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(71) Applicant: **Zajc, Franc**
1218 Komenda (SI)

(72) Inventor: **Zajc, Franc**
1218 Komenda (SI)

(74) Representative: **Isarpatent**
Patent- und Rechtsanwälte
Postfach 44 01 51
80750 München (DE)

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(54) **Multi gap inductor core, multi gap inductor, transformer and corresponding manufacturing method and winding**

(57) The invention provides a multi gap inductor core, a multi gap inductor, transformer, and a corresponding manufacturing method and winding. The multi gap inductor core (1; 1'; 1"; 1'''), comprises a first plurality of magnetic lamination sheets (2a-2g; 2a'-2m'; 2a"-2n") made of magnetic core material arranged in a stack and a second plurality of fixing layers (3a-3f; 3a'-3l'; 3a"-3l'') made

of a fixing material. Each fixing layer (3a-3f; 3a'-3l'; 3a"-3l'') is arranged between a corresponding pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a"-2n") and includes mechanical spacer means (4; 4') which define a gap (G) having a predetermined thickness (d2) between a corresponding pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a"-2n").

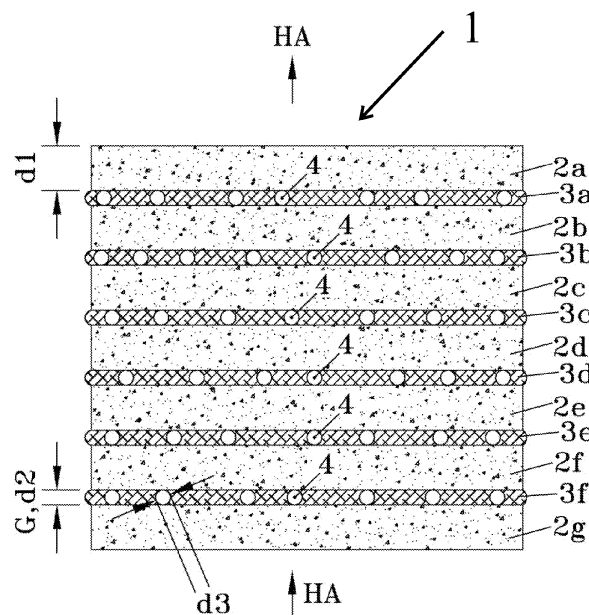


Fig. 1

Description

[0001] This invention relates to a multi gap inductor core, a multi gap inductor, especially for high frequency (HF) applications, a transformer, and a corresponding manufacturing method and winding..

State of the Art

[0002] US 7,573,362 B2 discloses a high-current, multiple air gap, conduction-cooled, stacked lamination inductor. Particularly, the magnetic core section of this known inductor includes substantially rectangular profiled magnetic laminations arranged in a stack.

[0003] Generally, in order to reduce the size of power electronics devices, converters are designed which use working frequencies that for small power converters up to 10 V have risen into the MHz range. The research of middle power converters up to 200V and high power converters up to 500V is seeking to reach frequencies in the range of 300 kHz up to 1 MHz.

[0004] In such converters, the inductor presents an important part regarding the losses and the size. Particularly, the inductor's size should be minimal, and if possible, the inductor shape should be square and the inductor should have the lowest possible AC/DC resistance ratio at the desired working frequency. In the existing inductors which are used in the high frequency area the skin effect, proximity effect and fringing effect are the reason for comparatively high losses and correspondingly required big size.

[0005] In order to obtain the smallest possible inductor with a low DC resistance the majority of the known switching converter inductors is wound with a circular or squared wire on different shape ferrite cores with one or two air gaps. Better results are reached with inductors having their winding enclosed in powder material which due to low permeability replaces the air gap.

[0006] Relatively best results are achieved by the prior art inductor shown in Fig. 14, where TC denotes a toroidal ferrite core with an air gap AG and having strand wire SW wound around the core TC. The prior art inductors shown in Fig. 14 show a favourable AC/DC current resistance ratio, however, their field radiation is high, their size is big, and their shape is inconvenient to be fixed on a circuit board.

[0007] High-frequency current in circular or square-shape free wires is conducted only in the wire surface area which is called skin effect. That effects that the known inductors wound with such wires to have very low resistance and also high inductivity vary their resistance with increasing frequency very dramatically. Therefore, the high-frequency losses make the known inductors only useful for low alternating current frequencies. The air gap also contributes to increase the high-frequency losses. The magnetic flux exits the core in the area of the air gap and enters the winding causing heating of the winding. Even the replacement of a single air gap by plural air

gaps does not reduce the effect of this heating phenomenon very much at high frequencies. Although the effect can be completely eliminated by using a composite ferrite material as core material, the permeability of a corresponding inductor depends very much on the magnetic density. Moreover, the composite ferrite material has a much lower saturation level than the sintered ferrite material. This effects that the inductivity of such composite ferrite material inductors varies drastically with current changes.

Disclosure of the Invention

[0008] The invention provides a multi gap inductor core as defined in independent claim 1, a multi gap inductor as defined in independent claim 7, and a corresponding manufacturing method as defined in independent claim 12 and a corresponding winding as defined in independent claim 17 and 18, respectively.

[0009] Preferred embodiments are listed in the respective dependent claims.

Advantages of the Invention

[0010] According to one aspect of the invention, the multi gap core prevents the flux scattering out of the gap. The laminations are connected to each other with respective hardened fixing layers. Spacer means are embedded in the fixing layers to control the respective gaps. High viscous glue mixed with spherical particles as distance balls can be used as fixing layer.

[0011] The spherical particles can very accurately define the thickness of the gap between adjacent laminations, if their diameter distribution is in a narrow range, i.e. $20\ \mu\text{m} \pm 2\ \mu\text{m}$. Such diameter distributions may, for example, be obtained with filtered carbon particles. Moreover spherical distance balls are well suited to provide a monolayer as homogeneous spacer means. In another aspect of the invention, pre-patterned bumps are used as homogeneous spacer means.

[0012] In a further aspect of the invention, the magnetic lamination sheets have a thickness between 0,1 and 1 mm and/or the predetermined gap thickness is between 10 and 100 μm .

[0013] The invention is well suited for high ripple current applications at high frequencies.

Brief Description of the Drawings

[0014] In the following embodiments of the invention will be described with reference to the drawings, wherein:

Fig. 1 shows a cross-section of a multi gap inductor core according to an embodiment of the present invention;

Fig. 2 shows a cross-section of a multi gap inductor core according to the first embodi-

	ment of the present invention in order to explain a corresponding manufacturing method thereof;		bands used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention;
Fig. 3, 4	are perspective views in order to explain the step of separating individual multi gap inductor cores from the hardened stack manufactured as explained in Fig. 2;	5	Fig. 12 shows a partial cross-section of a multi gap inductor core according to an embodiment of the present invention;
Fig. 5a	is a plain view of a first example of an insulated conductive flat band used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention;	10	Fig. 13 shows a schematic view of a transformer including a multi gap inductor core according to an embodiment of the present invention; and
Fig. 5b,c	are perspective views of the insulated conductive flat band shown in Fig. 5a in order to illustrate a first winding procedure;	15	Fig. 14 shows an example of a inductor core according to the prior art.
			Embodiments of the Invention
Fig. 6	is a perspective view of the first example of insulated conductive flat band used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention after the first winding procedure is finished;	20	[0015] Throughout the figures, the same reference signs denote same or equivalent parts. [0016] Fig. 1 shows a cross-section of a multi gap inductor core according to an embodiment of the present invention.
Fig. 7	shows a cross-section of a multi gap inductor having the winding type of Fig. 6 according to another embodiment of the present invention;	25	[0017] In Fig. 1 reference sign 1 denotes a multi gap inductor core according an embodiment of the present invention. The core 1 includes a plurality of seven magnetic lamination sheets 2a-2g made of a ferrite material with lowest possible losses for the desired frequency range. Reference sign HA denotes a length axis of the core 1, i.e. along the staggering direction of the laminations 2a-2g.
Fig. 8	shows a cross-section of a multi gap inductor having a strand wire winding type according to still another embodiment of the present invention;	30	[0018] If, for example, the 1 MHz frequency range is desired, an appropriate ferrite material would be Ferroux-cube 3F45. By presently known cutting methods a minimum lamination thickness d1 of about 0,2 mm can be reached, allowing the permeability to be low and to have a good gap distribution.
Fig. 9a	is a plain view of a second example of an insulated conductive flat band used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention;	35	[0019] Between corresponding pairs of adjacent magnetic laminations there is provided a corresponding hardened non magnetic and non conducting glue layer 3a-3f. Each glue layer 3a-3f includes a spacer means 4 in form of spherical particles made of carbon, so-called glassy carbon spherical powder, which define a gap G having a predetermined thickness d2 between each corresponding pair of magnetic lamination sheets 2a-2g. Since a narrow size diameter distribution can be obtained by filtering such carbon material, the diameter d3 of the carbon particles 4 substantially equals the predetermined thickness d2 of the gap G. In other words, there is a monolayer of carbon particles included in the hardened glue layers 3a-3f acting as said mechanical spacer means. Only a few carbon particles per mm ² are sufficient to ensure a very homogeneous gap G. The carbon particles are also non
Fig. 9b,c	are perspective views of multiple parallel windings of the insulated conductive flat band shown in Fig. 9a in order to illustrate a second winding procedure;	40	magnetic and badly conductive and solid even at the temperature which develops in the glue during hardening step, e.g. 180°C. Specifically, the spacer particles do not influence the magnetic flux and do not produce any dis-
Fig. 10	is a perspective view of the second example of multiple parallel windings of insulated conductive flat band used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention after the second second winding procedure is finished;	45	
Fig. 11 a,b	are plain views of the first example of insulated conductive flat bands in form of a first and second specially stacked flat	50	
		55	

turbing heating effect.

[0020] The core 1 according to the embodiment of Fig. 1 allows the production of an inductor having excellent performance and comparatively low losses in the desired frequency range, here 1 MHz. The total gap of the core of Fig. 1 is the sum of all gaps G from where the magnetic field is dissipated only in a very small area causing no additional losses in the winding. The winding therefore can take the space very close to the core 1.

[0021] Fig. 2 shows a cross-section of a multi gap inductor core according to the first embodiment of the present invention in order to explain a corresponding manufacturing method thereof.

[0022] As depicted in Fig. 2 the desired number of magnetic lamination sheets 2a-2g is stacked on top of each other, wherein between the pairs of adjacent magnetic lamination sheets the glue layers 3a-3f are dispensed by appropriate dispensing means. The glue layer is a premix of glue and the spherical carbon particles 4.

[0023] In order to obtain the favourable concentration of some particles per mm^2 the concentration of the particles in the glue is typically between 0,1 and 3 %, preferably 1 %. If the volume concentration is too high there would be the risk that the particles stick together making the gap thickness d2 inhomogeneous. On the other hand, if the volume concentration of the particles is too low, the particles could be not evenly distributed over the area between adjacent laminations and therefore also make the thickness d2 inhomogeneous. Despite of these lower and upper limitations which can normally be found very easily by experiments, the range of applicable concentrations still stays broad.

[0024] When the stack with the desired number of laminations 2a-2g and the intervening glue/spacer layers 3a-3f are completed, a pressure P is applied on the stack such that the spherical carbon particles 4 can exactly match and define the gap G with the predetermined thickness d2 according to their own diameters d3. Depending on the type of glue, e.g. epoxy glue, the hardening can then be performed at room temperature or elevated temperatures, while the application of pressure P is continued until the stack is completely hardened.

[0025] Fig. 3, 4 are perspective views in order to explain the step of separating individual multi gap inductor cores from the hardened stack manufactured as explained in Fig. 2.

[0026] It should be mentioned that especially for small core diameters, the dimensions of the stack orthogonal to the length axis HA do not correspond to the dimensions of the finished core.

[0027] In the example of Fig. 2, the dimensions of the hardened stack 100 are 80 mm width, 50 mm depth, and 25 mm length.

[0028] In order to provide individual cores 1', the hardened stack 100 is cut by means of a wafer saw (i.e. diamond saw) or wire saw into rows 100a and then into the cores 1', where the laminations are labelled 2a'-2m' and the glue/spacer layers 3a'-3l'.

[0029] By using an appropriate sawing process arbitrary core shapes may be obtained, for example, circular shapes as shown in Fig. 4 for the core 1" including laminations 2a"-2n" and glue/spacer layers 3a"-3l".

[0030] This manufacturing method allows an accuracy of typically 5% of the inductance value and very small gaps. In a further example, 1,3 mm of gap were distributed among 65 ferrite sheets. The tolerance accuracy can be improved by sorting out and assembling together two or more partial core stacks in order to provide air gaps with desired small tolerances.

[0031] Fig. 5a is a plain view of a first example of an insulated conductive flat band (also sometimes denoted in the art as strip) used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention; and Fig. 5b,c are perspective views of the insulated conductive flat band shown in Fig. 5a in order to illustrate a first winding procedure.

[0032] The insulated conductive flat band 5 shown in Fig. 5a-c is made of insulated conductive material such as copper or aluminum and includes a first linear region SR, a second linear region SL and a third linear region SM. The width b1 of the first linear region SR is equal to the width b1 of the second linear region SL, and the width b2 of the third linear region SM is $2 \times b1 + S$, where S is a given distance. This means that the first and second linear regions SR, SL are displaced by the distance S.

[0033] Moreover, the first and second linear regions SR, SL are orthogonally connected to the third linear region SM and run in anti-parallel directions as may be clearly obtained from Fig. 5a. Virtual segments SR1-SR5 of the first linear region SR having a length l are denoted in order to show the folding lines when winding the insulated conductive flat band 5 around a core according to an embodiment of the present invention occurs. Analogously SL1-SL5 denote virtual segments of the second linear region SL having all the length l which is a little bit larger than the diameter of the core to be used.

[0034] As may be obtained from Fig. 5b and 5c the first linear region SR and the second linear region SL are wound in opposite directions FU (clockwise) and FG (counter-clockwise) around the third linear region SM in order to form the winding around the core of the embodiments of the present invention.

[0035] Fig. 6 is a perspective view of the first example of insulated conductive flat band used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention after the first winding procedure is finished.

[0036] A finished winding 5' made of an insulated conductive flat band as shown in Figs. 5a-c is shown in Fig. 6. As depicted, it is preferred that the ends E1, E2 of the finished winding 5' are orthogonal to the length axis HA of the core to be inserted into the finished winding 5'.

[0037] Fig. 7 shows a cross-section of a multi gap inductor having the winding type of Fig. 6 according to another embodiment of the present invention.

[0038] The finished inductor of Fig. 7 includes a multi

gap core 1''' having 20 laminations with intervening glue/spacer layers as explained in connection with Figs. 1 and 2 and having a surrounding winding 5'' in analogy to the winding 5' described with reference to Fig. 6, however, having a larger number of winding turns.

[0039] As may be clearly obtained from Fig. 7, the gap β between the core 1''' and the winding 5'' can be made very small. The section A of Fig. 7 is shown in enlarged form on the righthand side of Fig. 7 and also shows the space s which corresponds to the distance S between the first and second linear regions SR, SL.

[0040] Reference sign V finally denotes a magnetic shielding which surrounds the inductor according to this embodiment and closes the magnetic field of the coil.

[0041] Fig. 8 shows a cross-section of a multi gap inductor having a strand wire winding type according to still another embodiment of the present invention.

[0042] In the embodiment shown in Fig. 8 the laminated core 1''' is surrounded by a strand wire 50. All further details are the same as described above with respect to Fig. 7.

[0043] Fig. 9a is a plain view of a second example of an insulated conductive flat band used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention; and Fig. 9b,c are perspective views of multiple parallel windings of the insulated conductive flat band shown in Fig. 9a in order to illustrate a second winding procedure.

[0044] The insulated conductive flat band 25 shown in Fig. 9a includes first linear region SU, a second linear region SO and a third linear region SM'. As in the example of Fig. 5a, the third linear region SM' is substantially orthogonally connected to the first linear region SU and to said second linear region SO, wherein the first linear region SU and the second linear region SO are displaced by a distance S, however, in contrast to the example in Fig. 5a run in parallel. The distance S arises from the difference of the width b2 of the third linear region SM' and the sum of the width b1 of the first and second linear regions SU, SO.

[0045] In these examples virtual segments SU1-SU5 of the first linear region SU and virtual segments SO1-SO5 of the second linear region SO are depicted in order to clarify the folding lines when the insulated conductive flat band 25 of Fig. 9a is wound to form a winding around a core according to an embodiment of the present invention.

[0046] As shown in Fig. 9b a plurality of insulated conductive flat bands of the 25, 25', 25'', 25''' of the type shown in Fig. 9a is isolatedly stacked on top of each other. The isolation can be achieved by using a foil, e.g. Kapton foil a resin or a native or artificial oxide on the surface of the insulated conductive flat bands 25, 25', 25'', 25'''.

[0047] As may be obtained from Fig. 9c, the stack of insulated conductive flat bands 25, 25', 25'', 25''' shown in Fig. 9b is then wound in opposite directions FU (clockwise) and FG (anticlockwise) around the third linear re-

gions of the insulated conductive flat bands 25, 25', 25'', 25''' in order to form the winding around a core according to an embodiment of the present invention.

[0048] Fig. 10 is a perspective view of the second example of multiple parallel windings of insulated conductive flat band used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention after the second winding procedure is finished.

[0049] The final winding shape is shown in Fig. 10, wherein the ends E1', E2' are also bend orthogonal to the length axis HA of the core in accordance with the embodiments of the present invention to be inserted into the wound winding.

[0050] In the embodiment shown in Fig. 10 the outer flat band 25 on one side becomes the inner flat band on the other side when wound in opposite directions FU, FG. This contributes to counteract the proximity effect which otherwise would tend to shift the high-frequency current in the outermost flat band area. In particular, the stack sequence change equalizes the induced voltage along the bands in order to avoid a current along the bands.

[0051] Fig. 11 a,b are plain views of the first example of insulated conductive flat band in form of a first and second specially stacked flat bands used as a winding in connection with the multi gap inductor core according to the embodiments of the present invention.

[0052] In the embodiment shown in Fig. 11 a winding around a core in accordance with the embodiments described is made of two insulated conductive flat bands 5a, 5b of the type shown in Fig. 5a which are specially stacked on top of each other in an isolated manner.

[0053] In the insulated conductive flat bands 5a, 5b shown in Fig. 11 a SRa, SRb denote the corresponding first linear region of the first and second flat band 5a, 5b and SLa, SLb denote the corresponding second linear region of the flat bands 5a, 5b, whereas SMa and SMb correspond to a respective third linear region connecting the first and second linear regions of the flat bands 5a, 5b.

[0054] Before being wound the insulated conductive flat bands 5a, 5b shown in Fig. 11 a are stacked isolatedly on each other such that there is a crossover such that on one side the first linear region SRa of the first insulated conductive flat band 5a lies above the first linear region SRb of the second insulated conductive flat band 5b, however, on the other side the second linear region SLa of the first insulated conductive flat band 5a lies below the second linear region SLb of the second insulated conductive flat band 5b. In the crossover region there is a small lateral gap S' x S between the insulated conductive flat bands 5a, 5b.

[0055] When winding the stacked arrangement of the first and second insulated conductive flat bands 5a, 5b shown in Fig. 11b it also becomes possible like in the embodiment shown in Fig. 10 that the outer flat band on one side becomes the inner flat band on the other side when wound in opposite directions FU, FG. This contrib-

utes to counteract the proximity effect which otherwise would tend to shift the high-frequency current in the outermost flat band area.

[0056] Fig. 12 shows a partial cross-section of a multi gap inductor core according to an embodiment of the present invention.

[0057] In this embodiment, spacer means 4' includes a photolithographically structured Al_2O_3 layer having a plurality of cube shape bumps 4' between which the hard-ended fixing layers 3f etc. are provided. Here the fixing layer 3f is not made of glue but of adhesive wax.

[0058] Fig. 13 shows a schematic view of a transformer including a multi gap inductor core according to an embodiment of the present invention.

[0059] In Fig. 13 reference sign 1 denotes a multi gap inductor core according to the embodiment of the present invention shown in Fig. 1, and W1, W2 denote a primary and secondary winding wound around the core so as to form a transformer T.

[0060] Although the present invention has been described with reference to particularly embodiments, various modifications can be performed without departing from the scope of the present invention as defined in the independent claims.

[0061] In particular, the spacer means is not restricted to the specified carbon particles or Al_2O_3 bumps, but other materials, e.g. sand particles or quartz particles, or spacer foils or meshes may be used as well. Also the shape of the particles or bumps is not restricted to the circular or square cube shape, but can have various other shapes, such as polyedral shape, etc., however, it still is important that the diameter distribution is narrow enough to achieve the desired homogeneity of the gap thickness between the individual laminations. Moreover, various materials can be used for the laminations, the fixing material and the windings, and the invention is not restricted to the materials and dimensions mentioned hereinbefore. E.g. further examples of the fixing material are Teflon, resist and grease which can be sufficiently hardenend.

Claims

1. Multi gap inductor core (1; 1'; 1"; 1'''), comprising:

a first plurality of magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') made of magnetic core material arranged in a stack;
a second plurality of fixing layers (3a-3f; 3a'-3l'; 3a''-3l'') made of a fixing material;
wherein each fixing layer (3a-3f; 3a'-3l'; 3a''-3l'') is arranged between a corresponding pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n''); and
wherein each fixing layer (3a-3f; 3a'-3l'; 3a''-3l'') includes embedded mechanical spacer means (4; 4') which define a gap (G) having a predetermined thickness (d2) between a correspond-

ing pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'').

2. Multi gap inductor core (1; 1'; 1"; 1''') of claim 1, wherein the fixing material is glue.

3. Multi gap inductor core (1; 1'; 1"; 1''') of claim 1, wherein the mechanical spacer means (4; 4') comprises substantially spherical particles (4), and wherein a diameter (d3) of the spherical particles (4) substantially equals said predetermined thickness (d2).

4. Multi gap inductor core (1; 1'; 1"; 1''') of claim 2, wherein the particles (4) are spherical carbon particles (14).

5. Multi gap inductor core (1; 1'; 1"; 1''') of one of claims 1 to 4, wherein the magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') are ferromagnetic sheets, particularly ferrite sheets.

6. Multi gap inductor core (1; 1'; 1"; 1''') of one of claims 1 to 5, wherein the the magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') have a thickness between 0,1 and 1 mm and/or the predetermined gap thickness (d2) is between 10 and 100 μ m.

7. Multi gap inductor, comprising:

a multi gap inductor core (1; 1'; 1"; 1''') of one of claims 1 to 6; and
a flat band winding (5; 5'; 5"; 25, 25', 25'', 25'''; 5a, 5b) and/or a strand wire winding (50) wound around a length axis (HA) of the multi gap inductor core (1; 1'; 1"; 1''').

8. Multi gap inductor of claim 7, comprising a flat band winding including at least one insulated conductive flat band (5; 5'; 5"; 5a, 5b) having a first linear region (SR; SRa; SRb), a second linear region (SL; SLa; SLb), and a third linear region (SM; SMa; SMb), wherein the third linear region (SM; SMa; SMb) is substantially orthogonally connected to said first linear region (SR; SRa; SRb) and to said second linear region (SL; SLa; SLb) such that said first linear region (SR; SRa; SRb) and said second linear region (SL; SLa; SLb) are displaced by a distance (S) and run in anti-parallel, and wherein said first linear region (SR; SRa; SRb) and said second linear region (SL; SLa; SLb) are wound in opposite directions (FU, FG) around the multi gap inductor core (1; 1'; 1"; 1''') and around said third region (SM; SMa; SMb).

9. Multi gap inductor of claim 8, wherein a first and second of said insulated conductive flat bands (5a, 5b) are stacked isolatedly on each other such that there is a crossover such that on one side the first linear

- region (SRa) of the first insulated conductive flat band (5a) lies above the first linear region (SRb) of the second insulated conductive flat band (5b) and on the other side the second linear region (SLa) of the first insulated conductive flat band (5a) lies below the second linear region (SLb) of the second insulated conductive flat band (5b), and wherein the stacked first and second of said insulated conductive flat bands (5a, 5b) are wound in opposite directions (FU, FG) around the multi gap inductor core (1; 1'; 1"; 1''').
10. Multi gap inductor of claim 7, comprising a flat band winding including at least one insulated conductive flat band (25, 25', 25'', 25''') having a first linear region (SU), a second linear region (SO), and a third linear region (SM'), wherein the third linear region (SM') is substantially orthogonally connected to said first linear region (SU) and to said second linear region (SO) such that said first linear region (SU) and said second linear region (SO) are displaced by a distance (S) and run in parallel, and wherein said first linear region (SU) and said second linear region (SO) are wound in opposite directions (FU, FG) around the multi gap inductor core (1; 1'; 1"; 1''') and around said third region (SM').
11. Multi gap inductor of claim 10, wherein a plurality of said insulated conductive flat bands (25, 25', 25'', 25''') is stacked isolatedly on each other, and wherein the stacked plurality of said insulated conductive flat bands (25, 25', 25'', 25''') is wound in opposite directions (FU, FG) around the multi gap inductor core (1; 1'; 1"; 1''') such that the stacking sequence is changed.
12. Method of manufacturing multi gap inductor cores (1; 1'; 1"; 1'''), comprising the steps of:
- stacking a first plurality of magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') made of magnetic core material;
 - dispensing a second plurality of fixing layers (3a-3f; 3a'-31'; 3a''-31'') made of a fixing material between each pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'');
 - providing mechanical spacer means (4; 4') between each pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') embedded in said fixing layers (3a-3f; 3a'-31'; 3a''-31'');
 - pressing said stacked first plurality of magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') having said second plurality of fixing layers (3a-3f; 3a'-31'; 3a''-31'') and said spacer means (4; 4') between each pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') such that said mechanical spacer means (4; 4') define a gap (G) having a predetermined thickness (d2) between a corresponding pair of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'');
 - hardening said fixing layers (3a-3f; 3a'-31'; 3a''-31'') while pressing so as to form a hardened stack; and
 - providing one or more multi gap inductor cores (1; 1'; 1"; 1''') from said hardened stack.
13. Method of claim 12, wherein said hardened stack is cut by means of a saw, preferably a wafer saw or awire saw, in order to provide said one or more multi gap inductor cores (1; 1'; 1"; 1''') from said hardened stack.
14. Method of claim 12 or 13, wherein said fixing layers (3a-3f; 3a'-31'; 3a''-31'') are dispensed between said corresponding pairs of adjacent magnetic lamination sheets (2a-2g; 2a'-2m'; 2a''-2n'') as a premix of glue as said fixing material and said mechanical spacer means (4; 4').
15. Method of one of claims 12 or 14, wherein said mechanical spacer means (4) comprises substantially spherical particles (4), and wherein a diameter (d3) of the spherical particles (4; 4') substantially equals said predetermined thickness (d2).
16. Transformer (T) comprising a multi gap inductor core (1; 1'; 1"; 1''') of one of claims 1 to 6.
17. Flat band winding for an inductor core, comprising:
- at least one insulated conductive flat band (5; 5'; 5''); 5a, 5b) having a first linear region (SR; SRa; SRb), a second linear region (SL; SLa; SLb), and a third linear region (SM; SMa; SMb), wherein the third linear region (SM; SMa; SMb) is substantially orthogonally connected to said first linear region (SR; SRa; SRb) and to said second linear region (SL; SLa; SLb) such that said first linear region (SR; SRa; SRb) and said second linear region (SL; SLa; SLb) are displaced by a distance (S) and run in anti-parallel, and wherein said first linear region (SR; SRa; SRb) and said second linear region (SL; SLa; SLb) are wound in opposite directions (FU, FG) around the inductor core (1; 1'; 1"; 1''') and around said third region (SM; SMa; SMb).
18. Flat band winding for an inductor core, comprising:
- at least one insulated conductive flat band (25, 25', 25'', 25''') having a first linear region (SU), a second linear region (SO), and a third linear region (SM'), wherein the third linear region (SM') is substantially orthogonally connected to said first linear region (SU) and to said second linear region (SO) such that said first linear re-

gion (SU) and said second linear region (SO) are displaced by a distance (S) and run in parallel, and wherein said first linear region (SU) and said second linear region (SO) are wound in opposite directions (FU, FG) around the inductor core (1; 1'; 1"; 1''') and around said third region (SM').

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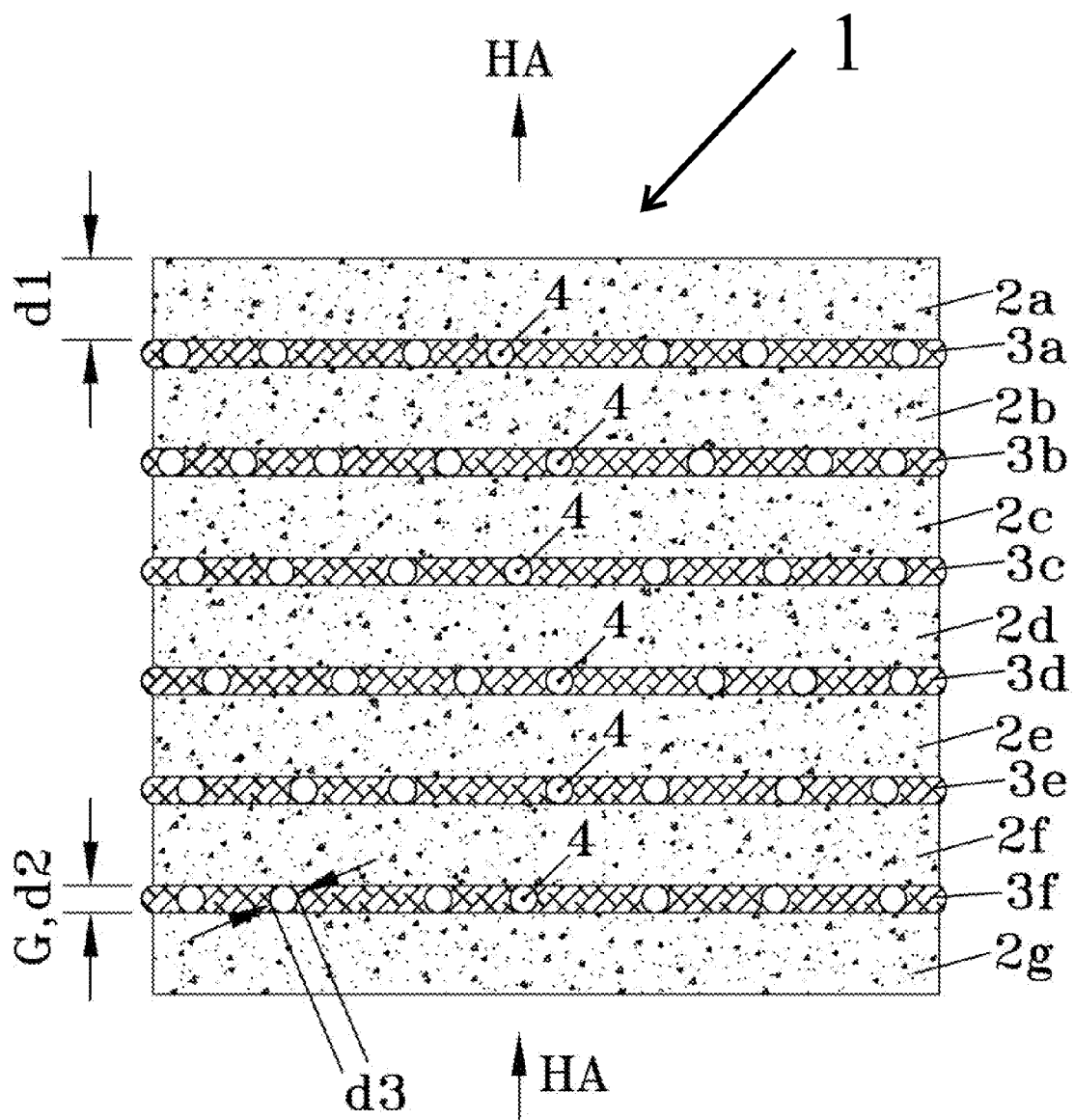


Fig. 1

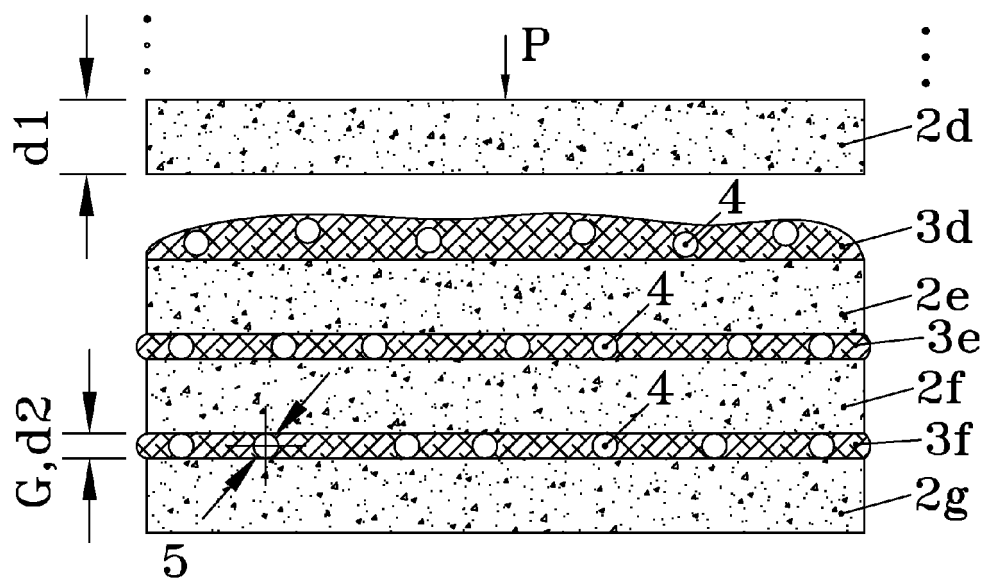


Fig. 2

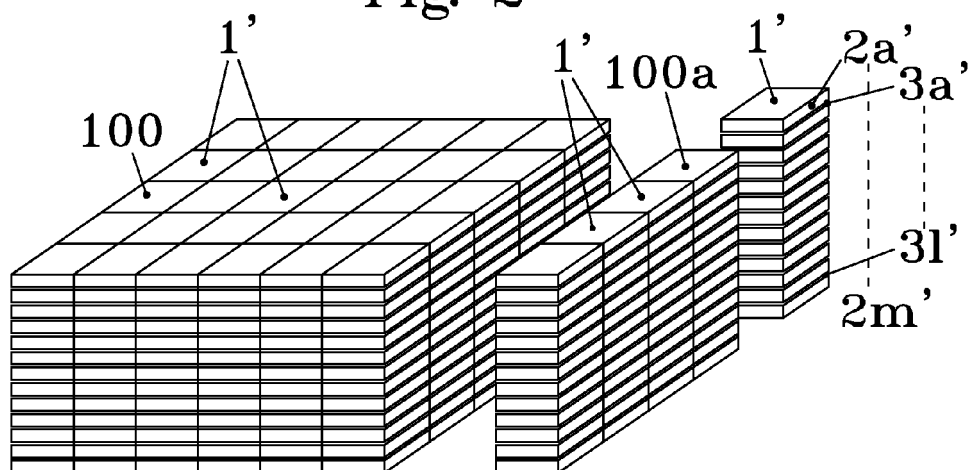


Fig. 3

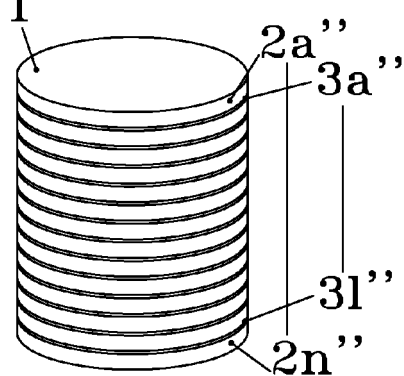


Fig. 4

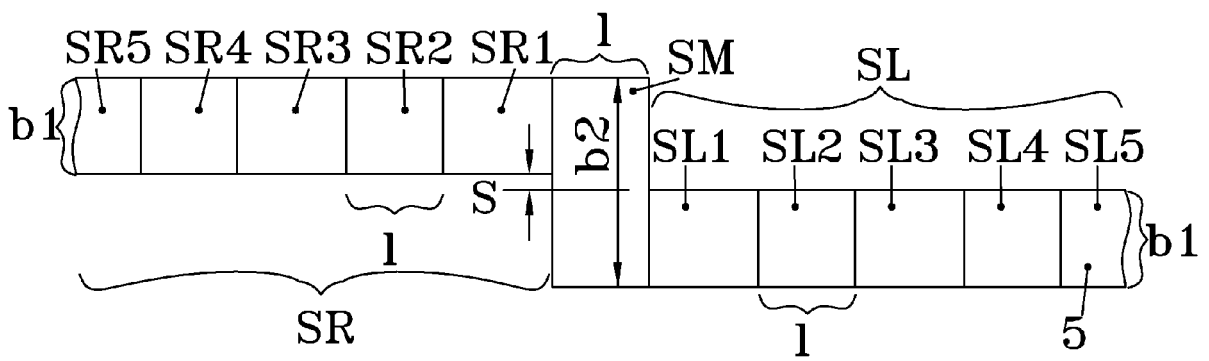


Fig. 5a

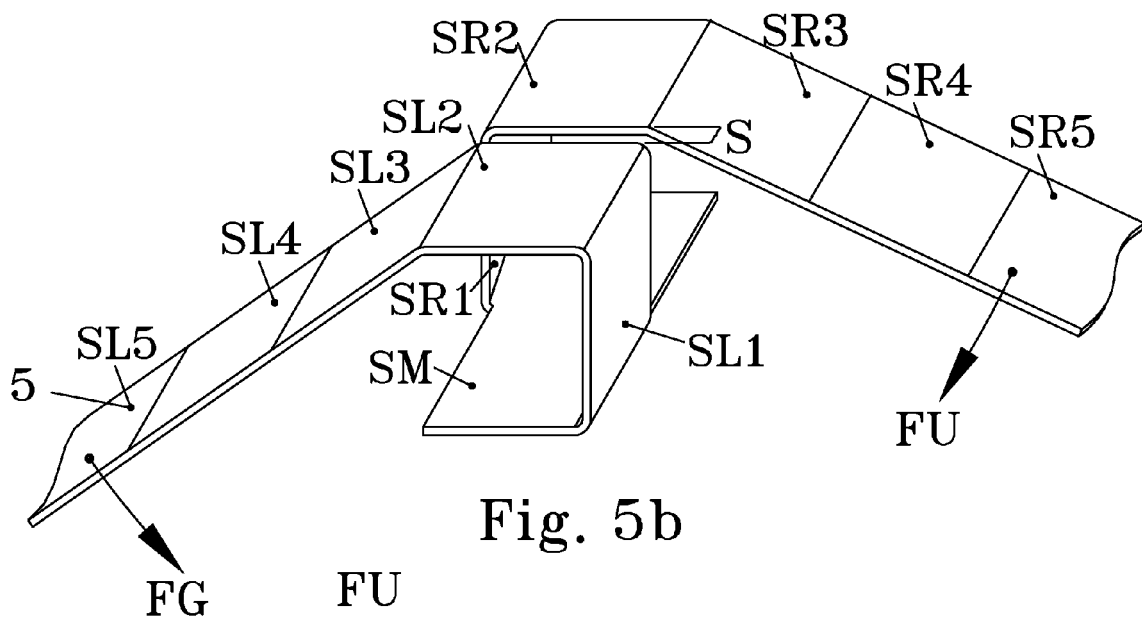


Fig. 5b

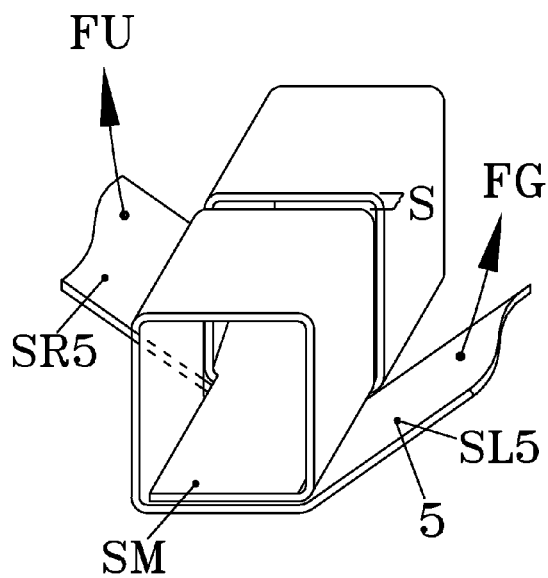


Fig. 5c

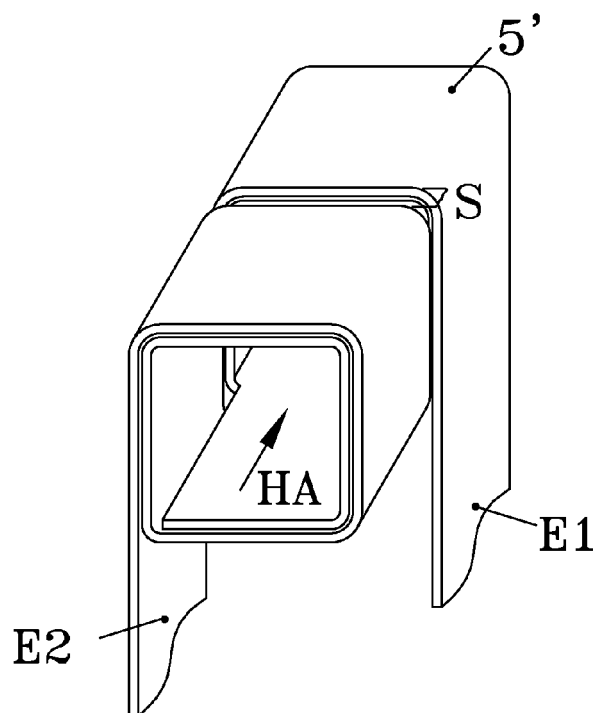


Fig. 6

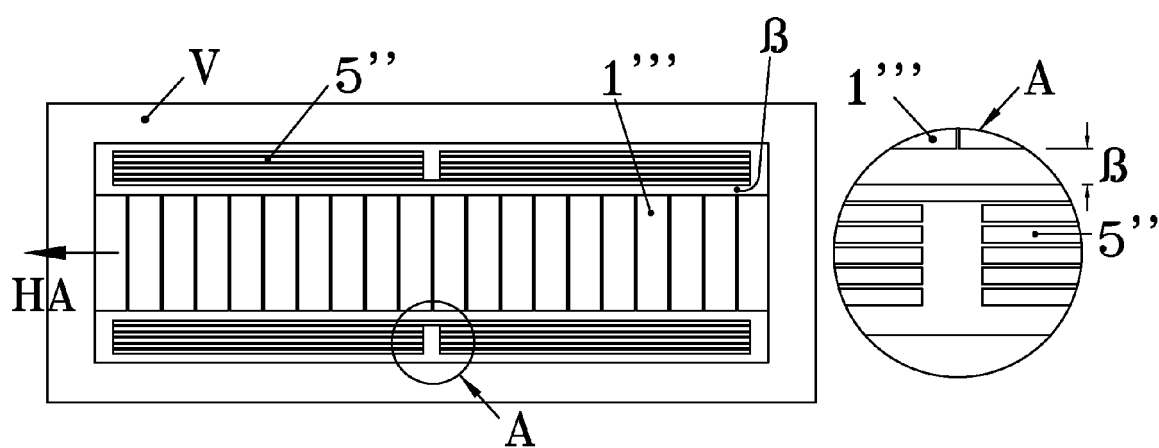


Fig. 7

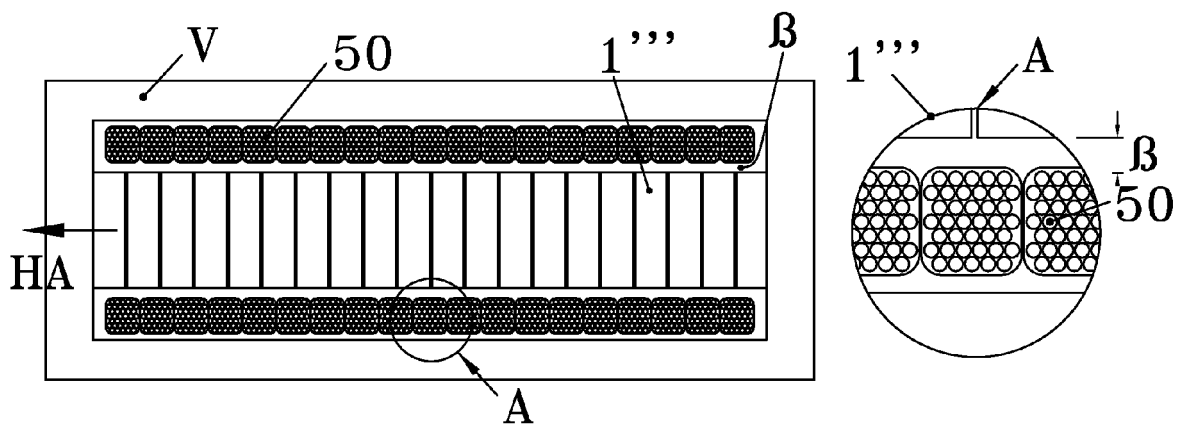


Fig. 8

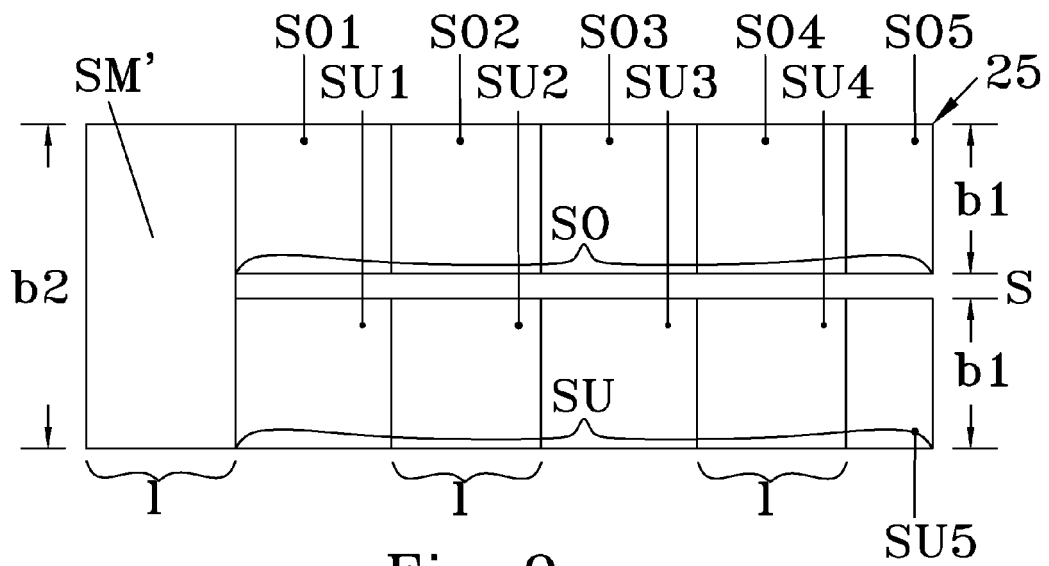


Fig. 9a

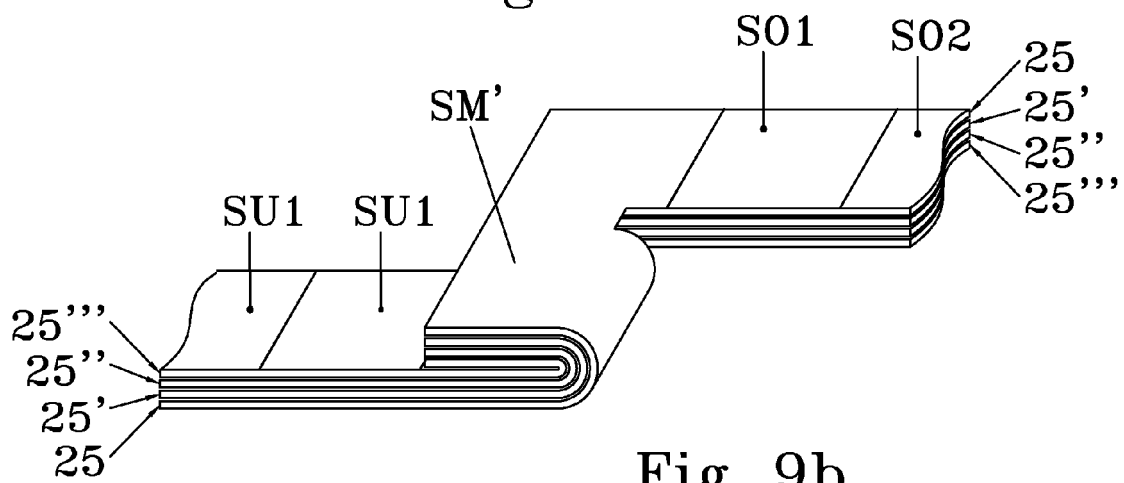


Fig. 9b

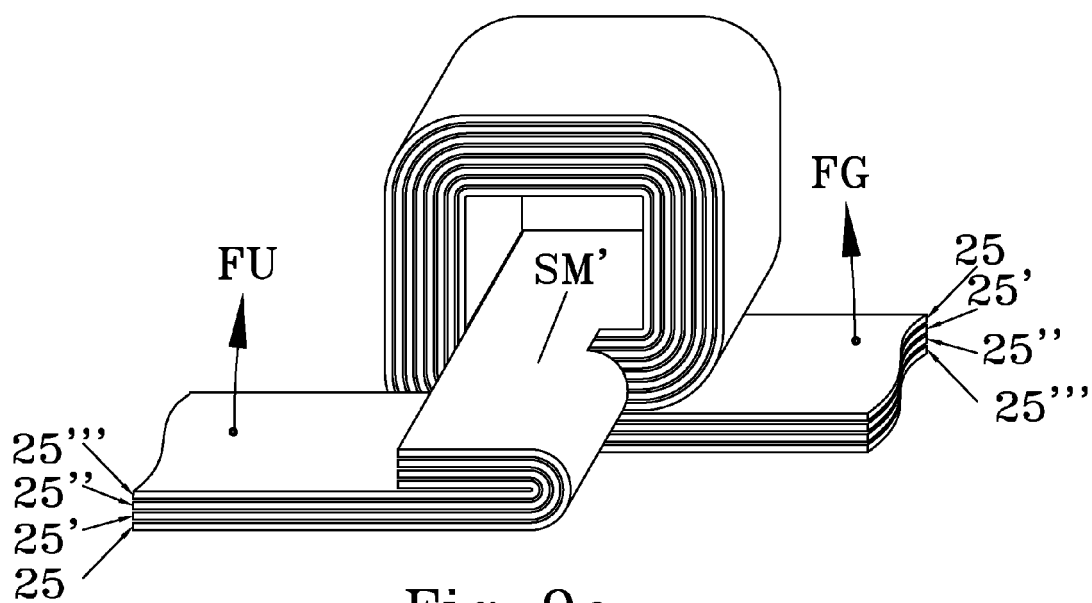


Fig. 9c

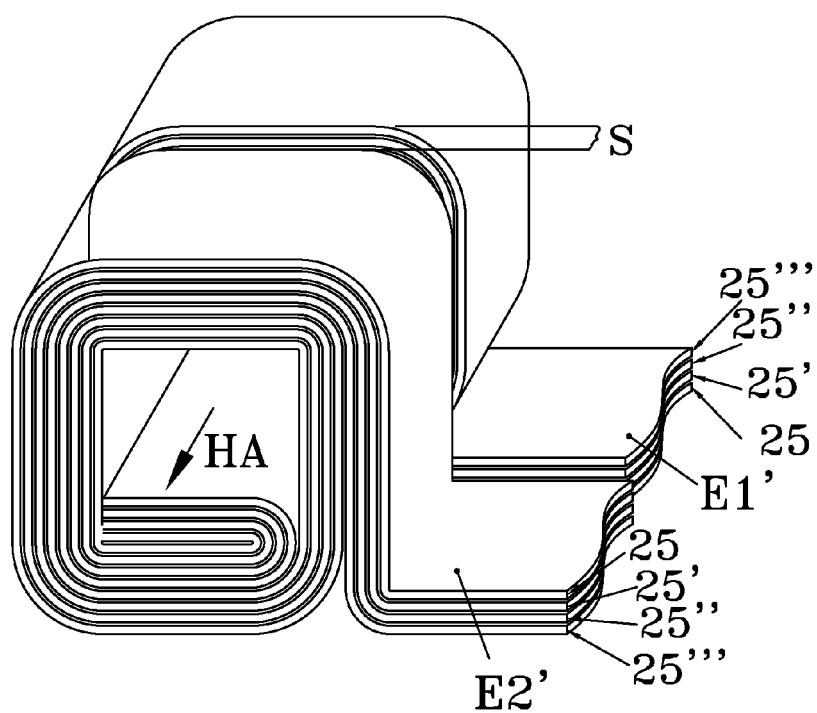


Fig. 10

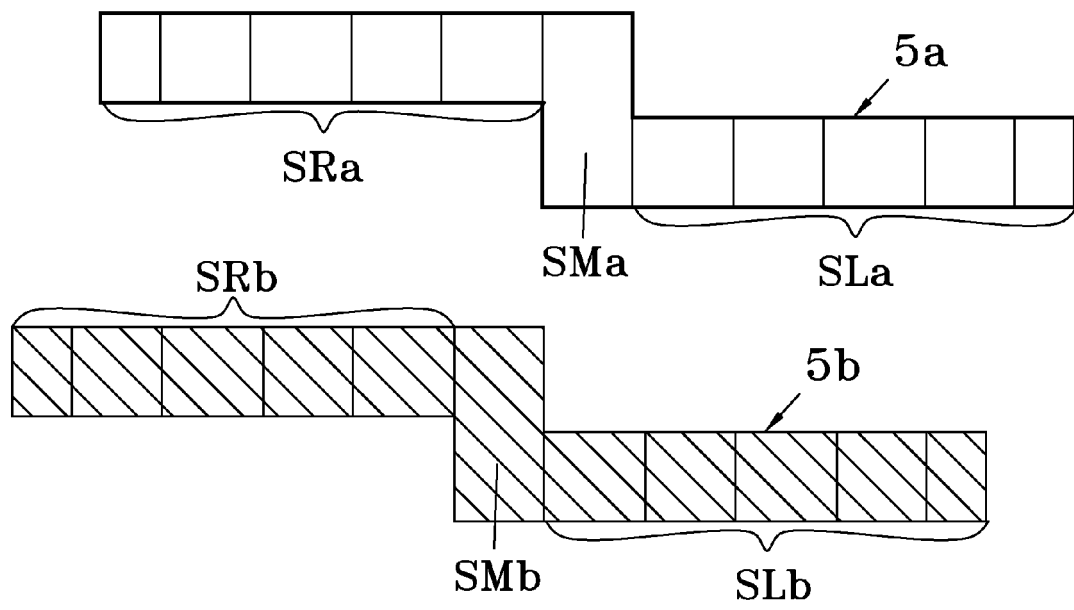


Fig. 11a

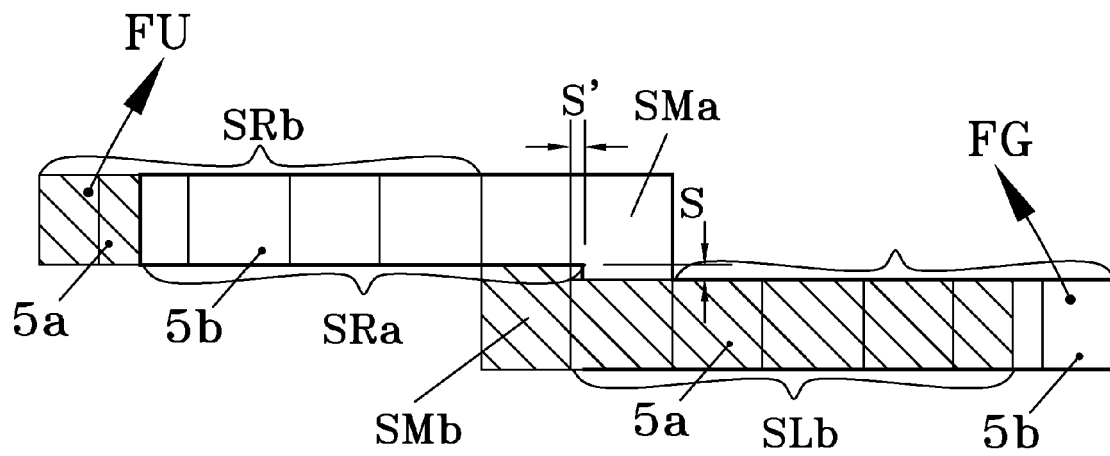


Fig. 11b

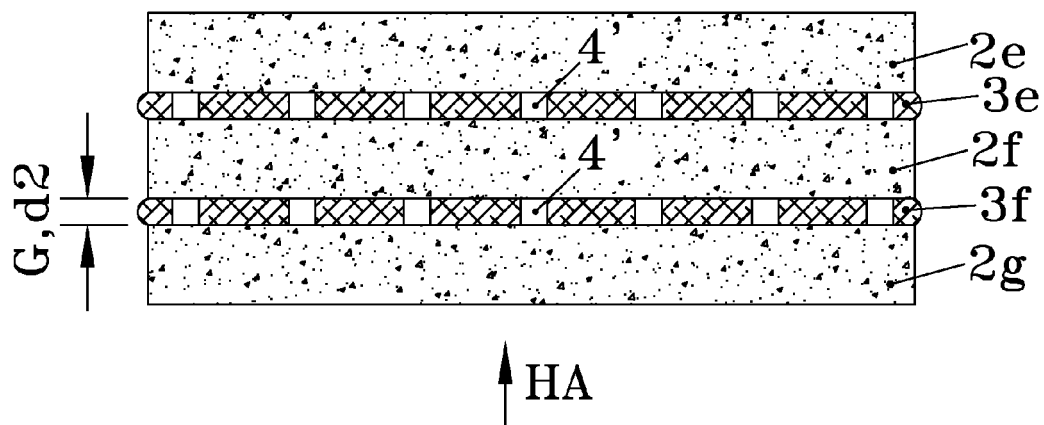


Fig. 12

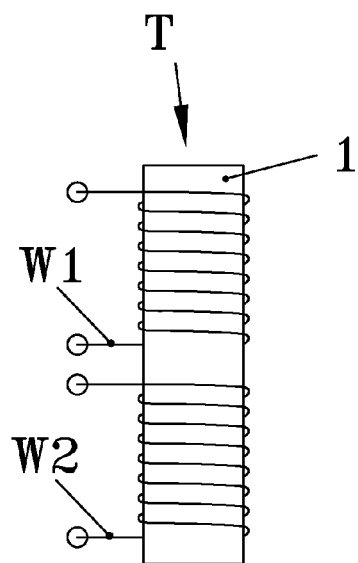


Fig. 13

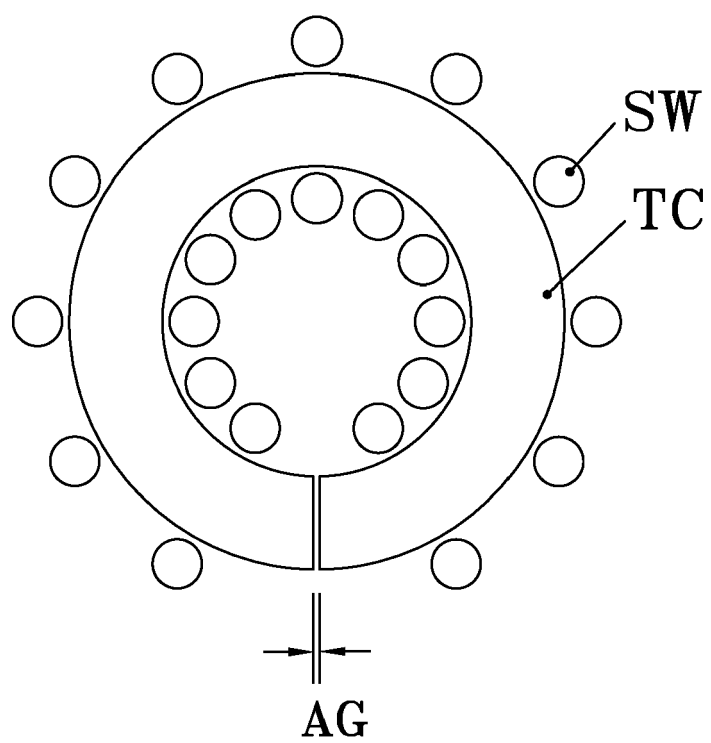


Fig. 14



EUROPEAN SEARCH REPORT

 Application Number
EP 11 16 7585

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	* page 1, lines 25-59,70-74 *	8,9	
X	US 5 676 768 A (MURAOKA SHUNSAKU [JP] ET AL) 14 October 1997 (1997-10-14) * column 6, lines 10-23; figure 1 * * column 7, line 16 - column 8, line 7; figures 11-17 *	1,2,5,7, 12,13	
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A	GB 1 562 276 A (VOGT GMBH & CO KG) 12 March 1980 (1980-03-12) * page 1, line 52 - page 2, line 2; figure 1 *	1-16	
X	DE 100 40 415 C1 (ROBERT SEUFFER GMBH & CO KG [DE]) 10 January 2002 (2002-01-10) * paragraphs [0023] - [0027]; figures 1-5 *	17 8	
Y			
		-/--	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 January 2012	Examiner Reder, Michael
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

2

EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
EP 11 16 7585

DOCUMENTS CONSIDERED TO BE RELEVANT			
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X	GB 2 037 089 A (PHILIPS NV) 2 July 1980 (1980-07-02)	1-7,12, 14-16	INV. H01F3/14
Y	* abstract; figures 1,2 * * page 1, lines 25-59,70-74 *	8,9	H01F27/28 H01F27/34

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A	GB 1 562 276 A (VOGT GMBH & CO KG) 12 March 1980 (1980-03-12) * page 1, line 52 - page 2, line 2; figure 1 *	1-16	

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Y	* paragraphs [0023] - [0027]; figures 1-5 *	8	

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 January 2012	Examiner Reder, Michael
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

 2
EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
EP 11 16 7585

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2007/136288 A1 (IVANOV SERGEY VASILIEVICH [RU]; SKOBLILOV ANDREY NIKOLAEVICH [RU]; SLI) 29 November 2007 (2007-11-29)	17	
Y	* abstract; figures 1-9 * -----	8,9	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 January 2012	Examiner Reder, Michael
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

2

EPO FORM 1503 03-82 (P04C01)



Application Number

EP 11 16 7585

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☒ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 11 16 7585

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-16

Invention 1: Multi gap inductor core and method of manufacturing the same.

The inductor core is characterized by the structure of the gaps which comprise mechanical spacer means and fixing material.

2. claims: 17, 18

Invention 2: Flat band winding for an inductor core.

The winding is characterized by two alternative arrangements of three linear regions.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 16 7585

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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09-01-2012

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EPO FORM P0459

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

REFERENCES CITED IN THE DESCRIPTION

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