(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 October 2015 (01.10.2015)

(10) International Publication Number
WO 2015/143643 A1

(51) International Patent Classification:
H01F 17/04 (2006.01)

(21) International Application Number:
PCT/CN2014/074117

(22) International Filing Date:
26 March 2014 (26.03.2014)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: NON-MAGNETIC FERRITE DIELECTRICS IN COMMON MODE CHOKES

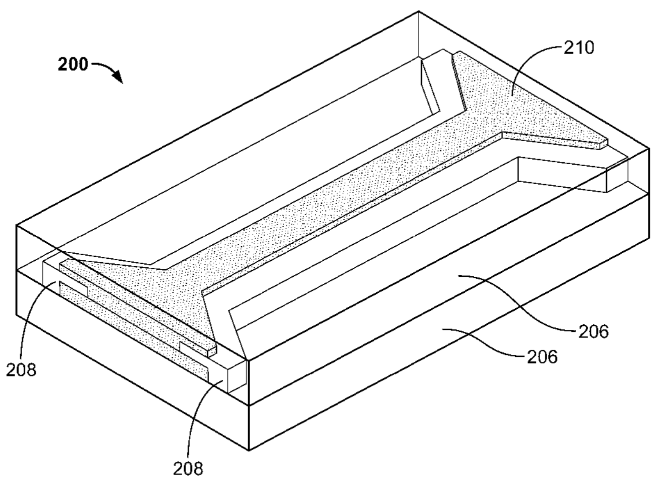

FIG. 2

(57) Abstract: According to various aspects, exemplary embodiments are disclosed of common mode chokes. Also disclosed are methods for making or manufacturing common mode chokes.In some exemplary embodiments,common mode chokes comprise a generally rectangular body having opposing first and second ends, and including a lower ferrite portion,an upper ferrite portion,and at least one pair of laterally spaced-apart interior conductors within the body generally between the upper and lower ferrite portions and longitudinally extending from about the first end to about the second end of the generally rectangular body. The common mode choke may also include a non-magnetic ferrite dielectric within the body and disposed laterally between the at least one pair of interior conductors.

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NON-MAGNETIC FERRITE DIELECTRICS IN COMMON MODE CHOKES

FIELD

The present disclosure generally relates to non-magnetic ferrite dielectrics in common mode chokes.

BACKGROUND

This section provides background information related to the present disclosure which is not necessarily prior art.

Chokes are commonly used in electronic circuits to block signal frequencies above a desired range, while at the same time allowing DC or low frequency signals to pass. Thus, chokes have been employed to prevent electromagnetic interference (EMI) from disturbing various electronic devices.

A choke is typically provided by a magnetic core through which, or around which, conductors or windings are positioned. Ferrite materials are commonly used as the core material for many chokes because, for example, ferrites have sensitive magnetic-frequency relationships. A dielectric layer may be positioned between the conductors or windings. Conventional dielectric layers may include titanium dioxide or aluminum dioxide.

SUMMARY

This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

According to various aspects, exemplary embodiments are disclosed of common mode chokes. Also disclosed are methods for making or manufacturing common mode chokes. In some exemplary embodiments, common mode chokes comprise a generally rectangular body having opposing first and second ends, and including a lower ferrite portion, an upper ferrite portion, and at least one pair of laterally spaced-apart interior conductors within the body generally between the upper and lower ferrite portions and longitudinally extending from about the first end to about the second end of the generally rectangular body. The common mode choke may also include a non-magnetic ferrite dielectric within the body and disposed laterally between the at least one pair of interior conductors.

Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

FIG. 1 is a perspective view of a common mode choke according to an exemplary embodiment;

FIG. 2 is a perspective view of a common mode choke illustrating an internal structure of the common mode choke according to an exemplary embodiment;

FIGS. 3A and 3B are scanning electron microscope (SEM) images of a non-magnetic ferrite dielectric material according to an exemplary embodiment;

FIGS. 4A and 4B are SEM images of a prior art titanium dioxide dielectric material; and

FIGS. 5 and 6 provide various performance test data measured for physical prototypes of common mode chokes according to exemplary embodiments, which test results are provided only for purposes of illustration and not for purposes of limitation.

Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

Example embodiments will now be described more fully with reference to the accompanying drawings.

The inventors hereof have recognized that some existing common mode chokes using titanium dioxide as a dielectric layer more easily fail at high temperature and high humidity conditions when a specified voltage is applied. After recognizing the above, the inventors hereof developed and disclose herein exemplary embodiments of non-magnetic ferrite dielectrics (*e.g.*, material layers, *etc.*) for common mode chokes.

For example, disclosed herein are exemplary embodiments of common mode chokes (*e.g.*, FIG. 1, FIG. 2, *etc.*), which comprise a generally rectangular body having opposing first and second ends, and including a lower ferrite portion, an upper ferrite portion, and at least one pair of laterally spaced-apart interior conductors within the body generally between the upper and lower ferrite portions and longitudinally extending from about the first end to about the second end of the generally rectangular body. The common mode choke may also include a non-magnetic ferrite dielectric within the body and disposed laterally between the at least one pair of interior conductors. The non-magnetic ferrite dielectric is configured to control magnetic coupling between the at least one pair of interior conductors.

Advantageously, the exemplary embodiments of common mode chokes including a non-magnetic ferrite dielectric layer disclosed herein may provide enhanced performance over other existing common chokes that have aluminum oxide or titanium dioxide dielectric layers. For example, exemplary embodiments of common mode chokes including a non-magnetic ferrite dielectric layer disclosed herein may provide one or more (but not necessarily any or all) of the following advantages, such as better material compatibility and reliability, high density, good firing compatibility, reduced de-lamination issues, increased service life, reduced silver migration when a specified voltage is applied, higher common mode impedance, lower normal mode impedance, *etc.*

FIG. 1 illustrates an exemplary embodiment of a common mode choke 100 embodying one or more aspects of the present disclosure. As shown in FIG. 1, the common mode choke 100 may comprise a generally rectangular body. The generally rectangular body may comprise ferrite. As illustrated in FIG. 1, the common mode choke 100 may include a first termination pair 102 at a first end of the body, and a second termination pair 104 at a second end of the body.

The common mode choke 100 may comprise a laminated structure including a magnetic substrate, a dielectric material layer and interior conductor layers laminated on the magnetic substrate in a direction of thickness. The dielectric layer may be printed on a conductor pattern using a thick-film process, which may electrically insulate the conductor layers.

FIG. 2 shows a perspective view illustrating an exemplary interior structure of a multi-layer common mode choke 200, which includes upper and lower ferrite portion magnetic substrates 206. The upper and lower ferrite portion magnetic substrates 206 may be separate layers, or the upper and lower ferrite portion magnetic substrates 206 may comprise a single monolithic layer. The common mode choke 200 may include a pair of spaced apart longitudinally extending parallel interior conductors 208 between the upper and lower ferrite portions magnetic substrates 206.

The height or thickness of the interior conductors 208 may create a tunnel or gap between them. A non-magnetic ferrite dielectric material layer 210 may partially encapsulate or cover the conductors 208. The non-magnetic ferrite dielectric material layer 210 may be below the conductors 208, within the tunnel between the conductors 208, and overlying the tunnel and adjacent portions of the conductors 208. The non-magnetic ferrite dielectric material layer 210 may be configured to control magnetic coupling between the at least one pair of interior conductors 208. The interior conductors 208 may be coupled to a first termination pair at the first end of the body and a second termination pair at the second end of the body (not shown). Although one example internal conductor and dielectric structure is illustrated in FIG. 2, it is understood that other suitable internal structures may be used in other exemplary embodiments.

Prior common mode chokes have used conventional titanium dioxide material for the dielectric layer, which may appear white in color or lighter than the ferrite magnetic layers of the common mode choke. Disclosed herein are exemplary embodiments of a common mode choke that include non-magnetic ferrite for the dielectric layer. In such exemplary embodiments, the non-magnetic ferrite dielectric layer may appear dark or black in color similar to the ferrite magnetic layers of the common mode choke.

According to example embodiments of the present disclosure, a raw material for a non-magnetic ferrite may include 42 to 60 mol % of ferrite oxide (Fe_2O_3), 45 to 55 mol % of zinc oxide (ZnO), and 2 to 10 mol % of copper oxide (CuO). In one particular embodiment, a raw material for a non-magnetic ferrite may include about 47 mol % of ferrite oxide (Fe_2O_3), about 49 mol % of zinc oxide (ZnO), and about 4 mol % of copper oxide (CuO). The non-magnetic ferrite may thus be Zn-Cu based and/or Fe-Zn-Cu based. Although example chemical formulas are given here containing specific relative chemical values, it is understood that other suitable raw materials comprising other amounts of ferrite oxide, zinc oxide, and copper oxide may be used in other exemplary embodiments.

The raw material may be wet prepared for a ball mill for a suitable predetermined amount of time. The obtained mixture may be dried and ground. The obtained powder may, for example, be calcinated at 900 +/- 50 degrees Celsius for 2 +/- 0.5 hours (*e.g.*, 920 degrees Celsius for two hours, *etc.*). Although specific temperatures and lengths of calcination time are given here, it is understood that other suitable temperatures and lengths of calcination time may be used in other exemplary embodiments.

The ferrite powder may be wet prepared for a ball mill for a suitable predetermined amount of time with 0.4 to 0.9 wt % of bismuth oxide (Bi_2O_3) added, then be dried and sieved to get low temperature co-fired powder. The obtained low temperature co-fired powder may be mixed with a binder resin and a solvent to prepare an ink. The ink may be printed by a roll miller a predetermined amount of times. Although one example process for making the non-magnetic ferrite dielectric layer is described herein, it is understood that other suitable processes may be used to make the non-magnetic ferrite dielectric layer in other exemplary embodiments.

The raw material of the non-magnetic ferrite may be similar to a nickel-copper-zinc (Ni-Cu-Zn) magnetic substrate. This may allow for a very high density and good firing compatibility between non-magnetic ferrite and magnetic ferrite. This may decrease de-lamination issues, and may increase the product's service life. Exemplary embodiments may include a ring core of Cu-Zn based non-magnetic ferrite and Ni-Cu-Zn based magnetic ferrite.

FIGS. 3A and 3B are scanning electron microscope (SEM) images of a non-magnetic ferrite dielectric material according to an exemplary embodiment. In this example embodiment, the non-magnetic ferrite is shown after firing at 910 degrees Celsius for four hours. FIGS. 3A and 3B show that there is good firing compatibility between the Cu-Zn based non-magnetic ferrite and the Ni-Cu-Zn based ferrite in this example. Also, no gap is shown in FIGS. 3A and 3B between the non-magnetic ferrite and the magnetic ferrite in this example.

FIGS. 4A and 4B are SEM images of a prior art dielectric material including titanium dioxide. As shown in FIGS. 4A and 4B, there is a gap between the titanium dioxide and the Ni-Cu-Zn ferrite. FIGS. 3A, 3B, 4A and 4B illustrate that this example non-magnetic ferrite material has a much higher density than the conventional titanium dioxide material. The loose structure of the conventional titanium dioxide material may lead to silver migration when a specified voltage is applied.

TABLE 1 below provides representative reliability testing data for an exemplary common mode choke. These testing data are examples only as other embodiments may provide different test results.

Material for dielectric layer	**Reliability testing condition**	**Duration**
Titanium dioxide	85 ºC, 85% H, 30V Voltage and 5A Current	105 hrs
	125 ºC, 5.5V Voltage and 5A Current	210 hrs
Non-magnetic ferrite	85 ºC, 85% H, 30V Voltage and 5A Current	>1000 hrs
	125 ºC, 5.5V Voltage and 5A Current	>1000 hrs

TABLE 1 illustrates that the reliability of products using non-magnetic ferrite is improved over products using conventional titanium dioxide. Products including titanium dioxide may fail at high temperature and high humidity conditions when a specified voltage is applied. By comparison, products including non-magnetic ferrite may endure more than 1000 hours under the same conditions. This may be attributable to no gap between the non-magnetic ferrite and Ni-Cu-Zn ferrite. The increased reliability may also be attributable to a higher density for non-magnetic ferrite. This increased reliability may prevent liquid immersing and polluting in an electroplating process, and may prevent silver migration during usage.

The performance of samples of the common mode chokes in accordance with aspects of the present disclosure may be demonstrated by the line graphs or plots of FIGS. 5 and 6. More particularly, FIG. 5 shows permeability versus frequency (in Megahertz (MHz)) of the non-magnetic ferrite. The relative magnetic permeability for non-magnetic ferrite may be about one, which is similar to air.

FIG. 6 shows impedance (in ohms (Ω)) versus frequency (in megahertz (MHz)) in the normal, open, and common modes for an example common mode choke. The plot illustrates that the common impedance using non-magnetic ferrite is higher than the conventional titanium dioxide dielectric, and the normal mode impedance using non-magnetic ferrite is lower than the conventional titanium dioxide dielectric. This improvement of electrical properties may be a result of firing compactness, which may lead to less magnetic leakage.

The exemplary common mode chokes of the present disclosure may be adapted to be surface mounted to a circuit board. A DC to DC converter may include a common mode choke according to one or more aspects of the present disclosure.

A method for making a non-magnetic ferrite dielectric layer for a common mode choke may include combining ferrite oxide, zinc oxide, and copper oxide to obtain a mixture. The obtained mixture may be dried and ground to obtain a powder. The obtained powder may be calcinated to obtain a ferrite powder. The ferrite powder may be ball milled with bismuth oxide to obtain a low temperature co-fired powder. The low temperature co-fired powder may be mixed with a binder resin and a solvent to prepare an ink for printing. The prepared ink may be laminated as a non-magnetic ferrite dielectric layer within a body of the common mode choke by printing the ink using a roll miller a predetermined amount of times.

Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms, and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail. In addition, advantages and improvements that may be achieved with one or more exemplary embodiments of the present disclosure are provided for purpose of illustration only and do not limit the scope of the present disclosure, as exemplary embodiments disclosed herein may provide all or none of the above mentioned advantages and improvements and still fall within the scope of the present disclosure.

Specific dimensions, specific materials, and/or specific shapes disclosed herein are example in nature and do not limit the scope of the present disclosure. The disclosure herein of particular values and particular ranges of values for given parameters are not exclusive of other values and ranges of values that may be useful in one or more of the examples disclosed herein. Moreover, it is envisioned that any two particular values for a specific parameter stated herein may define the endpoints of a range of values that may be suitable for the given parameter (*i.e.*, the disclosure of a first value and a second value for a given parameter can be interpreted as disclosing that any value between the first and second values could also be employed for the given parameter). For example, if Parameter X is exemplified herein to have value A and also exemplified to have value Z, it is envisioned that parameter X may have a range of values from about A to about Z. Similarly, it is envisioned that disclosure of two or more ranges of values for a parameter (whether such ranges are nested, overlapping or distinct) subsume all possible combination of ranges for the value that might be claimed using endpoints of the disclosed ranges. For example, if parameter X is exemplified herein to have values in the range of 1 – 10, or 2 – 9, or 3 – 8, it is also envisioned that Parameter X may have other ranges of values including 1 – 9, 1 – 8, 1 – 3, 1 - 2, 2 – 10, 2 – 8, 2 – 3, 3 – 10, and 3 – 9.

The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

When an element or layer is referred to as being “on,” “engaged to,” “connected to,” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to,” “directly connected to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (*e.g.*, “between” versus “directly between,” “adjacent” versus “directly adjacent,” *etc.*). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

The term “about” when applied to values indicates that the calculation or the measurement allows some slight imprecision in the value (with some approach to exactness in the value; approximately or reasonably close to the value; nearly). If, for some reason, the imprecision provided by “about” is not otherwise understood in the art with this ordinary meaning, then “about” as used herein indicates at least variations that may arise from ordinary methods of measuring or using such parameters. For example, the terms “generally,” “about,” and “substantially,” may be used herein to mean within manufacturing tolerances. Or for example, the term “about” as used herein when modifying a quantity of an ingredient or reactant of the invention or employed refers to variation in the numerical quantity that can happen through typical measuring and handling procedures used, for example, when making concentrates or solutions in the real world through inadvertent error in these procedures; through differences in the manufacture, source, or purity of the ingredients employed to make the compositions or carry out the methods; and the like. The term “about” also encompasses amounts that differ due to different equilibrium conditions for a composition resulting from a particular initial mixture. Whether or not modified by the term “about,” the claims include equivalents to the quantities.

Although the terms first, second, third, *etc.* may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

Spatially relative terms, such as “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements, intended or stated uses, or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

What is claimed is:

1. A common mode choke comprising a generally rectangular body having opposing first and second ends, and including:

a lower ferrite portion;

an upper ferrite portion; and

at least one pair of laterally spaced-apart interior conductors within the body generally between the upper and lower ferrite portions and longitudinally extending from about the first end to about the second end of the generally rectangular body; and

a non-magnetic ferrite dielectric within the body and disposed laterally between the at least one pair of interior conductors, the non-magnetic ferrite dielectric configured to control magnetic coupling between the at least one pair of interior conductors.

2. The common mode choke of claim 1, wherein the non-magnetic ferrite dielectric comprises copper and zinc.

3. The common mode choke of claim 1, wherein the non-magnetic ferrite dielectric comprises iron, copper, zinc, and bismuth.

4. The common mode choke of claim 1, wherein the non-magnetic ferrite dielectric comprises a raw material including ferrite oxide, zinc oxide, copper oxide, and bismuth oxide.

5. The common mode choke of claim 1, wherein the non-magnetic ferrite dielectric comprises a raw material including 42 to 60 mol % of ferrite oxide (Fe_2O_3), 45 to 55 mol % of zinc oxide (ZnO), 2 to 10 mol % of copper oxide (CuO), and 0.4 to 0.9 wt % of bismuth oxide (Bi_2O_3).

6. The common mode choke of claim 1, further comprising:

at least one first pair of end terminations on the first end of the generally rectangular body and connected to the at least one pair of interior conductors; and

at least one second pair of end terminations on the second end of the generally rectangular body and connected to the at least one pair of interior conductors.

7. The common mode choke of claim 1, wherein:

the non-magnetic ferrite dielectric partially encapsulates the at least one pair of interior conductors such that portions of the non-magnetic ferrite dielectric are respectively disposed below, laterally between, and above the at least one pair of interior conductors; and/or

the common mode choke is surface mounted to a circuit board.

8. A DC to DC converter comprising the common mode choke of any preceding claim.

9. A common mode choke having a ferrite body and at least one pair of laterally spaced-apart interior conductors within the body, the common mode choke comprising a non-magnetic ferrite dielectric within the body and disposed laterally between the at least one pair of laterally spaced-apart interior conductors within the body.

10. The common mode choke of claim 9, wherein the non-magnetic ferrite dielectric comprises copper and zinc.

11. The common mode choke of claim 9, wherein the non-magnetic ferrite dielectric comprises iron, copper, zinc, and bismuth.

12. The common mode choke of claim 9, wherein the non-magnetic ferrite dielectric comprises a raw material including ferrite oxide, zinc oxide, copper oxide, and bismuth oxide.

13. The common mode choke of claim 9, wherein the non-magnetic ferrite dielectric comprises a raw material including 42 to 60 mol % of ferrite oxide (Fe_2O_3), 45 to 55 mol % of zinc oxide (ZnO), 2 to 10 % of copper oxide (CuO), and 0.4 to 0.9 wt % of bismuth oxide (Bi_2O_3).

14. The common mode choke of claim 9, further comprising:

at least one first pair of end terminations on a first end of the ferrite body and connected to the at least one pair of interior conductors; and

at least one second pair of end terminations on the second end of the ferrite body and connected to the at least one pair of interior conductors.

15. The common mode choke of claim 9, wherein:

the non-magnetic ferrite dielectric partially encapsulates the at least one pair of interior conductors such that portions of the non-magnetic ferrite dielectric are respectively disposed below, laterally between, and above the at least one pair of interior conductors; and/or

the common mode choke is surface mounted to a circuit board.

16. A DC to DC converter comprising the common mode choke of any one of claims 9-15.

17. A non-magnetic ferrite dielectric material for a multilayered ferrite common mode structure, the non-magnetic ferrite dielectric material comprising ferrite oxide, zinc oxide, and copper oxide.

18. The non-magnetic ferrite dielectric material of claim 17, wherein the non-magnetic ferrite dielectric material comprises a raw material including 42 to

60 mol % of ferrite oxide (Fe_2O_3), 45 to 55 mol % of zinc oxide (ZnO), 2 to 10 % of copper oxide (CuO), and 0.4 to 0.9 wt % of bismuth oxide (Bi_2O_3).

19. A method for making a non-magnetic ferrite dielectric layer for a common mode choke comprising:

combining ferrite oxide, zinc oxide, and copper oxide to obtain a mixture;

drying and grounding the obtained mixture to obtain a powder;

calcinating the obtained powder to obtain a ferrite powder;

ball milling with bismuth oxide to obtain a low temperature co-fired powder;

mixing the low temperature co-fired powder with a binder resin and a solvent to prepare an ink for printing; and

laminating the ink as a non-magnetic ferrite dielectric layer within a body of the common mode choke.

20. The method of claim 19, wherein combining includes using a ball mill to wet prepare 42 to 60 mol % of ferrite oxide (Fe_2O_3), 45 to 55 mol % of zinc oxide (ZnO), 2 to 10 % of copper oxide (CuO), and 0.4 to 0.9 wt % of bismuth oxide (Bi_2O_3).

21. The method of claim 19 or 20, wherein:

calcinating includes calcinating the obtained mixture at 900 +/- 50 degrees Celsius for 2 +/- 0.5 hours; and/or

laminating includes using a roll miller to print the prepared ink a predetermined amount of times.

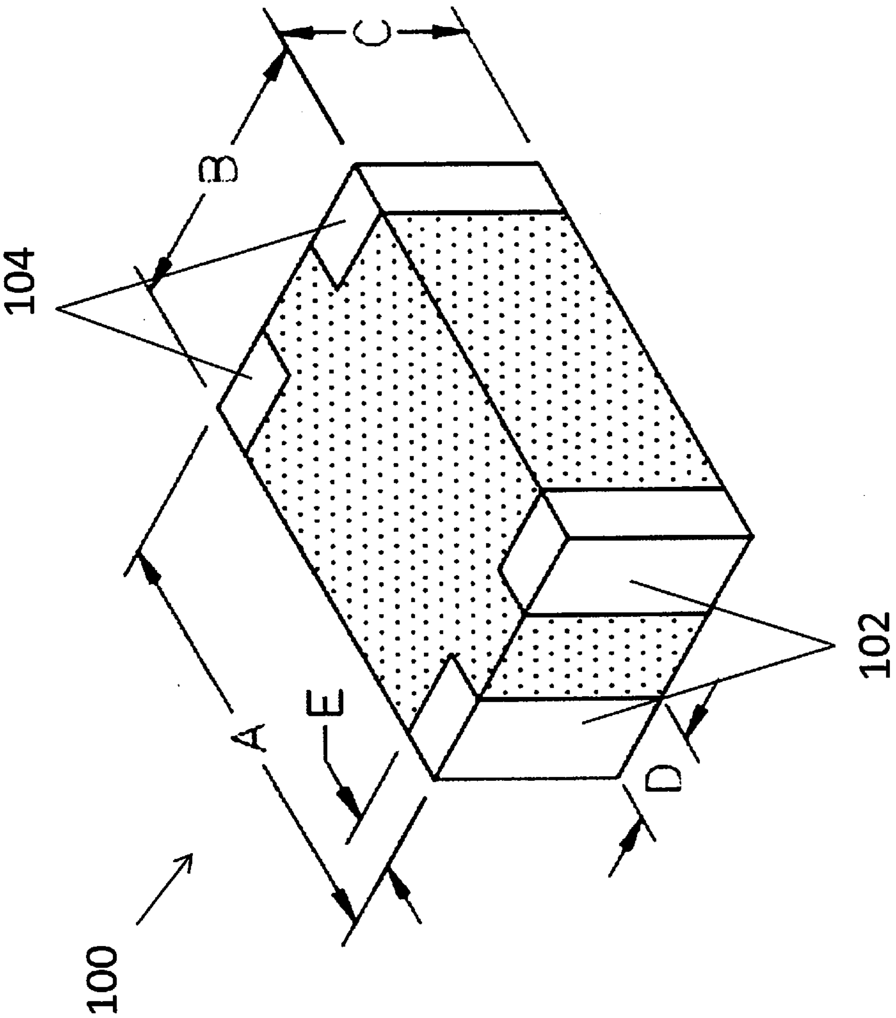

FIG. 1

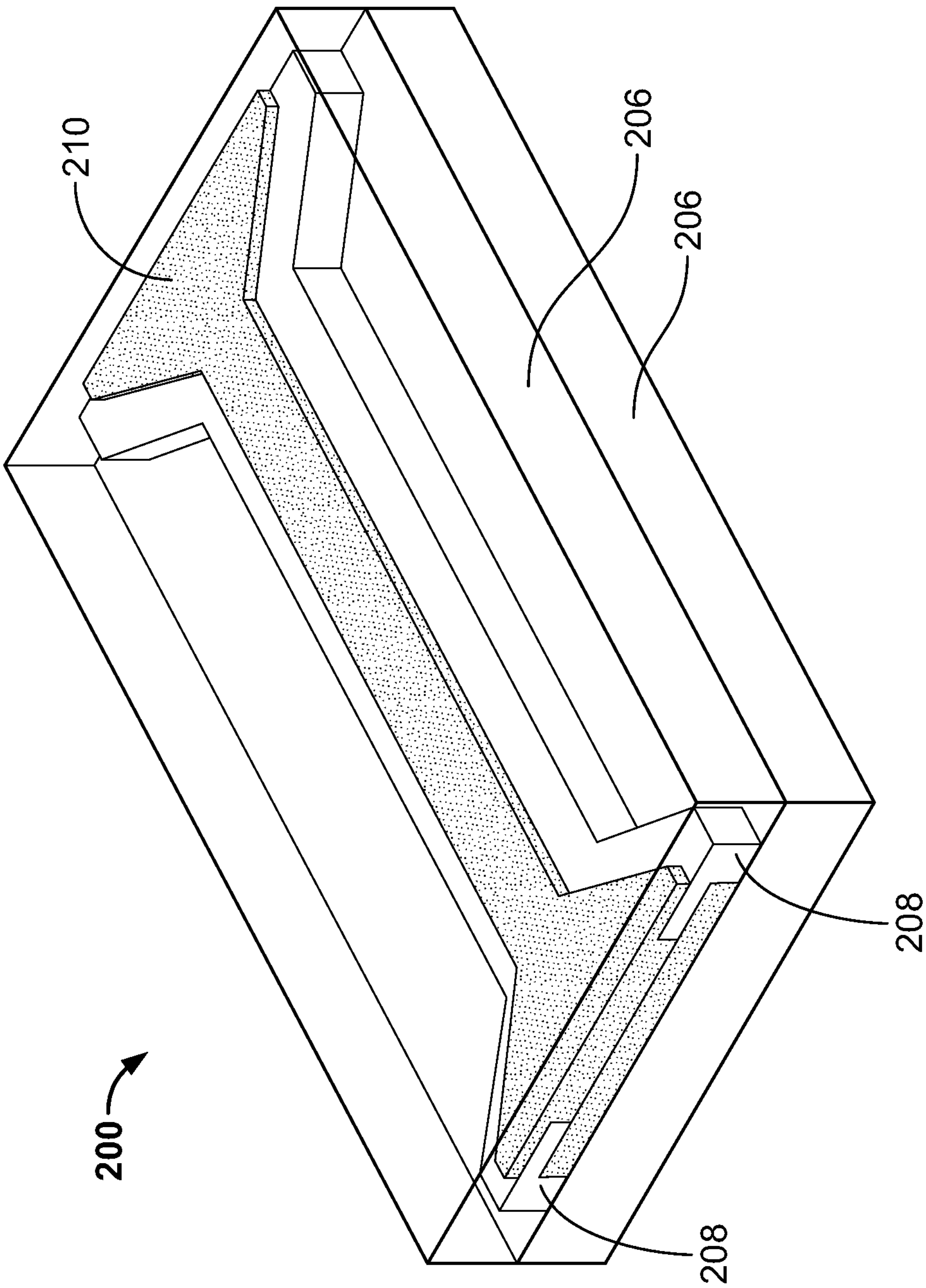

FIG. 2

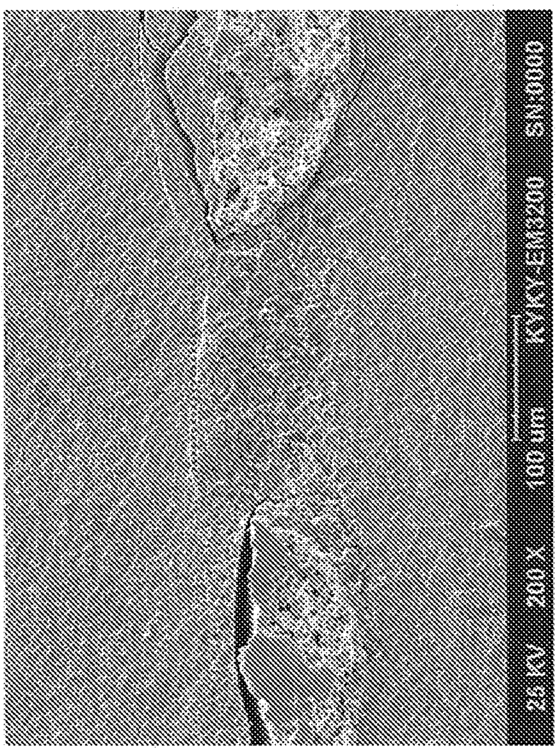
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FIG. 3A

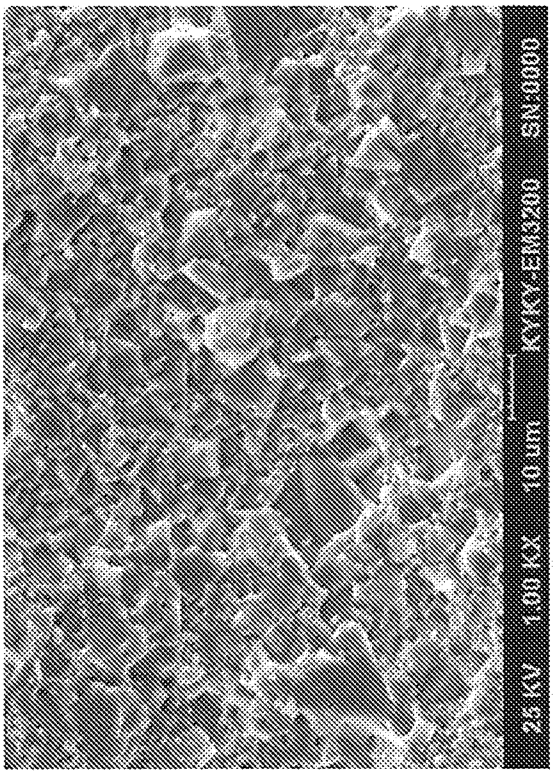
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FIG. 3B

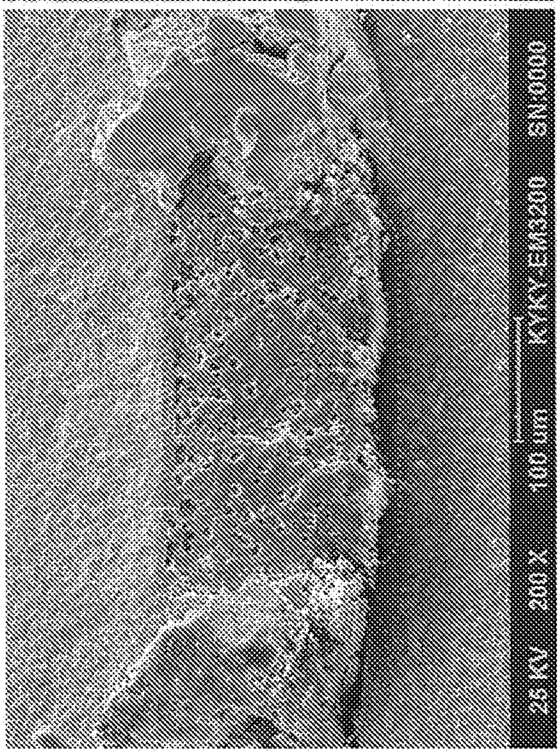
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FIG. 4A

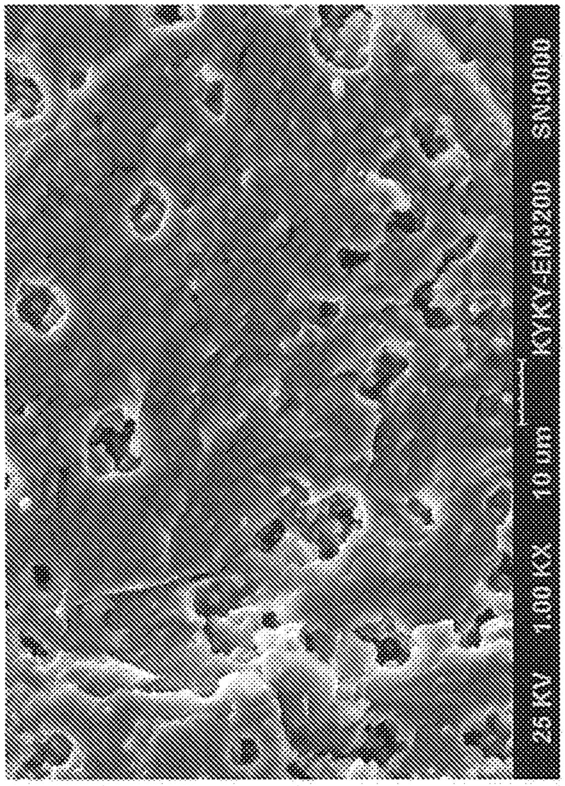
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FIG. 4B

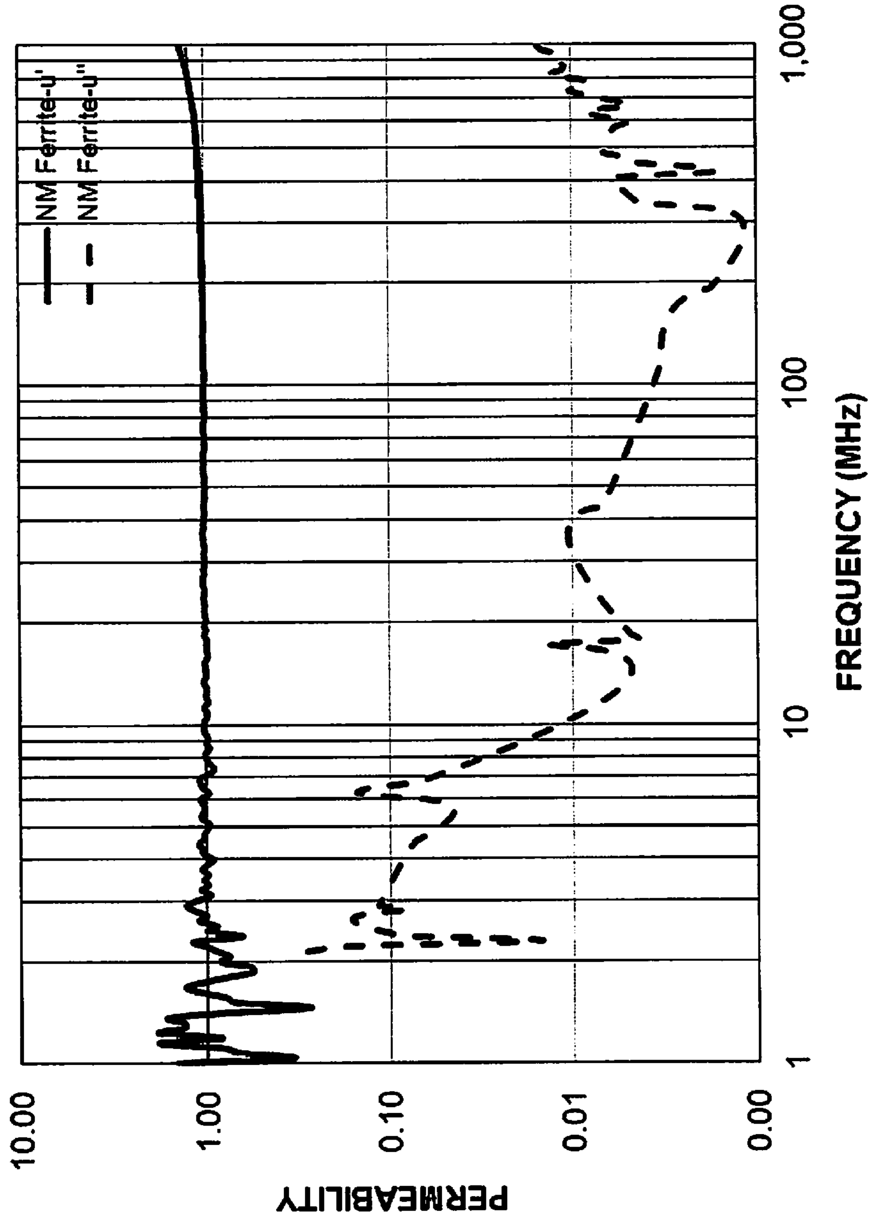
NM Ferrite-u'
NM Ferrite-u''
PERMEABILITY
10.00
1.00
0.10
0.01
0.00
1
10
100
1,000
FREQUENCY (MHz)

FIG. 5

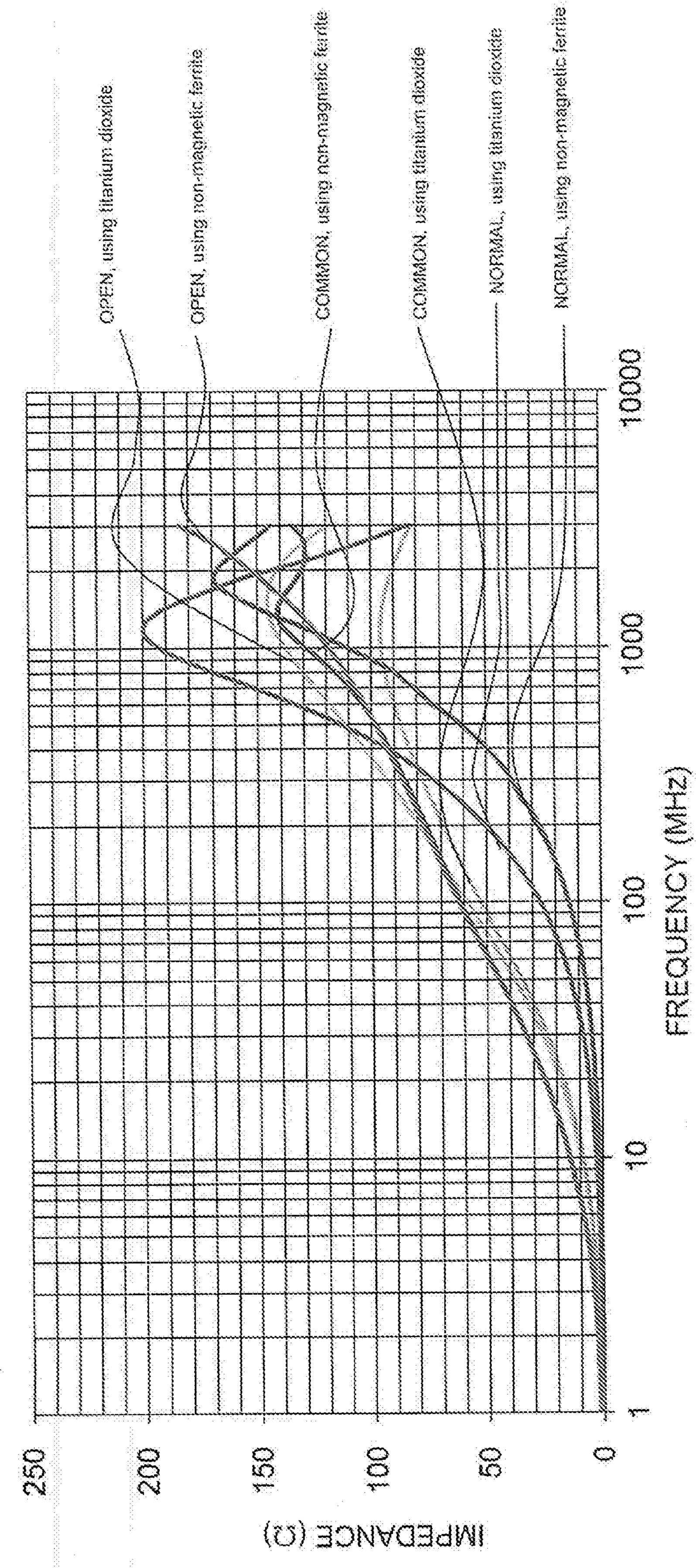
OPEN, using titanium dioxide
OPEN, using non-magnetic ferrite
COMMON, using non-magnetic ferrite
COMMON, using titanium dioxide
NORMAL, using titanium dioxide
NORMAL, using non-magnetic ferrite
IMPEDANCE (Ω)
250
200
150
100
50
0
1
10
100
1000
10000
FREQUENCY (MHz)

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2014/074117

A. CLASSIFICATION OF SUBJECT MATTER

H01F 17/04 (2006.01) i

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)

CNPAT, CNKI, WPI, EPODOC, IEEE: choke, coil, laminat+, ferrite, non-magnetic, dielectric, insulat+, iron, copper, zinc, bismuth, oxide, Fe, CuO, ZnO, Bi

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008266041 A1 (LAIRD TECHNOLOGIES, INC.) 30 October 2008 (2008-10-30) description, paragraphs [0025]-[0040], and figures 1-4	1, 6, 8, 9, 14, 16
Y	US 2008266041 A1 (LAIRD TECHNOLOGIES, INC.) 30 October 2008 (2008-10-30) description, paragraphs [0025]-[0040], and figures 1-4	2-5, 7, 10-13, 15
X	US 5476728 A (TDK CORP.) 19 December 1995 (1995-12-19) description, column 2, line 1 to column 3, line 64	17
Y	US 5476728 A (TDK CORP.) 19 December 1995 (1995-12-19) description, column 3, line 54 to column 15, line 45	2-5, 10-13, 18-21
Y	CN 101529535 A (HITACHI METALS, LTD.) 09 September 2009 (2009-09-09) description, page 8, paragraph 8 to page 12, paragraph 7	3-5, 11-13, 18-21
Y	JP 2003124028 A (TOKO INC.) 25 April 2003 (2003-04-25) description, paragraphs [0008]-[0011], and figure 1	7, 15
A	CN 101763933 A (TDK CORP.) 30 June 2010 (2010-06-30) the whole document	1-21

☐ 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	Date of mailing of the international search report
10 December 2014	**31 December 2014**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA(ISA/CN) **6,Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China**	**LI,Jing**
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Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2008266041 A1	30 October 2008	None	
US 5476728 A	19 December 1995	JP H0677022 A	18 March 1994
CN 101529535 A	09 September 2009	WO 2008004633 A1	10 January 2008
		US 8004381 B2	23 August 2011
		JP 5446262 B2	19 March 2014
		KR 20090026318 A	12 March 2009
		EP 2040272 A1	25 March 2009
		CN 101529535 B	23 May 2012
		US 2010033286 A1	11 February 2010
JP 2003124028 A	25 April 2003	None	
CN 101763933 A	30 June 2010	US 2010157565 A1	24 June 2010
		JP 2011071457 A	07 April 2011
		US 8174349 B2	08 May 2012
		CN 101763933 B	17 July 2013
		JP 2013153184 A	08 August 2013