimed in claim 7, wherein the yoke comprises two yoke parts extending on either side of the stack.

25 9. Device as claimed in claim 7, wherein
the yoke comprises two ferromagnetic plates at least magnetically coupled to the end zones of the core and a ferromagnetic jacket at least magnetically coupled to these plates; and
situated in the jacket and/or in at least one of the plates is a passage for allowing through
electrical conductors connected to both terminals of the or each winding.

30 10. Device as claimed in claim 7, 8 or 8, wherein
the ferromagnetic yoke comprises a plastic substrate into which magnetic material in powder form is mixed and is thus embedded therein in substantially homogenous distribution; and
the yoke is manufactured by injection moulding.

35 11. Device as claimed in any of the foregoing claims, wherein respective electrically

conductive pins are connected to both terminals of the or each winding, which pins extend outside the peripheral surface of the device.

12. Device as claimed in claim 11, wherein the pins are located in a zone forming part of a flat part of the peripheral surface of the device extending in longitudinal direction, and the pins extend perpendicularly of this flat part.

13. Device as claimed in claim 11, configured to serve as transformer, wherein the tracks of the elements of the stack together form at least two windings, wherein a primary winding is configured to receive a relatively high alternating voltage and the or each other secondary winding is configured to generate a relatively low alternating voltage; and the pins connected to the primary windings are located on the one axial side of the device, and the pins connected to the or each secondary winding are located on the other axial side of the device.

14. Device as claimed in claim 13, wherein the pins are located in a zone forming part of a flat part of the peripheral surface of the device extending in axial direction, and the pins extend perpendicularly of this flat part.

15. Device as claimed in either of the claims 13 or 14, wherein the tracks of the or each secondary winding have a larger cross-section than the tracks of the primary winding.

16. Device as claimed in either of the claims 13 or 14, wherein a frequency converter is added to the device embodied as transformer which converts the frequency of the alternating current to be supplied to the primary winding from a relatively low value, for instance 50 or 60 Hz, to a relatively high value of a minimum of 100 kHz.

17. Device as claimed in claim 16, wherein the relatively high value of the frequency amounts to a minimum of 1 MHz.

18. Device as claimed in any of the foregoing claims, wherein thermally conductive protrusions are situated on the outer side of the device, for instance pins, wires or fins, which at least partially relinquish heat generated in the device to the surrounding area.

19. Device as claimed in claim 18, wherein the protrusions consist together or in groups of a plastic substrate through which thermally conductive material in powder form, for instance

aluminium powder, copper powder, silver powder, carbon powder, diamond powder, is mixed and thus embedded therein in substantially homogenous distribution; and

the protrusions are manufactured together or in groups by injection moulding or extrusion.

5 20. Device as claimed in any of the foregoing claims, wherein each flat carrier consists of film material with a thickness of a maximum of about 100 μm , preferably a maximum of 50 μm , to the order of 10 μm .

10 21. Device as claimed in claim 18, wherein the film material is PI (polyimide) or PEI (polyetherimide).

15 22. Device as claimed in any of the foregoing claims, wherein the maximum linear dimension of the device, for instance the diameter of a cylindrical device, transversely of the central axis amounts to 10 mm, preferably 8 mm, still more preferably 6 mm.

1/13

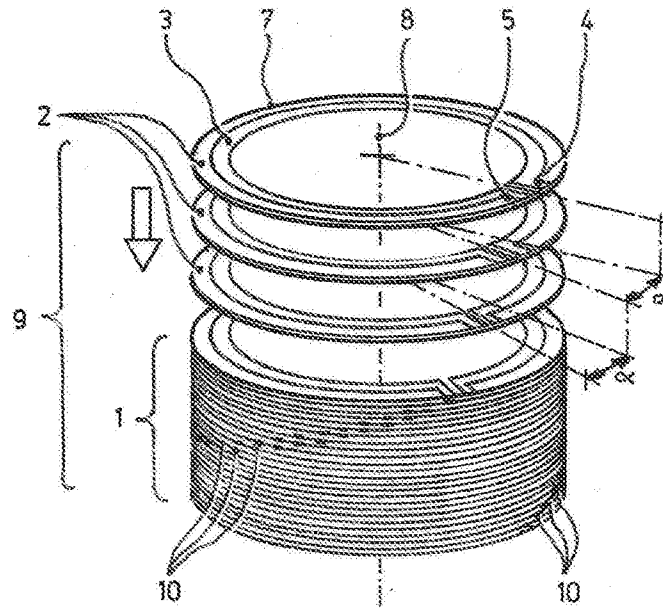


fig. 1

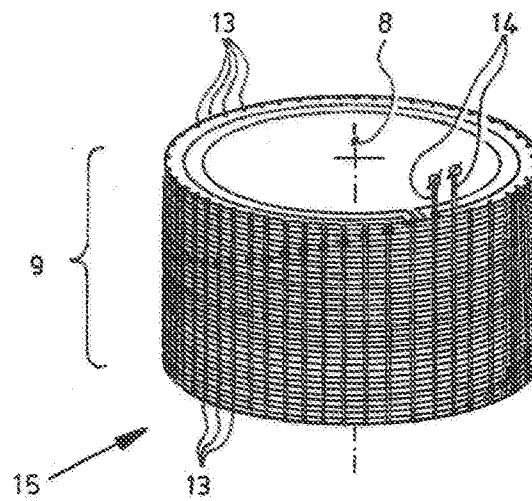


fig. 2

2/13

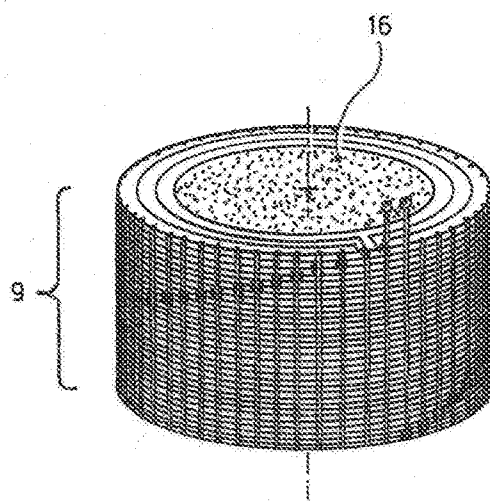


fig. 3

3/13

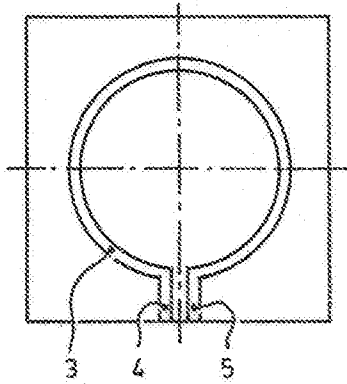


fig. 4

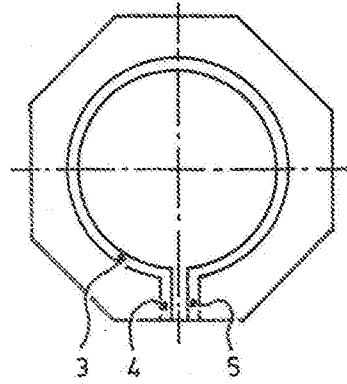


fig. 5

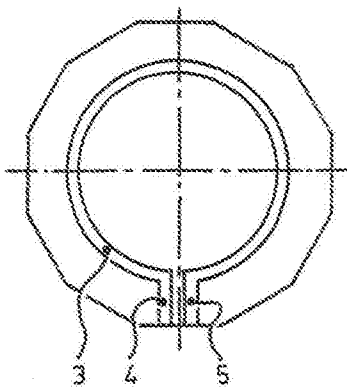


fig. 6

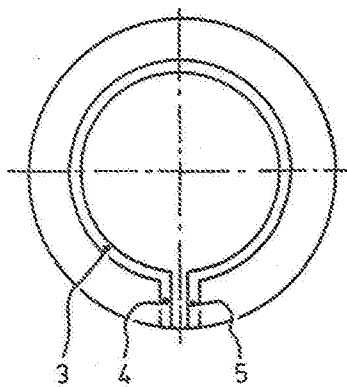


fig. 7

4/13

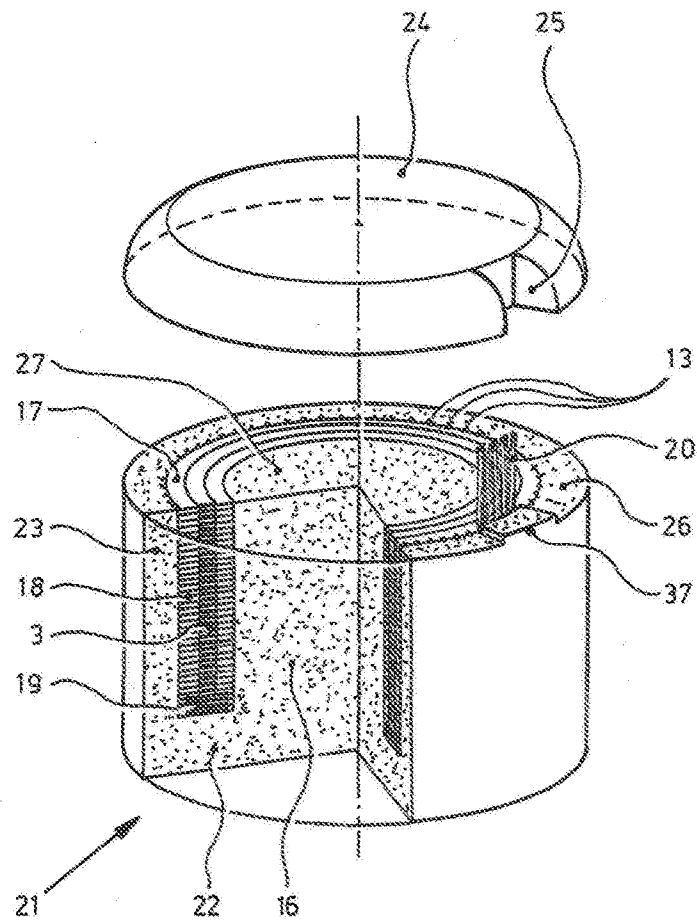


fig.8

5/13

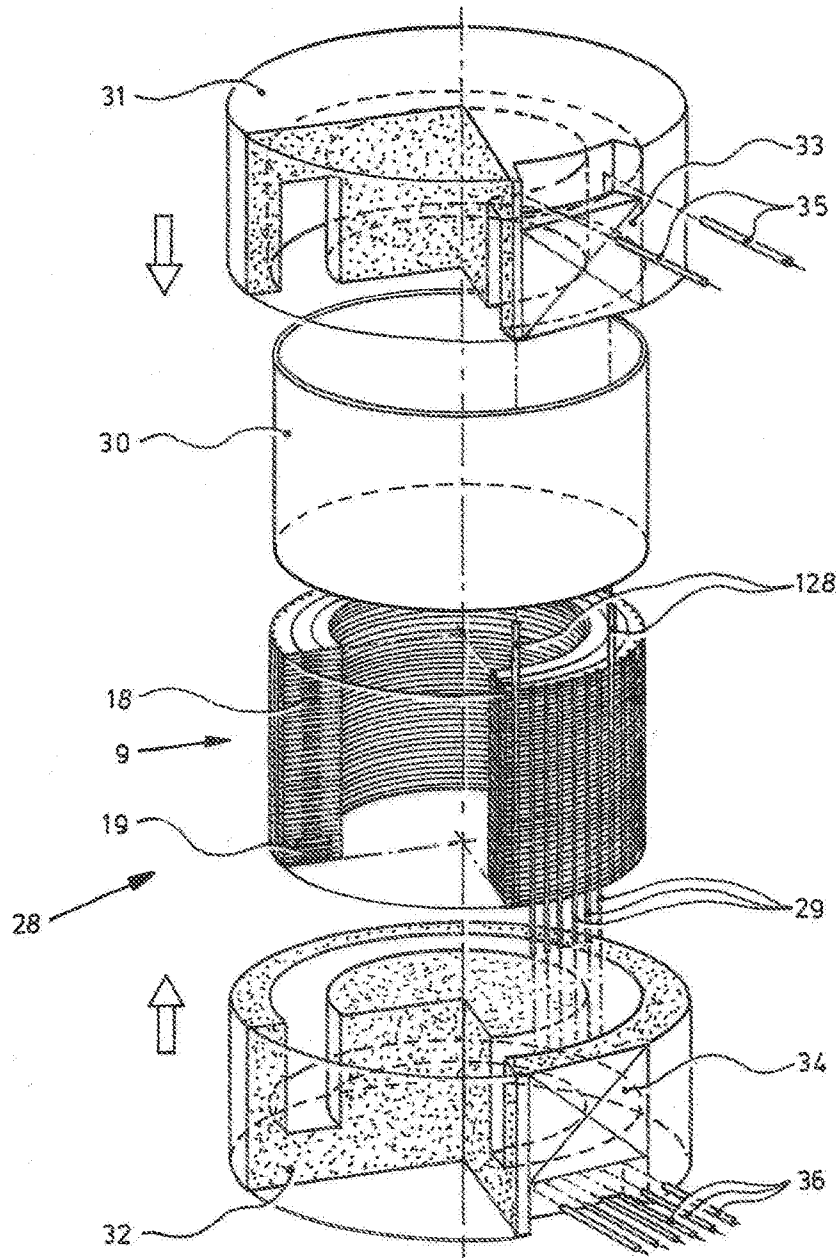


fig. 9

6/13

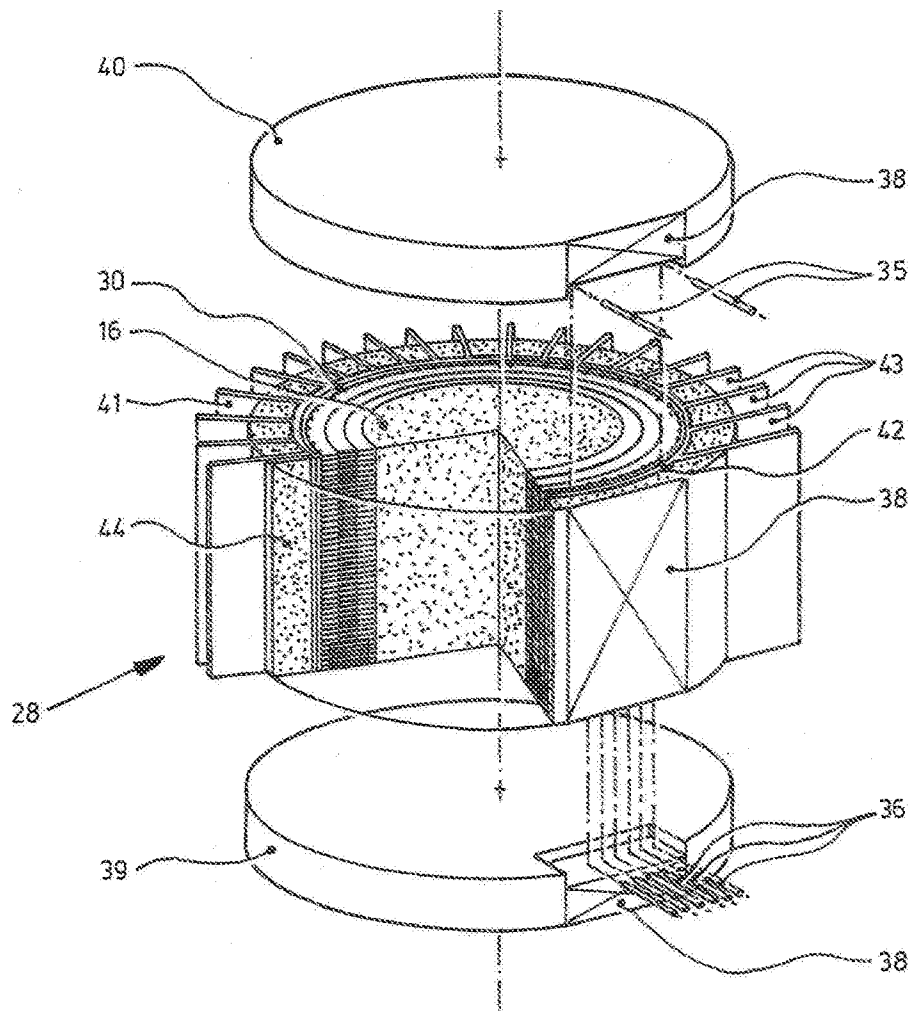


fig.10

7/13

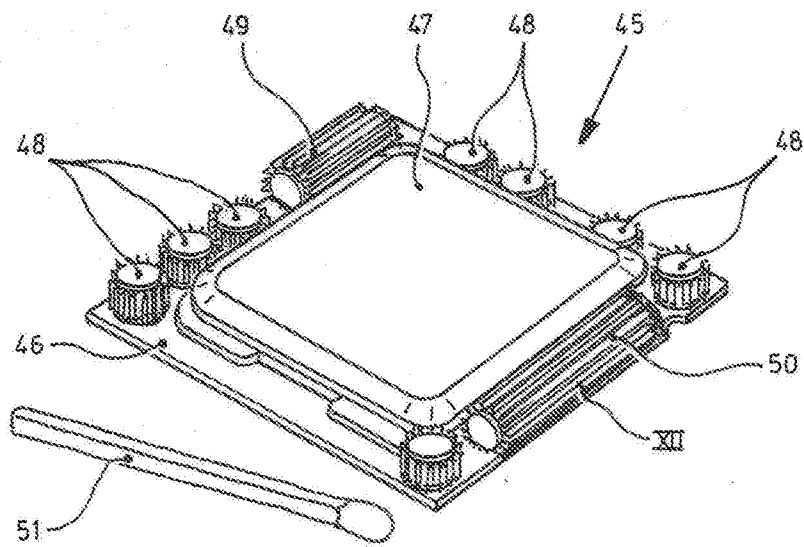


fig.11

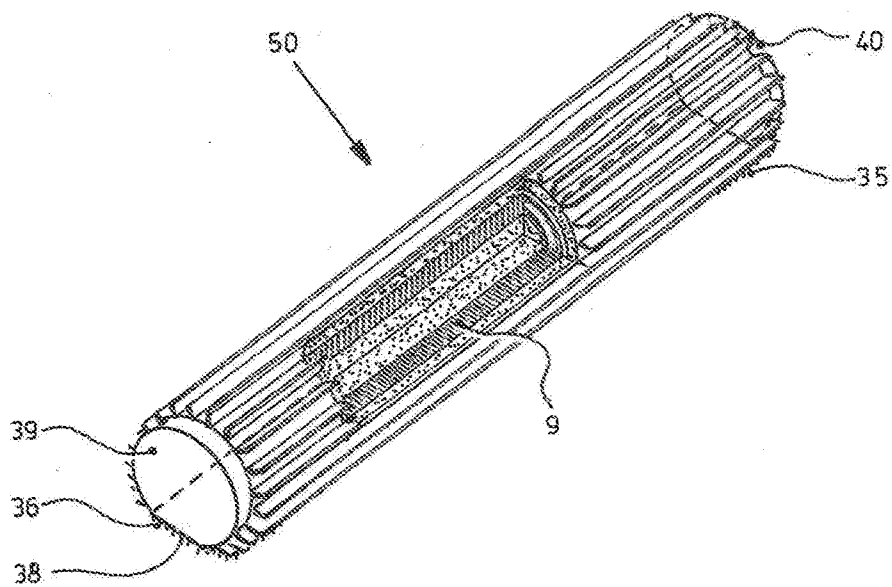


fig.12

8/13

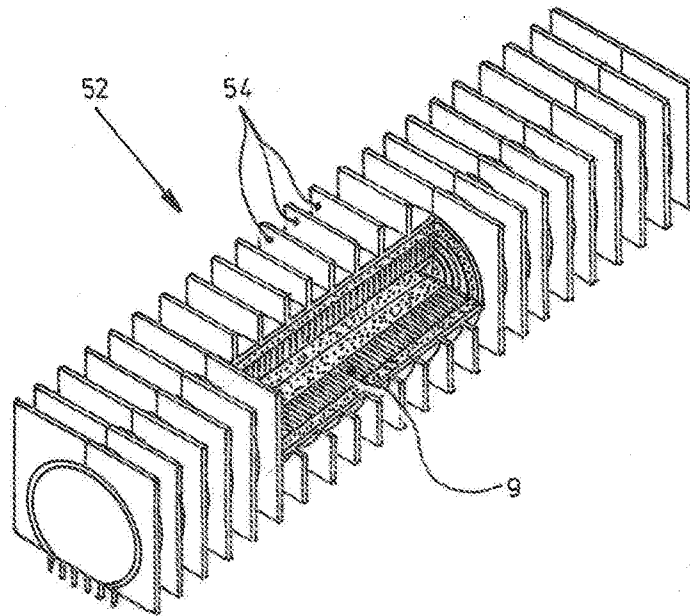


fig.13

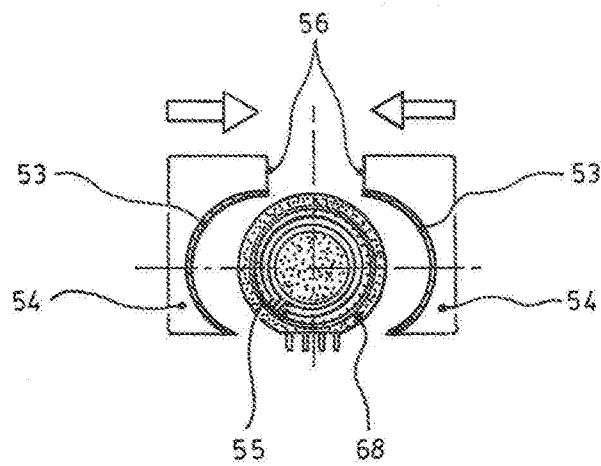


fig.14

9/13

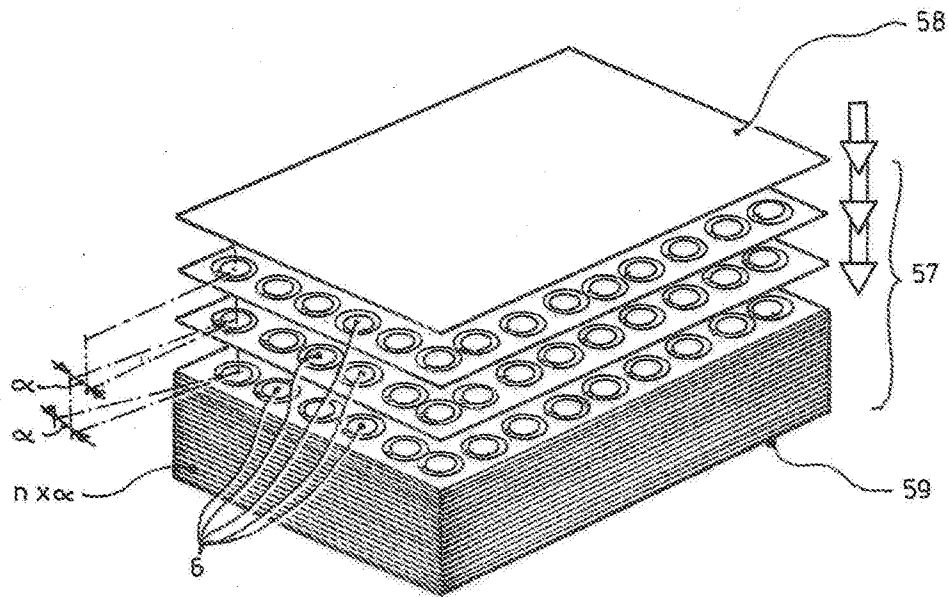


fig.15

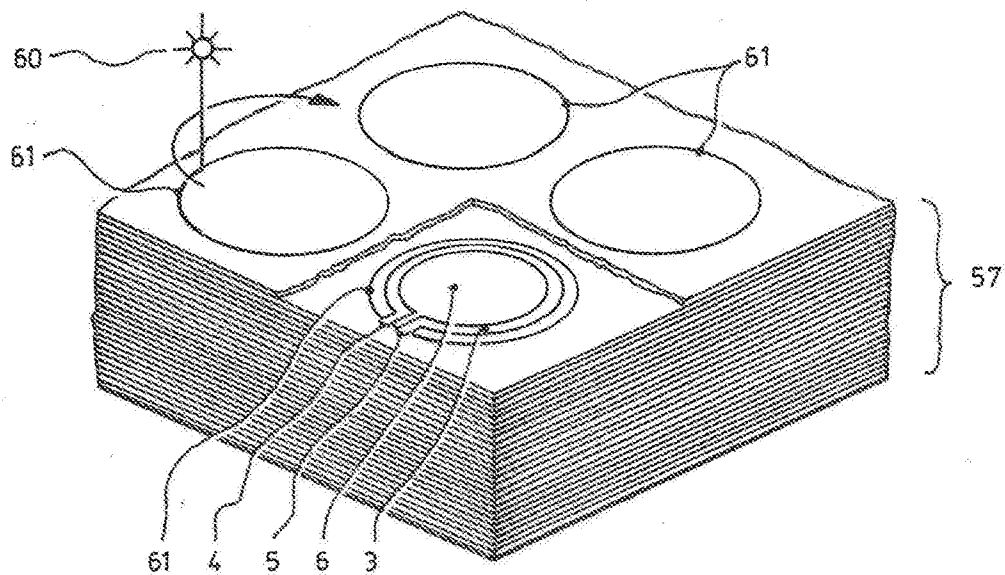


fig.16

10/13

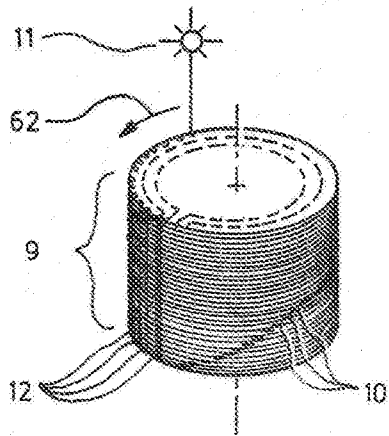


fig.17

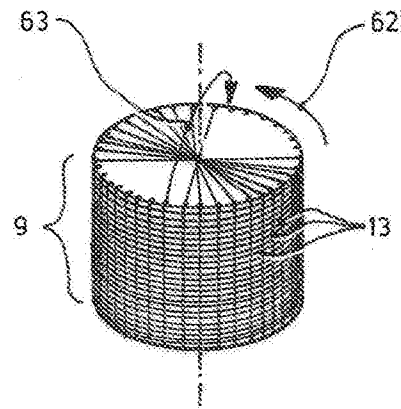


fig.18

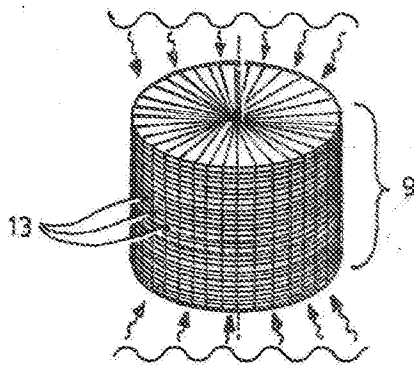


fig.19

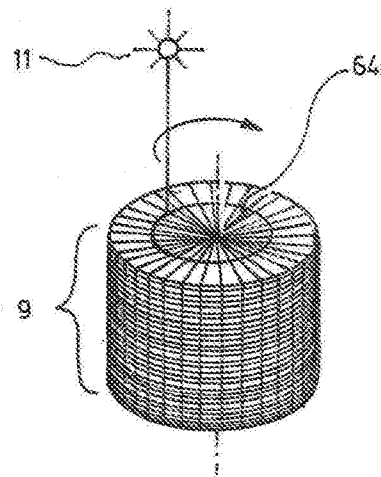


fig.20

11/13

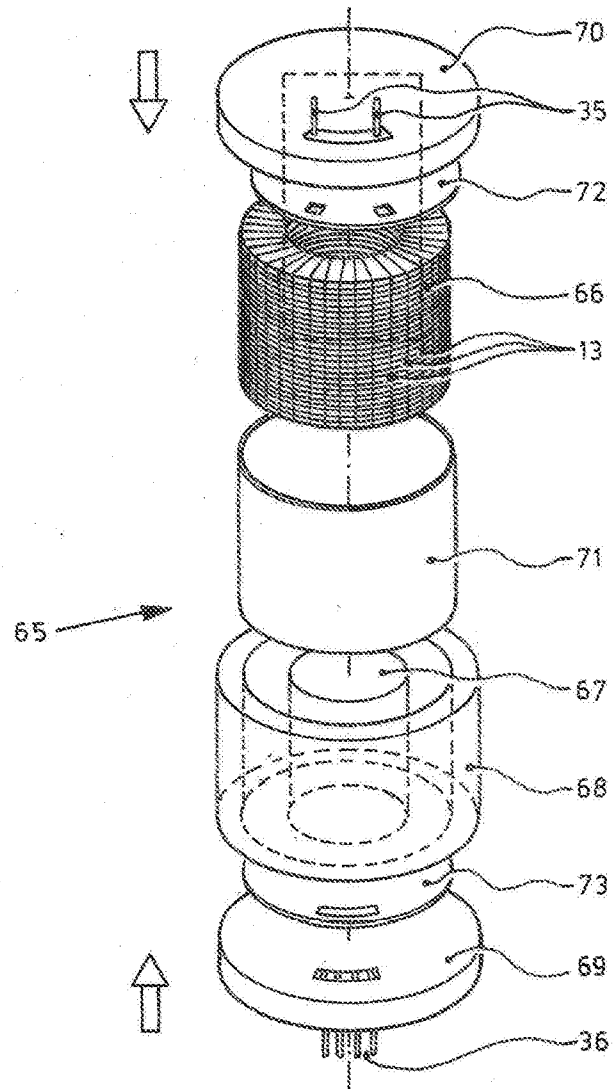


fig.21

12/13

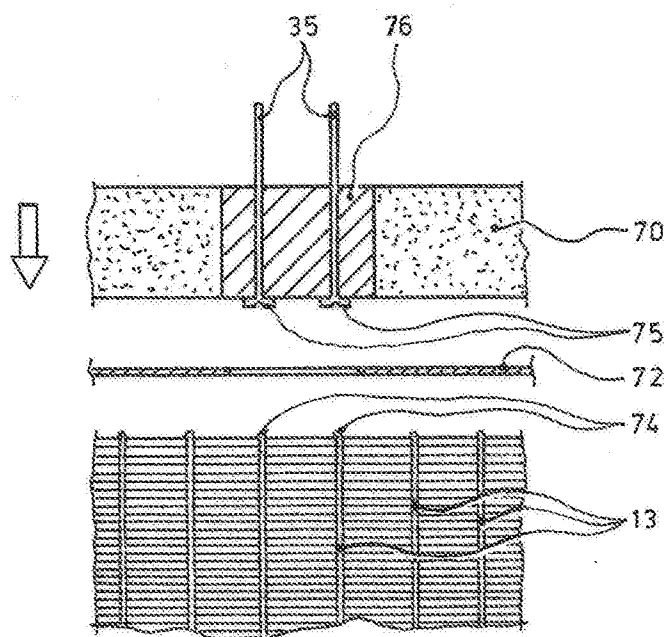


fig.22

13/13

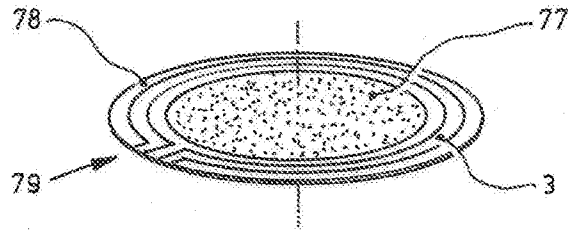


fig.23

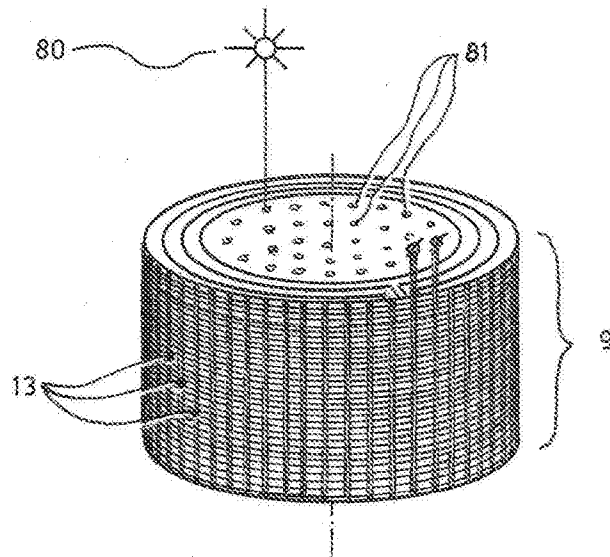


fig.24

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2015/050551

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01F17/00 H01F27/02 H01F27/255 H01F27/28 H01F38/02
H01F27/08

ADD.

According to International Patent Classification (IPC) or to 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 practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 316 354 A (LUCIEN GAULARD) 21 April 1885 (1885-04-21) page 1, lines 23-74 page 2, lines 12-83	1,3,5
Y	EP 0 435 461 A2 (AMERICAN TELEPHONE & TELEGRAPH [US] AT & T CORP [US]) 3 July 1991 (1991-07-03) column 1, line 54 - column 2, line 22 column 3, line 35 - column 4, line 21 column 4, line 31 - column 6, line 8	1-3,5,7, 8,11,12
Y	EP 0 601 791 A1 (AMERICAN TELEPHONE & TELEGRAPH [US]) 15 June 1994 (1994-06-15) column 3, line 21 - column 4, line 26	1,3,11, 12
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

20 October 2015

Date of mailing of the international search report

04/01/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Gols, Jan

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2015/050551

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 953 993 A2 (THOMSON BRANDT GMBH [DE]) 3 November 1999 (1999-11-03) paragraphs [0006], [0007], [0010], [0012], [0013], [0015], [0018], [0019] -----	1-3,5,7, 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NL2015/050551

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of Item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-3, 5, 7, 8, 11, 12

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3, 5, 7, 8, 11, 12

An electrical device, wherein the elements are connected non-releasably to each other.

2. claim: 4

An electrical device, wherein each carrier has the form of a regular polygon.

3. claim: 6

An electrical device, wherein the ferromagnetic zone comprises a magnetic material in powder form which is mixed through the substrate material and is thus embedded therein in substantially homogenous distribution.

4. claims: 9, 10

An electrical device, wherein the yoke comprises two ferromagnetic plates at least magnetically coupled to the end zones of the core and a ferromagnetic jacket at least magnetically coupled to these plates; and situated in the jacket and/or in at least one of the plates is a passage for allowing through electrical conductors connected to both terminals of the or each winding.

5. claims: 13-17

An electrical device, wherein a primary winding is configured to receive a relatively high alternating voltage and the or each other secondary winding is configured to generate a relatively low alternating voltage, and the pins connected to the or each secondary winding are located on the other axial side of the device

6. claims: 18-22

An electrical device, wherein thermally conductive protrusions are situated on the outer side of the device, for instance pins, wires or fins, which at least partially relinquish heat generated in the device to the surrounding area.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2015/050551

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 316354	A	21-04-1885	NONE	

EP 0435461	A2	03-07-1991	DE 69016187 D1	02-03-1995
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