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(54) FE-BASED AMORPHOUS MAGNETIC POWDER, MAGNETIC POWDER CORE WITH EXCELLENT HIGH FREQUENCY PROPERTIES AND METHOD OF MAKING THEM

(76) Inventors: **Zhichao Lu**, Beijing (CN); **Caowei Lu**, Beijing (CN); **Deren Li**, Beijing (CN); **Ke Sun**, Beijing (CN); **Shaoxiong Zhou**, Beijing (CN)

Correspondence Address:
THELEN REID BROWN RAYSMAN & STEINER LLP
2225 EAST BAYSHORE ROAD
SUITE 210
PALO ALTO, CA 94303 (US)

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(57) ABSTRACT

The present invention provides an amorphous alloy powder and magnetic powder cores exhibiting excellent high frequency properties and a method for making themof The composition of said alloy powder by atomic percentage satisfies the following formula: $(Fe_{1-x}M_x)_{100-a-b-c}P_aT_bD_c$, wherein M represents at least one element of Co and Ni; T is over three elements selected from Al, C, B and Si, D is at least one element of Sn, Cr, Mn, Mo, W, V, Nb, Ta, Ti, Zr, Hf, Pt, Pd and Au; the subscripts x, a, b, and c satisfy the relationships $0.01 \leqq x \leqq 0.16$, $8 \leqq a \leqq 15$, $10 \leqq b \leqq 25$ and $0.5 \leqq c \leqq 6$. The said amorphous alloy powder is made by atomization method and a magnetic powder core comprises a molded article of mixture of the said alloy powder and an insulating material. A method of making the amorphous alloy powder core includes the steps of screening, insulating, compacting, annealing and spray painting.

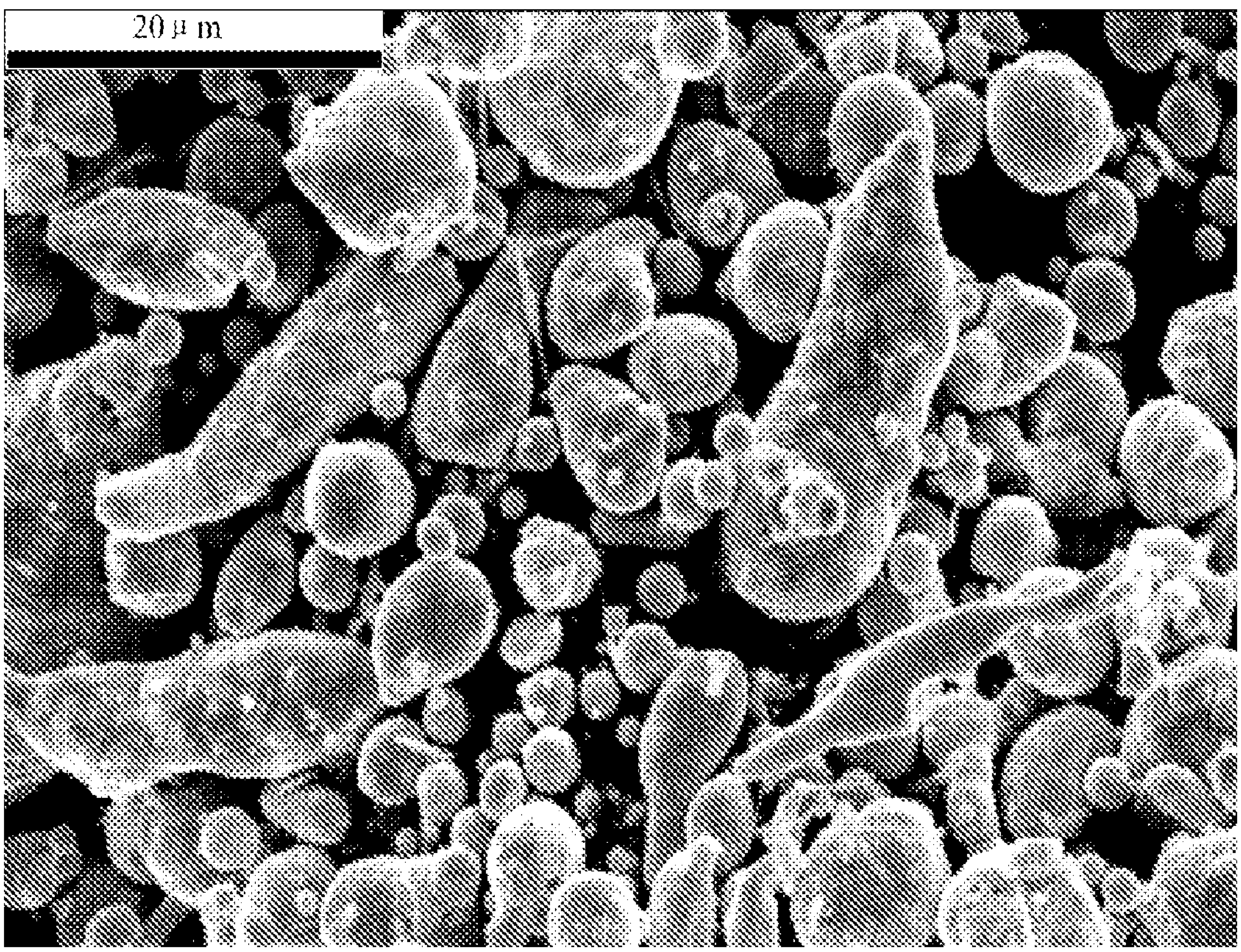


Fig 1

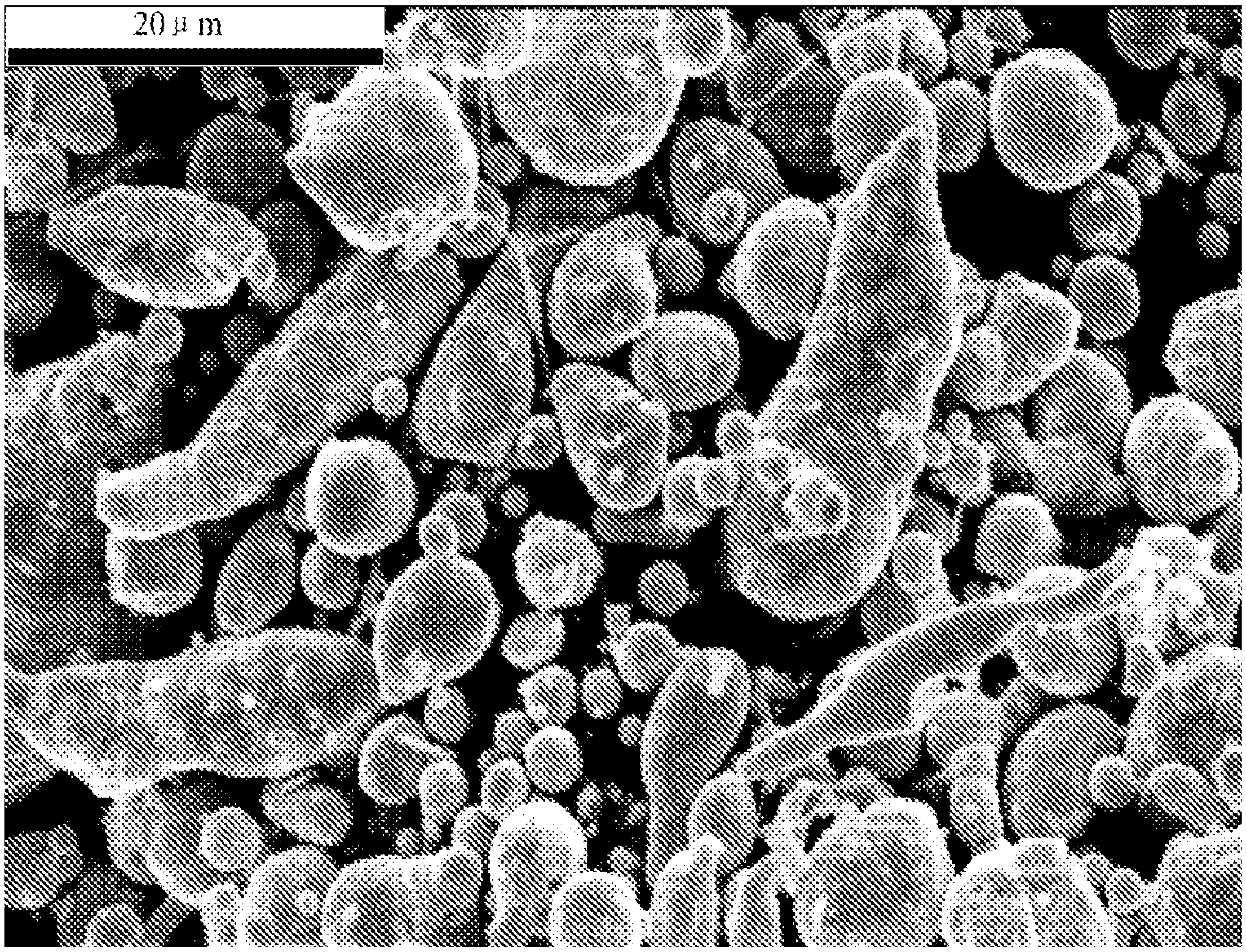

20 μm

Fig 2

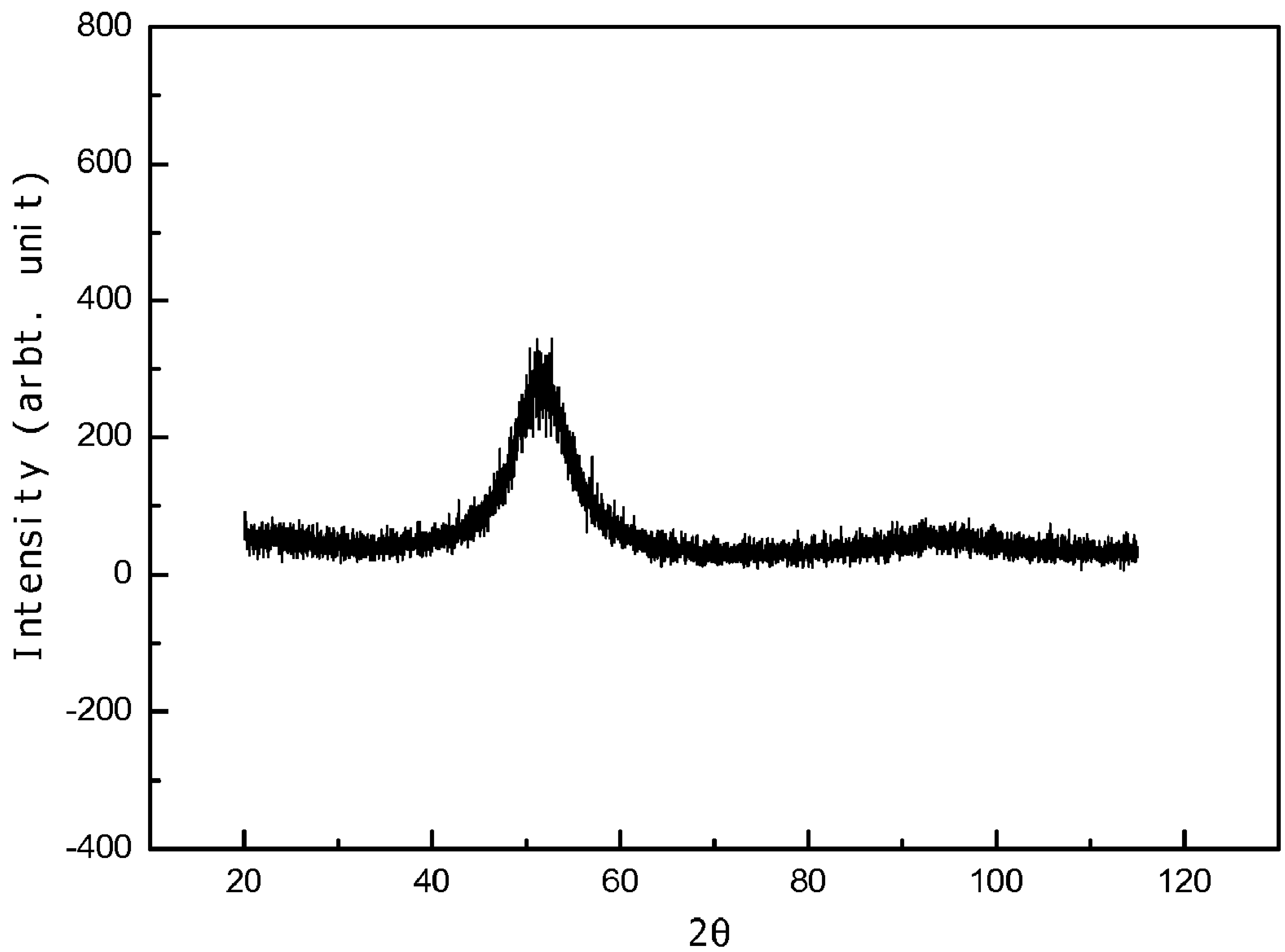
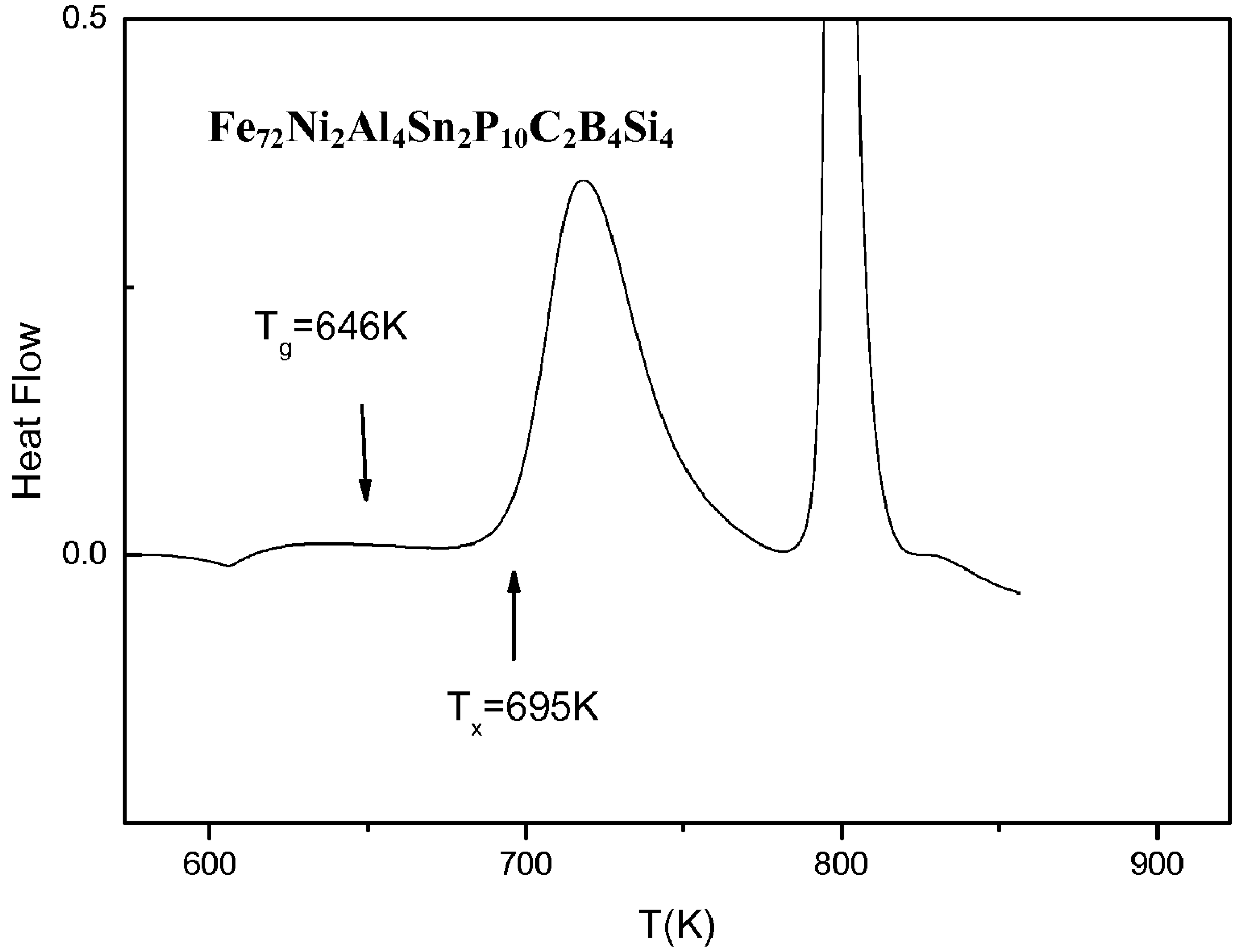
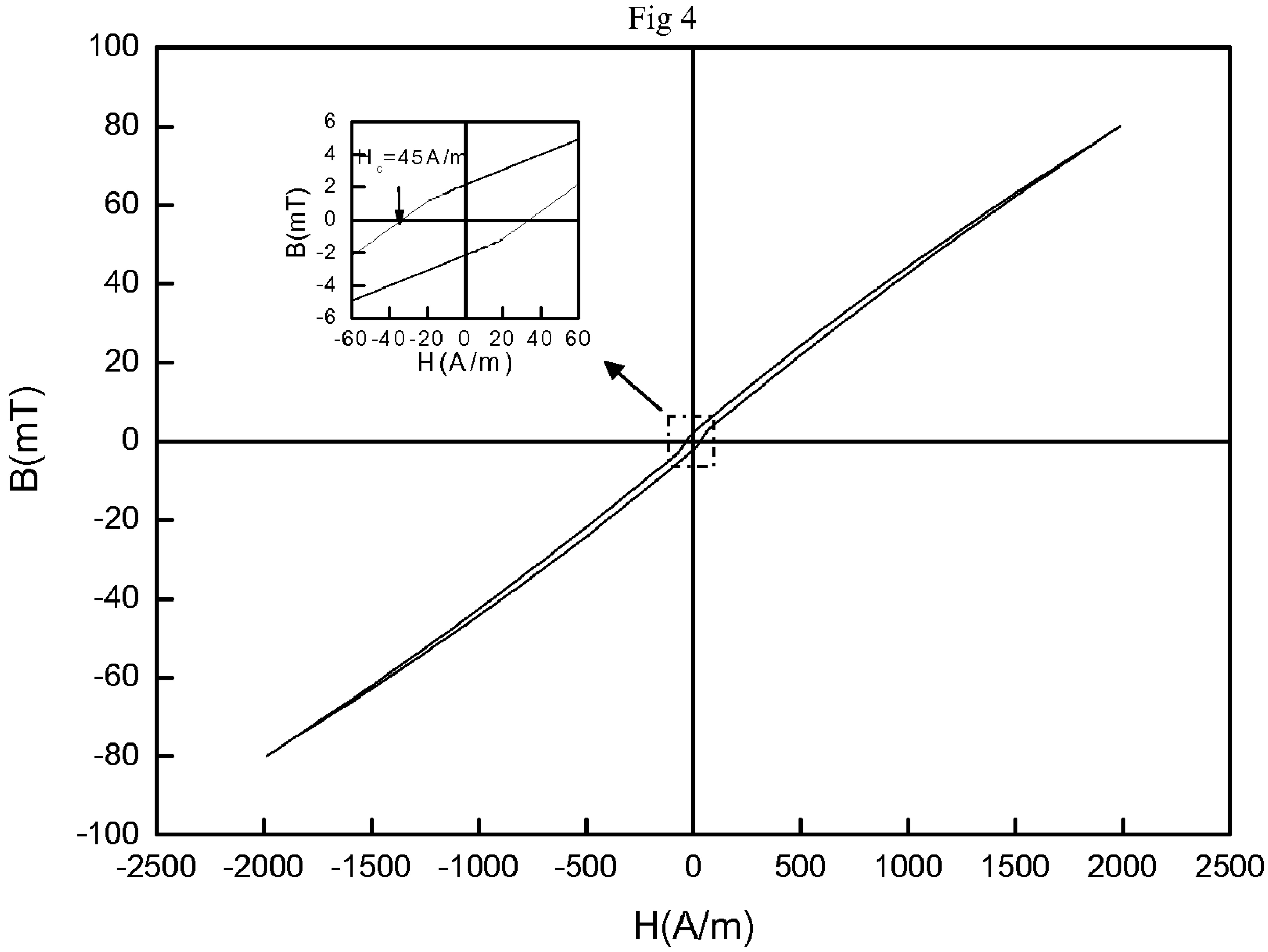

800
600
400
200
0
-200
-400
Intensity (arbt. unit)
20
40
60
80
100
120
2θ

Fig 3



Fe72Ni2Al4Sn2P10C2B4Si4
Heat Flow
0.5
0.0
Tg=646K
Tx=695K
600
700
800
900
T(K)

Fig 4



B(mT)
H(A/m)
Hc=45A/m
100
80
60
40
20
0
-20
-40
-60
-80
-100
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500

Fig 5

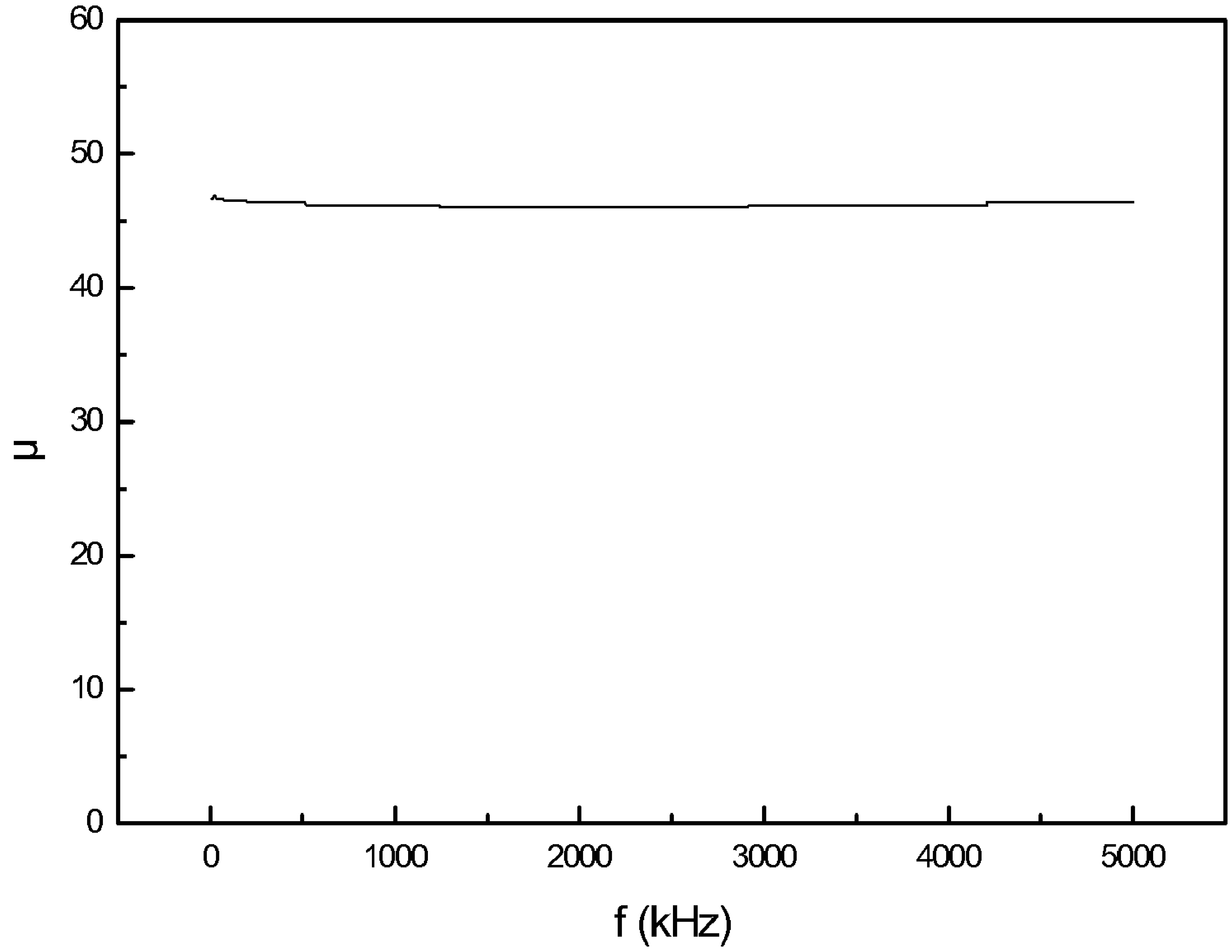

60
50
40
30
20
10
0
μ
0
1000
2000
3000
4000
5000
f (kHz)

Fig 6

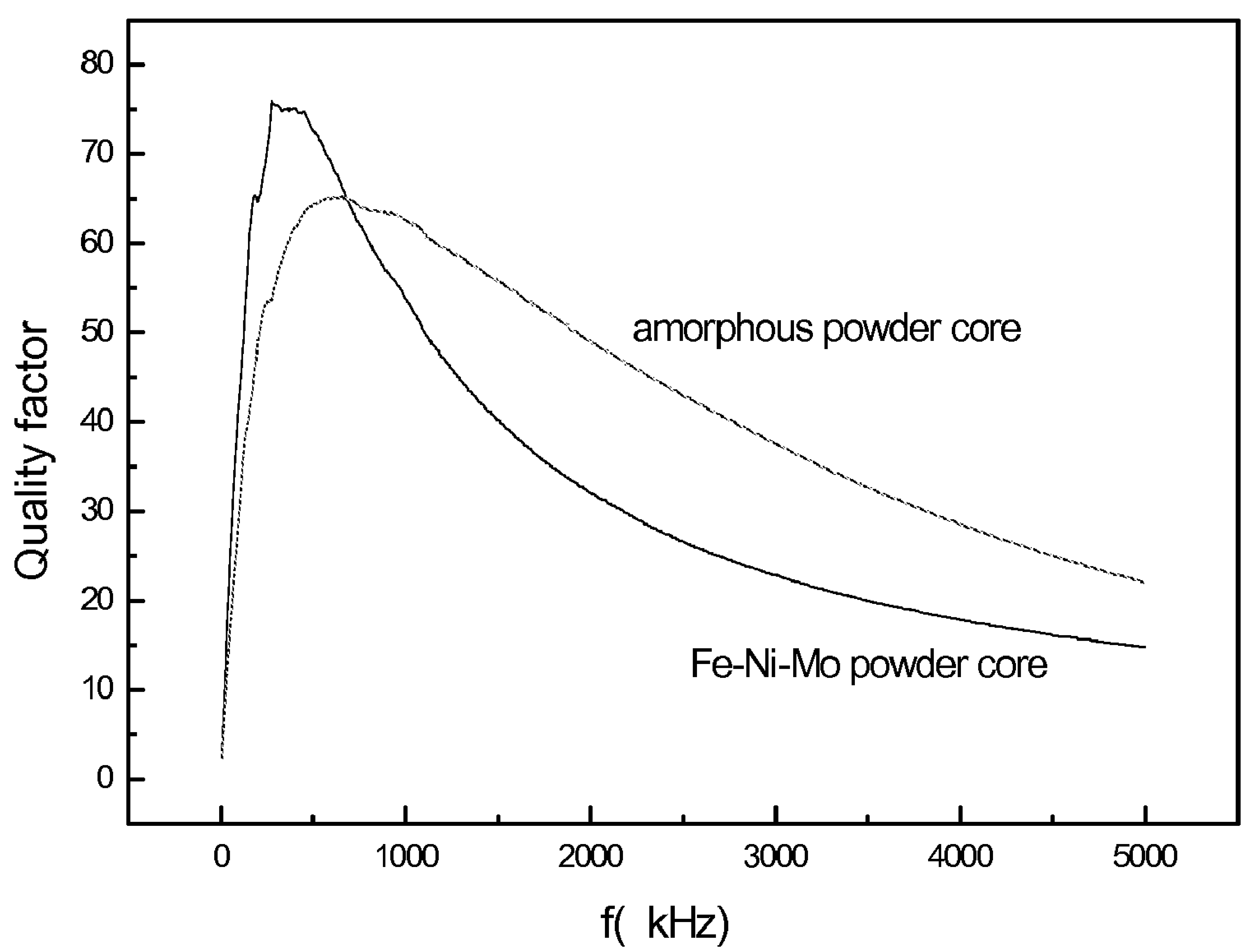

80
70
60
50
40
30
20
10
0
Quality factor
amorphous powder core
Fe-Ni-Mo powder core
0
1000
2000
3000
4000
5000
f(kHz)

Fig 7

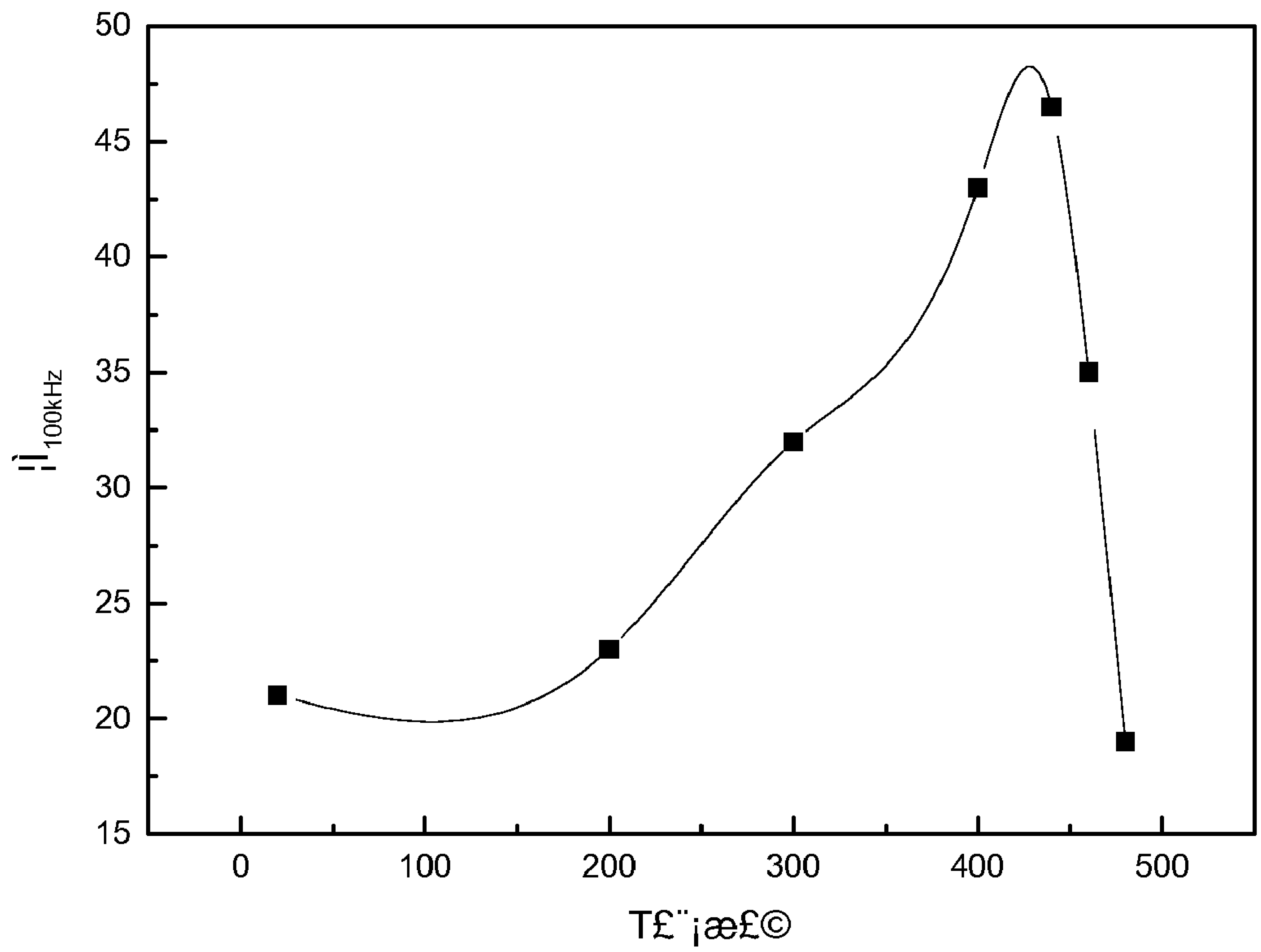

50
45
40
35
30
25
20
15
¦Ì100kHz
0
100
200
300
400
500
T£¨¡æ£©

Fig 8

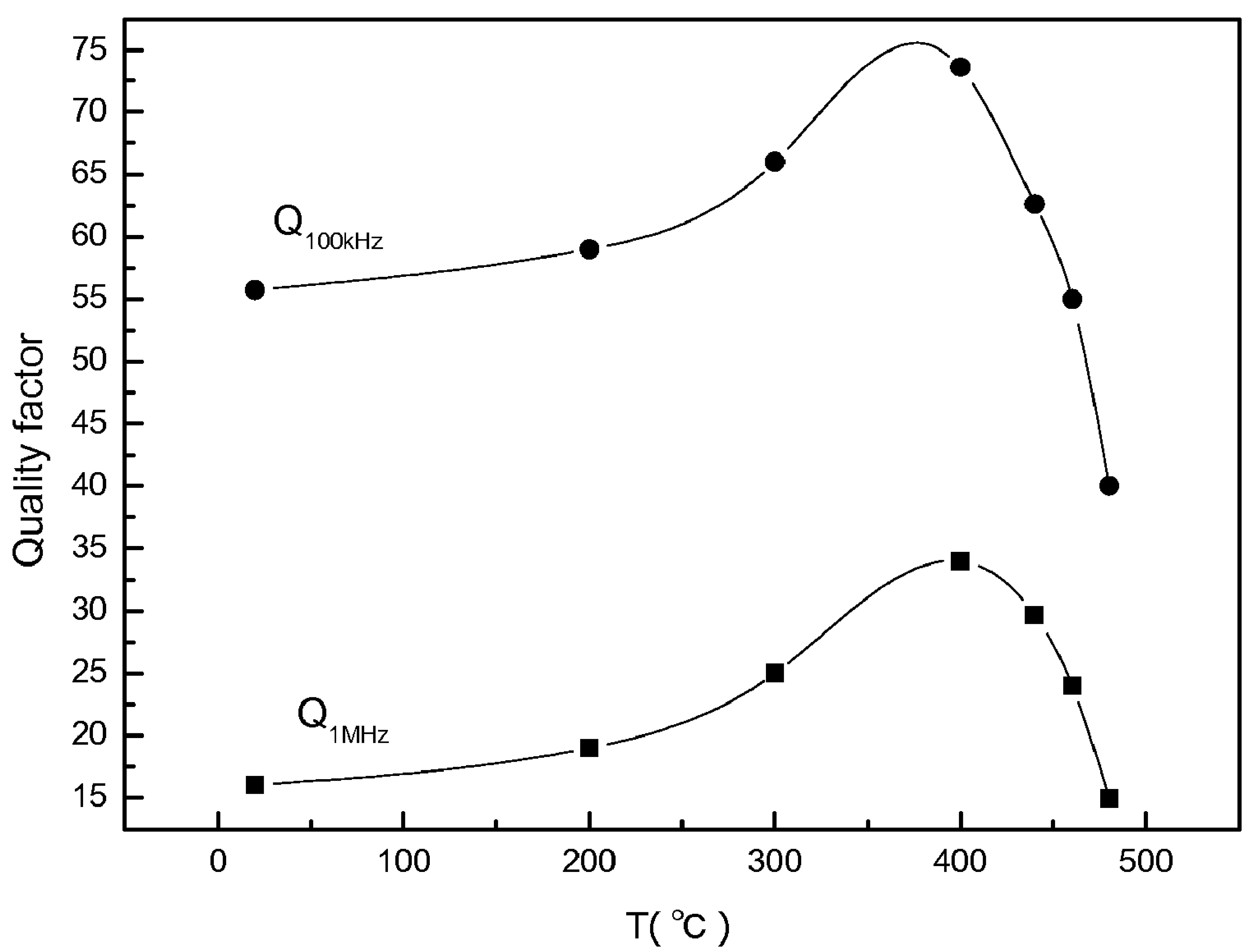
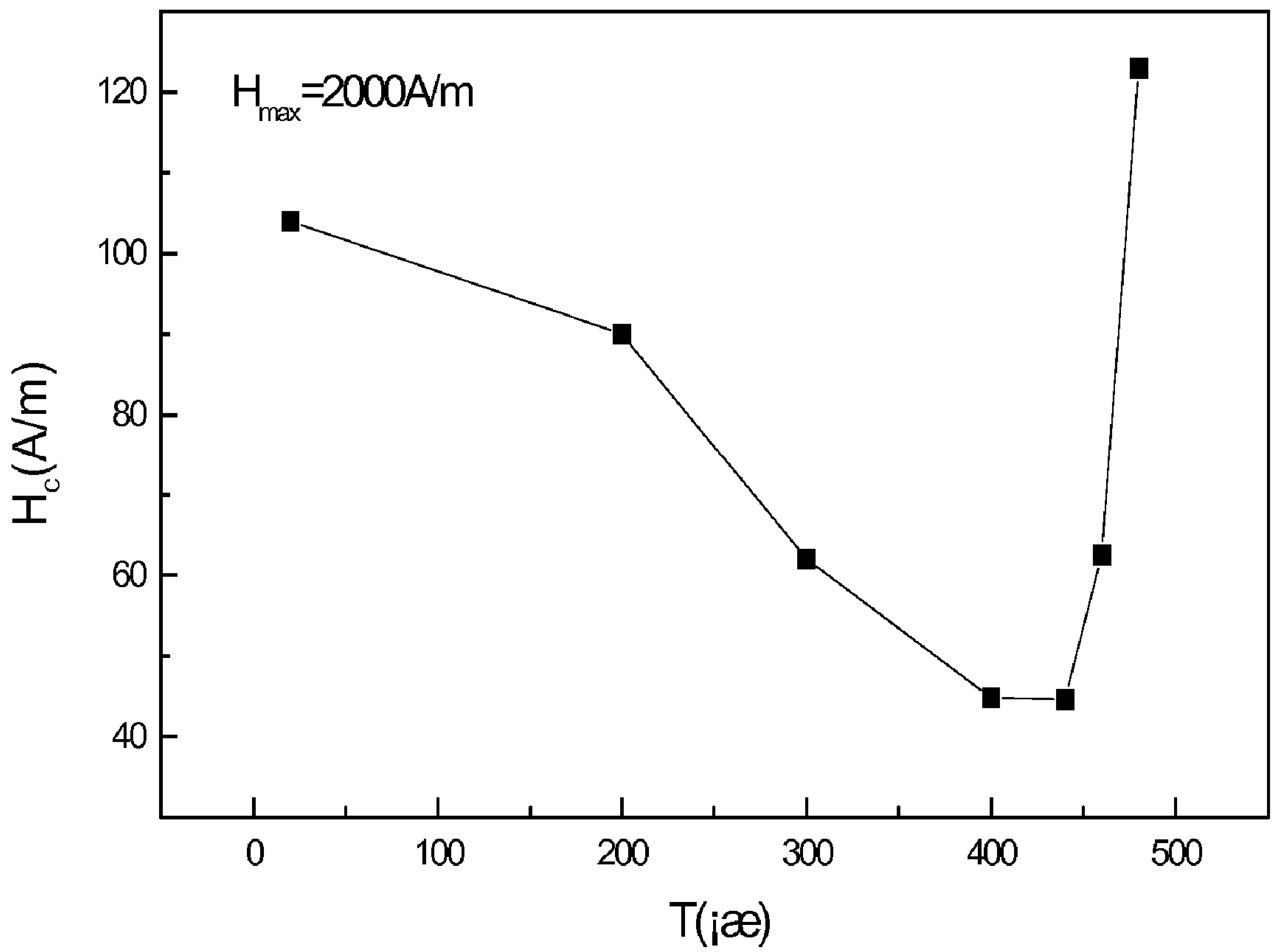

75
70
65
60
55
50
45
40
35
30
25
20
15
Quality factor
Q100kHz
Q1MHz
0
100
200
300
400
500
T(℃)

Fig 9



FE-BASED AMORPHOUS MAGNETIC POWDER, MAGNETIC POWDER CORE WITH EXCELLENT HIGH FREQUENCY PROPERTIES AND METHOD OF MAKING THEM

PRIORITY REFERENCE TO PRIOR APPLICATION

[0001] This application incorporates by reference and claims priority under 35 U.S.C. §119 to Chinese Patent Application No. 200510114933.4 filed Nov. 16, 2005.

RELATED TECHNICAL FIELD

[0002] The present invention relates to a Fe-based amorphous alloy powder, and more particularly, relates to an amorphous soft magnetic alloy powder core manufactured by said amorphous alloy powder and a method for making themof.

ART OF BACKGROUND

[0003] Fe-based amorphous and nanocrystallineline soft magnetic alloy, for instance, amorphous Fe-Si-B series alloy disclosed by U.S. Pat. No. 4,217,135 and Fe—Cu-M-Si—B series (wherein M is one of Nb, Mo, Hf, Ta, etc.) nanocrystalline soft magnetic alloy disclosed by U.S. Pat. No. 4,881,989 have been widely used in various electronic parts and components because of their excellent soft magnetic properties. To obtain the said Fe-based amorphous alloy, a high cooling rate of approximately 10^{-5} K/s is necessary. Though amorphous alloy ribbon can be produced in large scale by single roller rapidly quenched technology, it is still difficult to obtain amorphous alloy powder directly from rapid quenching.

[0004] Fe-based amorphous and nanocrystalline alloy powder can be obtained by pulverizing ribbons, wherein the magnetic powder core can be obtained by several procedures such as sticking, pressing annealing and so forth. The problem of said magnetic powder core is that the powder obtained by pulverizing ribbons contains much deformed powder and the insulation of the powder is difficult, thus the core generally has low quality factor, high core losses.

[0005] Bulk amorphous Fe—Al—Ga—P—C—B—Si systems disclosed by U.S. Pat. No. 5,876,519 have large glass formation ability, wherein the supercooled liquid region is over 50K, bulk amorphous alloy of 1.5 mm in thickness can be obtained by mold casting and the said alloy has excellent soft magnetic properties. By using the large glass formation ability of the said alloy system, amorphous powder can be prepared by atomization method, wherein a magnetic powder core can be made thereof. The problem of said soft magnetic alloy powder is that, firstly, it contains expensive element of Ga, which is difficult to popularize due to its high price; secondly, it does not contain antioxidation elements such as Ni, Cr, therefore, antioxidation properties are poor and the powder easily oxidates and its properties deteriorate while preparing powder by atomization method. Moreover, aFe-based amorphous alloy system disclosed by Chinese Patent Publication No. CN1487536A at least contains elements of P, C, B and a small amount of elements such as Cr, Mo, W, V, Nb, etc. Said alloy system contains only a small amount of antioxidation element such as Cr and Mo etc, resulting in poor antioxidation ability during the process of atomization.

SUMMARY OF THE INVENTION

[0006] Accordingly, a primary object of the present invention is to provide an amorphous alloy powder with excellent high frequency properties, large glass formation ability, low-cost and low oxygen content, and a method for making it.

[0007] Another object of the present invention is to provide a magnetic powder core with excellent high frequency properties and method for making them thereof.

[0008] In order to achieve the objects mentioned above, the present invention involves the following aspects:

[0009] In one aspect, the present invention provides an amorphous alloy powder with excellent soft magnetic properties in high frequency. The compositions of said alloy powder by atomic percent satisfies the following formula: $(Fe_{1-x}M_x)_{100-a-b-c}P_aT_bD_c$, wherein M represents at least one element of Co and Ni; T is over three elements selected from Al, C, B and Si; D is at least one element selected from Sn, Cr, Mn, Mo, W, V, Nb, Ta, Ti, Zr, Hf, Pt, Pd and Au. The subscripts x, a, b, and c satisfy the relationships $0.01 \leqq x \leqq 0.16$, $8 \leqq a \leqq 15$, $10 \leqq b \leqq 25$ and $0.5 \leqq c, \leqq 6$. Preferably, $0.01 \leqq x \leqq 0.12$, $9 \leqq a \leqq 12$, $10 \leqq b \leqq 23$ and $1 \leqq c \leqq 5$, $22 \leqq (a+b+c) \leqq 38$.

[0010] The reduced glass transition temperature T_{rg} of said amorphous alloy powder satisfies $T_{rg} \leqq 0.53$, wherein $T_{rg}=T_g/T_m$, T_g represents glass transition temperature, T_m represents melting point of alloy. The supercooled liquid region $\Delta T_x \geqq 20K$, wherein $\Delta T_x=T_x-T_g$, T_x represents crystallization temperature. The oxygen content of the powder is below 4000 ppm.

[0011] In another aspect, the present invention provides a method for making an amorphous alloy powder with excellent soft magnetic properties in high frequency. The alloy components mentioned above are used to prepare the alloy powder by atomization method, wherein said atomization is water atomization and/or gas atomization, while said gas atomization is one of vacuum gas atomization, non-vacuum gas atomization, adjustable gas atomization or their combination.

[0012] The loose packed density of the powder ρ obtained by the process should satisfy the relation: $\rho \geqq 2.4$ g/cm^3.

[0013] In the third aspect, the present invention provides an amorphous magnetic powder core with excellent soft magnetic properties in high frequency, comprising the components by weight percentage as follows: 0.2%-7% of insulating agent, 0.01%-5% of adhesives, 0.01%-2% of lubricants, the rest is said amorphous alloy powder.

[0014] Wherein, said insulating agent is at least one selected from following groups of substances:

[0015] Oxide powder selected from SiO_2, CaO, Al_2O_3 and TiO_2,

[0016] Salts selected from silicates and phosphates,

[0017] Mineral powder selected from mica powder and kaolinite, and

[0018] surface film produced by chemical deposition or self-oxidation.

[0019] Said adhesives are organic adhesives and/or inorganic adhesives, wherein, the organic adhesives are at least one selected from epoxy resins, the inorganic adhesives are at least one selected from phosphates.

[0020] Said lubricants are one or a combination selected from stearates and talc powder.

[0021] The magnetic properties of said magnetic powder core shall satisfy the requirements of at least one, several or their combination of the followings:

[0022] Magnetic permeability is no less than 35;

[0023] Quality factor Q is not less than 30 at 1 MHz;

[0024] Per unit initial permeability is not less than 98% at 100 k Hz, not less than 90% at 1 M Hz;

[0025] Coercive force H_c corresponding with static magnetic hysteresis loop in maximum magnetic field of 2000 A/m is below 70 A/m.

[0026] In the fourth aspect, the present invention provides a method for making the amorphous magnetic powder core with excellent soft magnetic properties in high frequency. Said method comprises the following steps:

[0027] (a) Using said amorphous alloy powder and a required content of insulating agent, adhesives and lubricants, mixing them and then drying them to obtain dry powder;

[0028] (b) Compacting said d) powder under a pressure of 500 MPa-3000 MPa to make magnetic powder core;

[0029] (c) Annealing said molded magnetic powder core below the crystallization temperature of said amorphous powder.

[0030] After step (c), the process further including: (d) spray painting magnetic powder core and (e) testing the properties of magnetic powder core.

[0031] In step (c), the temperature for annealing said magnetic powder core is between (T_x−100° C.) and T_x, wherein T_x represents the crystallization temperature of said alloy powder; annealing time is from 5 minutes to 300 minutes; the atmosphere is one of vacuum, nitrogen and argon.

[0032] In step (c), the annealing temperature is between (T_x−70° C.) and (T_x−20° C.), wherein T_x represents the crystallization temperature of said alloy powder.

[0033] The magnetic properties of magnetic powder core obtained by said process shall satisfy the requirements of at least one, or their combination of the followings:

[0034] Magnetic permeability is over 35;

[0035] Quality factor Q is not less than 30 at 1 MHz;

[0036] Per unit of initial permeability is not less than 98% at 100 kHz, not less than 90% at 1 MHz;

[0037] Coercive force Hc corresponding with static magnetic hysteresis loop in maximum magnetic field of 2000 A/m is below 70 A/m.

[0038] To sum up, the present invention provides a technical solution for making amorphous alloy powder and amorphous magnetic powder core, wherein the antioxidation properties and glass formation ability of the alloy are enhanced by the improvement of the components of the alloy, therefore, the amorphous alloy powder can be made by atomization method. Said powder is prepared into dried powder after insulating treatment and mixing with a small amount of adhesives, then molded into core. After proper heat treating, magnetic powder core can be obtained. The detailed procedures will be described hereinafter.

Improvement of Alloy Composition

[0039] The iron element is the main component of the amorphous alloy powder of the present invention and a small amount of Co and Ni is included thereof, so soft magnetic properties are improved and antioxidation properties of powder are enhanced in the presence of Co and Ni; meanwhile the present invention contains more glass formation elements such as P, Al, C, B and Si, thus amorphous alloy powder is formed. Moreover, the present invention contains more than one kind of elements such as Sn, Cr. Mn, Mo, W, V, Nb, Ta, Ti, Zr, Hf, Pt, Pd, Au, etc., which will further improve the glass formation ability of alloy and antioxidation properties. For instance, the glass formation ability is improved in presence of the elements such as Sn, Zr, etc., and the addition of Cr and Mo and some other elements can not only improve glass formation ability, but also enhance the antioxidation properties of powder as well.

[0040] In said amorphous alloy powder of the present invention, the compositions of atomic percent of the alloy should satisfy the following formula:

$$(Fe_{1-x}M.)_{100-a-b-c}P_aT_bD_c$$

[0041] Wherein M represents at least one element of Co and Ni; T is over three elements selected from Al, C, B and Si; D is at least one element selected from Sn, Cr, Mn, Mo, W, V, Nb, Ta, Ti, Zr, Hf, Pt, Pd and Au; and all by atomic percentage $0.01 \leqq x \leqq 0.16$; $8 \leqq a \leqq 15$; $10 \leqq b \leqq 25$; $0.5 \leqq c \leqq 6$.

[0042] As to the amorphous alloy powder of the present invention, the content of Co and Ni is preferably from 1 at. % to 12 at. %; the content of P is preferably from 9 at. % to 12 at. %; the content of Al, C, B and Si is preferably from 10 at. % to 23 at. %; the content of Sn, Cr, Mn, Mo, W, V, Nb, Ta, Ti, Zr, Hf, Pt, Pd and Au is preferably from 1 at. % to 5 at. %. As to the amorphous alloy powder of the present invention, the sum of elements of Fe, Co and Ni is preferably from 62 at. % to 78 at. %; the sum of elements of P, Al, C, B, Si, Sn, Cr, Mn, Mo, W, V, Nb, Ta, Ti, Zr, Hf, Pt, Pd and Au is preferably from 22 at. % to 38 at. %.

[0043] The alloy of the present invention will inevitably contain a small amount of O and other impurities, wherein the total quantity of these impurities is no more than 0.5 wt. %.

Preparation of Amomhous Alloy Powder by Atomization Method

[0044] The amorphous alloy powder of the present invention has large glass formation ability, so amorphous alloy powder can be prepared by atomization method; the supercooled liquid region $\Delta T_x \geqq 20K(\Delta T_x=T_x-T_g$, wherein T_x represents crystallization temperature and, T_g represents glass transition temperature, the reduced glass transition temperature $T_{rg} \geqq 0.5^3$ ($T_{rg}=T_g/T_m$, wherein T_m represents melting point of alloy)

[0045] The amorphous alloy powder of the present invention can be prepared by water atomization method under non-vacuum condition, wherein the maximum particle size of said amorphous alloy powder is greater than 75 μm and the oxygen content of the powder is below 4000 ppm. The loose packed density of said water atomized amorphous alloy powder is characterized in that, when the particle size is between −200 mess (about 74 μm) and +300 mess (about 49 μm), the loose packed density of powder is more than 2.7 g/cm^3; when the particle size is between −300 mess (about 49 μm) and +400 mess (about 38 μm), the loose packed density of powder is more than 2.6 g/cm^3; when the particle size is below −400 mess (about 38 μm) and over 5 μm, the loose packed density of powder is over 2.5 g/cm^3.

[0046] In the present invention, the water atomized amorphous alloy powder is used to make magnetic powder core, wherein oxygen content is below 4000 ppm. If the oxygen content is too high, magnetic properties of powder will deteriorate. If properties of magnetic powder core prepared by using said powder are not fine which results in the decrease of permeability and increase of coercive force of magnetic powder core.

[0047] In the present invention, the water atomized amorphous alloy powder is used to prepare a magnetic powder core, wherein the loose packed density of the amorphous alloy powder is over 2.5 g/cm^3. If the loose packed density is too small, properties of magnetic powder core will not be fine. Too small loose packed density is generally resulted from small particle size of powder or complicated shapes of powder or much more pores contained in powder. The magnetic powder core prepared by using said powder has the drawbacks of low density, large air gaps distributed in magnetic powder core, low magnetic permeability of powder core, larger coercive force and high core losses. The loose packed density of amorphous alloy powder of the present invention is over 2.5 g/cm^3, preferably over 2.8 g/cm^3.

[0048] Compared with water atomization, gas atomization has lower cooling rate. In the alloy system of the present invention, the nearly ball-shaped amorphous alloy powder is made by vacuum gas atomization, non-vacuum gas atomization and adjustable gas atomization (a method that alloy liquid is atomized to prepare powder by gas and then the powder particles are cooled by water) and so on, wherein the particle size of said amorphous alloy powder is greater than 50 μm and the oxygen content of the powder is below 1500 ppm. The loose packed density of gas atomized amorphous alloy powder is over 3.5 g/cm^3.

Magnetic Powder Core Prepared by Amorphous Alloy Powder

[0049] In the present invention, the gas atomized amorphous alloy powder is used to prepare magnetic powder core, wherein the oxygen content is below 1500 ppm. The magnetic powder core prepared by using said amorphous alloy powder has good magnetic properties, high magnetic permeability and low coercive force. Compared with water atomized powder, magnetic powder core prepared by using gas atomized powder has a higher cost and advanced properties, which will satisfy the requirements of some high-level products.

[0050] The process for preparing magnetic powder core by using amorphous alloy powder of the present invention comprises the following steps:

[0051] 1. Mixing the powder with insulating agent, adhesives and lubricant and then drying them to made dried powder;

[0052] 2. Pressing the powder to form magnetic powder core;

[0053] 3. Annealing magnetic powder core;

[0054] 4. Spray painting magnetic powder core;

[0055] 5. Testing properties of magnetic powder core.

[0056] The amorphous alloy powder prepared is screened by test sieve, standard spanking vibration sieve, other types of vibration sieves and pneumatic powder classifier equipments. Magnetic powder core is prepared according to the following steps:

Step 1

[0057] In order to increase the resistivity of the magnetic powder core, reduce eddy current losses and enhance magnetic permeability in high frequency, the present invention shall preferably select the following types of insulating agent and amorphous alloy powder to mix and insulate: 1. Oxide powder, such as SiO_2, CaO, Al_2O_3, TiO_2, etc., generally, oxide powder has the advantages of stable properties, excellent properties of insulation and heat-resistance and low cost. 2. Silicates, phosphates, etc. 3. Other mineral powder such as mica powder, kaolinite, etc. 4. Surface film chemically formed or surface oxide occurred.

[0058] If said insulating agent is used to insulate the amorphous alloy powder, the weight percentage of insulating agent should be between 0.2 wt. % and 7 wt. % of the total mixture weight. If the insulating agent is less, the amorphous alloy powder will be difficult to be fully separated, thus resulting in more contact surface; if the insulating layer is too thin, the insulating layer between powder will easily breakdown, losing insulating effect under the action of electromagnetic induction, causing larger losses of magnetic powder core and low magnetic permeability in high frequency. If too much insulating agent is provided, the gap between powders will be too large, resulting in a decrease of magnetic permeability of the magnetic powder core. The weight percentage of insulating agent more preferably is from 0.5 wt. % to 5 wt. %.

[0059] Molding properties of amorphous alloy powder are not good. The molding of gas atomized powder is especially difficult. So the following types of adhesive substances are preferable to serve as the adhesives for the present invention: 1. Organic adhesives, such as epoxy resin, which has been commonly used in industrial product and the mixing with curing agent shall have better effect on sticking. 2. Inorganic adhesives, such as phosphates, etc., inorganic adhesives have the advantages of good heat-resistant properties and excellent insulation properties in itself and dual functions of insulation and sticking, and an additional proper amount will make the powder fully adhesive.

[0060] The content of adhesive shall not more than 5% of the total weight while using said adhesive materials. If too much adhesive is added, properties of magnetic powder core will deteriorate and so will magnetic permeability.

[0061] The mixture of lubricant functions as: 1. The powder is easy to flow while pressing the powder, thus increase the density of magnetic powder core; 2. Magnetic core is not prone to stick with press mold, thus demolding becomes easier. Stearates and talc powder is selected preferably as lubricant substances for the present invention, wherein the weight is no more than 2 wt. % of total weight of mixture. If too much lubricant is added, the density of amorphous alloy powder in magnetic powder core will decrease, resulting in the deterioration of magnetic properties and reduction of magnetic permeability.

[0062] In order to obtain fully insulated and mixed amorphous magnetic powder and excellent magnetic properties, the insulating substances, adhesives and lubricants preferably occupy from 0.5 wt. % to 10 wt. % of total weight of mixture for the present invention, more preferably from 1 wt. % to 7 wt. %.

Step 2

[0063] The molding pressure of the amorphous alloy powder of the present invention should be preferably from 500 MPa to 3000 MPa. If the pressure is less than 500 MPa, the powder will be difficult to mold or cracks will still exist after molding, the magnetic permeability will be low and the properties of magnetic powder core will not be good. If the pressure is over 3000 MPa, the withstand pressure of mold will be large, thus the mold will be easily destroyed, and the powder will be difficult to insulate, losses of powder core will be high and the quality factor will not be fine. The molding pressure of magnetic powder core is more preferably from 800 MPa to 2500 MPa.

Step 3

[0064] The cooling rate of amorphous alloy powder is comparatively large during the preparation process, so stress will inevitably exist inside said powder; magnetic powder core shall have stress inside it while preparing under the action of stirring and compression and these stress shall influence the properties of magnetic powder core. The internal stress of powder and magnetic powder core can be eliminated and the magnetic properties can be improved by annealing the amorphous magnetic powder core. The temperature of annealing amorphous magnetic powder core shall satisfy the requirements of: 1. Annealing temperature should be below the the crystallization temperature of said alloy powder. The crystallization of amorphous alloy powder in said powder core results in magnetic permeability and the increase in losses. 2. Annealing temperature shall not be below (T_x−100° C.), wherein T_x represents the crystallization temperature of said alloy powder. 3. The annealing temperature of powder shall preferably be between (T_x−70° C.) and (T_x−20° C.). Since if the annealing temperature of the powder core is too low, heat disturbance will be ununiform, the internal stress in amorphous powder core will not be eliminated and the magnetic properties will not be fully enhanced.

[0065] The annealing time of amorphous powder core shall satisfy the requirements of: 1. The annealing time of powder core is less than 3 hours since the manufacture cost will increase with too long annealing time and low effectiveness. 2. The annealing time of the powder core is more than 5 minutes since uniform treatment cannot be achieved while batch processing and the properties of powder core cannot be uniform if the annealing time is too short. 3. The annealing time of the powder core shall preferably be between 30 minutes and 90 minutes. For the present invention, the annealing process mentioned above should preferably be carried out in a protective atmosphere, which can be vacuum, hydrogen, nitrogen and argon atmosphere.

Step 4

[0066] In order to protect magnetic powder core from powder dropping and being eroded by air and from the deterioration of magnetic properties, the magnetic powder core is protected by spray painting. The spray painting materials shall preferably be of epoxy resin or a mixture of epoxy resin and estrodur compounds with relatively small curing stress. The thickness of the spray painting is preferably from 50 μm to 300 μm.

Step 5

[0067] Various parameters of properties of amorphous magnetic powder core for the present invention is tested respectively by the following methods: 1. Test method for inductance and quality factor Q, using enameled copper wires with diameter of 0.2 mm to wind 10 turns uniformly and to measure by Agilent 4294A precision impedance analyzer; magnetic permeability of magnetic powder core is calculated by the formula

$$\mu_e = \frac{\bar{l}L}{0.4\pi N^2 A}\cdot 10^8,$$

wherein $\bar{l}$ (unit is cm) represents average length of magnetic path, N represents the turns of winding, A represents across section of magnetic path (unit is cm^2). 2. Measuring static magnetic hysteresis loop of magnetic powder core by galvanometer, wherein the maximum magnetic field is 2000 A/m.

[0068] The magnetic powder core prepared by alloy powder of the present invention via said method has excellent soft magnetic properties in high frequency. In detail, the properties of amorphous magnetic powder core satisfy the following requirements: the quality factor is larger than 50 and the magnetic permeability is larger than 40 at 500 kHz; the quality factor is larger than 30 and the magnetic permeability is larger than 40 at 1 MHz; the quality factor of magnetic powder core is larger than 20 and the magnetic permeability is larger than 40 at 3 MHz; while the decrease of magnetic permeability should be less than 10% in the frequency range from 100K to 1M.

[0069] The amorphous alloy prepared according to the technical solution of the present invention has large glass formation ability and good antioxidation properties. Said alloy is characterized in large glass formation ability, good antioxidation properties and excellent soft magnetic properties. By preparing amorphous alloy powder with low oxygen content via atomization method, the amorphous alloy powder with excellent high-frequency magnetic properties, low oxygen content and low cost and corresponding magnetic powder core can be obtained.

BRIEF DESCRIPTION OF DRAWINGS

[0070] FIG. 1 is a photo of morphology of amorphous alloy powder having composition of $Fe_{72}Ni2Al_4Sn_2P_{10}C_2B_4Si_4$ prepared according to embodiment 1 of the present invention.

[0071] FIG. 2 is a graph illustrating an X-ray diffraction pattern of amorphous alloy powder having composition of $Fe_{72}Ni2Al_4Sn_2P_{10}C_2B_4Si_4$ prepared according to embodiment 1 of the present invention.

[0072] FIG. 3 is DSC thermogram of amorphous alloy powder having a composition of prepared according to embodiment 1 of the present invention.

[0073] FIG. 4 is a graph illustrating the static magnetic hysteresis loop of magnetic powder core prepared according to embodiment 1 of the present invention with maximum magnetic field of 2000 A/m.

[0074] FIG. 5 is a graph illustrating the dependence of permeability on frequency of an amorphous magnetic powder core prepared according to embodiment 1 of the present invention in different frequency.

[0075] FIG. 6 is a graph illustrating the dependence of quality factors on frequency of an amorphous magnetic powder core prepared according to embodiment 1 of the present invention and of MPP magnetic powder core as comparison in different frequency.

[0076] FIG. 7 is a graph illustrating the dependence of magnetic permeability on annealing temperature of an amorphous magnetic powder core prepared according to embodiment 5 of the present invention under different annealing temperature at 100 kHz.

[0077] FIG. 8 is a graph illustrating the dependence of quality factor on annealing temperature of an amorphous magnetic powder core prepared according to embodiment 5 of the present invention under different annealing temperatures at 100 kHz and 1 MHz.

[0078] FIG. 9 is a graph illustrating the dependence of coercive force H_c on annealing temperature corresponding with the static magnetic hysteresis loop of magnetic powder core prepared according to embodiment 5 of the present invention under different annealing temperatures in a maximum magnetic field of 2000 A/m.

EMBODIMENTS OF THE INVENTION

Embodiment 1

[0079] In said embodiment, amorphous $Fe_{72}Ni2Al_4Sn_2P_{10}C_2B_4Si_4$ (composition serial number is 1) alloy powder is prepared by water atomization method. The raw materials shall be Fe, Ni, Al, Sn, P—Fe alloy, B—Fe alloy, graphite and Si.

[0080] The morphology of the powder having composition of $Fe_{72}Ni2Al_4Sn_2P_{10}C_2B_4Si_4$ is shown in FIG. 1. As shown in this figure, the small particle powder is basically spherical, the big particle powder is elliptical and a small amount of powder is irregular.

[0081] The X-ray diffraction pattern of powder having composition of $Fe_{72}Ni2Al_4Sn_2P_{10}C_2B_4Si_4$ is shown in FIG. 2. As shown in this figure, distinct wide atlas exists in X-ray diffraction pattern and there is no notable crystallization peak in it, which indicates that the alloy powder is amorphous. Thereby, $Fe_{72}Ni_2Al_4Sn_2P_{10}C_2B_4Si_4$ alloy can prepare amorphous alloy powder by water atomization method.

[0082] The DSC thermogram of $Fe_{72}Ni2Al_4Sn_2P_{10}C_2B_4Si_4$ powder is shown in FIG. 3. The speed is 10K/minute while performing DSC testing. As shown in this figure, alloy glass transition temperature T_g is 646K and crystallization temperature T_x is 695K. The melting point T_m tested by high temperature DSC is 1209K, so we can calculate that the supercooled liquid region of said alloy ΔT_x is 49K and the reduced glass transition temperature T_{rg} is 0.54.

[0083] The analysis of oxygen content of the powder indicates that the oxygen content of the powder is 3500 ppm, which implies that alloy bears stronger antioxidation properties and lower oxygen content.

[0084] The amorphous alloy powder of −300 mess obtained by screening is isothermal annealed for 30 minutes at a temperature of 440° C., wherein the annealing process is in nitrogen atmosphere. Said amorphous alloy powder uniformly mixes with 1.5 wt. % of SiO_2 powder, 1 wt. % of epoxy resin and 0.3 wt. % of zinc stearate and then the mixture is dried in the help of alcohol as a co-solvent. The molding of the magnetic powder core is pressed under the pressure of 2 GPa. The magnetic powder core is annealed under vacuum condition. The annealing temperature is 400° C. and the annealing time is 90 minutes. The epoxy resin and estrodur compounds are used to spray and paint the surface of magnetic powder core. The thickness of the spray painting layer is 100 μm. Static magnetic hysteresis loop of said magnetic powder core with the maximum magnetic field of 2000 A/m is shown in FIG. 4. As shown in this figure, magnetic powder core basically keeps constant permeability properties within the range of testing magnetic field and coercive force H_c is 45 A/m.

[0085] The measuring result of magnetic permeability of said magnetic powder core is given in FIG. 5. As shown in this figure, magnetic permeability of said magnetic powder core is 46.9. With the increase of frequency, magnetic powder core keeps excellent constant permeability properties. Within the range of 6.3 kHz to 5 MHz, magnetic permeability drops from 46.9 to 46.4. The percentage of dropping is less than 2%.

[0086] FIG. 6 shows the dependence of quality factor of said magnetic powder core on frequency and the comparison example of FeNiMo magnetic powder core is also shown. As shown in this figure, amorphous alloy magnetic powder core has higher quality factor in high frequency.

Embodiment 2

[0087] In said embodiment, amorphous Fe—Ni—Sn—Al—P—C—B—Si series alloy powder is prepared by water atomization method. The raw materials shall select Fe, Ni, Sn, Al, P—Fe alloy, graphite, B—Fe alloy and Si.

[0088] The nominal compositions of said embodiment are listed in Table 1. Glass transition temperature of corresponding alloy, crystallization temperature, melting point, reduced glass transition temperature and width of supercooled liquid region are listed in Table 1 respectively. As seen from this table, except that composition 10 is in a crystallization process, alloy with other composition of said series alloy has high reduced glass transition temperature. The minimum is 0.54 and the maximum is 0.58. The width of supercooled liquid region is over 20K.

TABLE 1

No.	Alloy composition in atomic percentage	T_g/K	T_x/K	T_m/K	T_g/T_m	$(T_x - T_g)$/K
1	$Fe_{72}Ni_2Al_4Sn_2P_{10}C_2B_4Si_4$	646	695	1209	0.54	49
2	$Fe_{68.5}Ni_3Al_7P_{11.5}C_3B_5$	650	700	1209	0.54	50
3	$Fe_{67}Ni_7Sn_2Al_4P_{10}B_4C_2Si_4$	654	694	1208	0.54	40
4	$Fe_{70.5}Ni_{10}Sn_1Al_4P_{13}C_2B_3Si_6$	665	690	1204	0.55	25
5	$Fe_{71}Ni_4Sn_4Al_1P_{10}C_4B_2Si_4$	666	698	1206	0.55	32
6	$Fe_{72}Ni_2Sn_1Al_3P_9C_2B_8Si_3$	675	703	1211	0.56	28
7	$Fe_{73}Ni_1Sn_2Al_4P_{10}C_2B_4Si_4$	668	715	1202	0.56	47
8	$Fe_{73.5}Ni_2Sn_5P_{9.5}C_2B_5Si_3$	680	702	1200	0.57	22
9	$Fe_{74.5}Ni_1Sn_2Al_2P_{11.5}B_4Si_5$	698	729	1210	0.58	31
10	$Fe_{77}Ni_3Sn_1Al_3P_8C_2B_2Si_4$	—	—	1208	—	—
Comparative 1	$Fe_{68.5}Ni_3Al_7P_{11.5}C_3B_3Si_2$	652	700	1209	0.54	48

[0089] In the amorphous alloy powder with the composition mentioned above, the oxygen content and the loose packed density of amorphous alloy powder of −300 mess are listed in Table 2. As can be seen in this table, except for the Comparison 1 of said series alloy, the loose packed density of said series alloy is over 2.5 g/cm^3 and the average oxygen content is below 3900 ppm, which implies that the alloy has stronger antioxidation properties.

[0090] The amorphous alloy powder of −300 mess obtained by screening the amorphous alloy powder with the compositions mentioned above is isothermal annealed for 30 minutes at 440° C., wherein annealing process is in vacuum protection. Said amorphous alloy powder uniformly mixes with 1 wt. % of SiO_2 powder, 1.5 wt. % of epoxy resin and 0.3 wt. % of zinc stearate and then the mixture is dried in the help of alcohol as co-solvent. The mold magnetic powder core is pressed under the pressure of 2 GPa. The magnetic powder core is annealed under vacuum situation. The annealing temperature is 440° C. and annealing time is 60 minutes. The epoxy resin and estrodur compounds are used to spray and paint the surface of magnetic powder core. The thickness of spray painting layer is 100 μm.

TABLE 2

	Powder characteristic									
	Oxygen content	Loose packed density		H_c	Properties of powder core					
序号	(ppm)	(g/cm^3)	structure	(A/m)	$\mu_{10\ kHz}$	$\mu_{100\ kHz}$	$\mu_{1\ MHz}$	$Q_{10\ kHz}$	$Q_{100\ kHz}$	$Q_{1\ MHz}$
1	3500	2.7	amorphous	45	47	47	46	7	38	67
2	3500	2.6	amorphous	53	43	43	41	6	32	72
3	2600	2.7	amorphous	40	60	60	59	8	35	77
4	3800	2.5	amorphous	40	53	53	53	5	29	66
5	3000	2.7	amorphous	26	42	42	42	6	33	75
6	3300	2.6	amorphous	34	39	39	39	4.5	30	69
7	2800	2.6	amorphous	35	62	62	60	5.5	32	75
8	3900	2.5	amorphous	50	38	38	38	4	27	48
9	3500	2.6	amorphous	47	46	46	44	4.5	28	63
10	3200	2.8	crystallized	120	8	8	8	5	7	33
Comparative 1	5200	2.3	amorphous	65	35	35	35	4.5	27	60

[0091] The properties of amorphous alloy powder core prepared by said method mentioned above are also listed in Table 2, wherein the atomization method is not suitable for Comparison 1, which will get the amorphous alloy powder with high oxygen content and low loose packed density. It can be concluded from Table 2 that the magnetic powder core made of amorphous alloy powder with lower coercive force and higher magnetic permeability compared with Comparison 1. Magnetic properties of composition 10 deteriorate because of crystallization; coercive force of alloy with other compositions (except 10 and Comparison 1) is below 60 A/m, the average magnetic permeability is over 35 which is 98% or more than the magnetic permeability at 100 kHz and 90% or more at 1 MHz, wherein the quality factor is over 40 at 1 MHz.

Embodiment 3

[0092] In said embodiment, amorphous Fe—Co—Cr—Sn—Al—P—C—B—Si series alloy powder is prepared by water atomization method. The raw materials are Fe, Co, Cr, Sn, Al, P—Fe alloy, graphite, B—Fe alloy abd Si.

[0093] The nominal composition of said embodiment is listed in Table 3. The lists of glass transition temperature of corresponding alloy, crystallization temperature, melting point, approximate glass transition temperature and width of super cooled liquid region are listed in Table 3 respectively. As seen from this table, except that composition 20 cannot be fully formed into amorphous materials, alloy other compositions all has high reduced glass transition temperature. The minimum is 0.58 and the maximum is 0.60. The width of super cooled liquid region is over 20K.

TABLE 3

表3

No.	Alloy composition in atomic percentage	T_g/K	T_x/K	T_m/K	T_g/T_m	$(T_x - T_g)$/K
11	$Fe_{70}Co_2Cr_2Sn_2Al_4P_{10}C_2B_4Si_4$	705	744	1208	0.58	39
12	$Fe_{68.5}Co_2Cr_1Sn_2Al_7P_{11.5}C_3B_3Si_2$	715	740	1197	0.60	25
13	$Fe_{68.5}Co_1Cr_5Sn_3Al_2P_{11.5}C_5B_2Si_2$	715	753	1223	0.58	38
14	$Fe_{69.5}Co_1Cr_{0.5}Sn_1Al_4P_{13}C_2B_3Si_6$	701	738	1183	0.59	37
15	$Fe_{69.5}Co_2Cr_4Sn_4Al_1P_{10}C_4B_2Si_4$	723	758	1215	0.60	35
16	$Fe_{70}Co_2Cr_2Sn_1Al_3P_9C_2B_8Si_3$	704	739	1216	0.58	35
17	$Fe_{71}Co_2Cr_1Sn_2Al_4P_{10}C_2B_4Si_4$	671	724	1204	0.56	53
18	$Fe_{71}Co_5Cr_1Al_2P_{10.5}C_2B_5Si_3$	698	731	1201	0.58	33
19	$Fe_{72.5}Co_2Cr_2Al_4P_{9.5}C_1B_4Si_5$	701	732	1209	0.58	31
20	$Fe_{75}Co_3Cr_3Al_3P_8C_2B_2Si_4$	—	—	1250	—	—

[0094] In the amorphous alloy powder with the compositions mentioned above, the oxygen content and the loose packed density of amorphous alloy powder of −300 mess are listed in Table 4. As shown in this table, the average loose packed density of said series alloy is not less than 2.5 g/cm^3 and the average oxygen content is below 3300 ppm, which implies that the alloy has stronger antioxidation properties.

[0095] The amorphous alloy powder of −300 mess obtained by screening the amorphous alloy powder with the compositions mentioned above is isothermal annealed for 30 minutes at a temperature of 440° C., wherein annealing process is in vacuum protection. Said amorphous alloy powder uniformly mixes with 1 wt. % of SiO_2 powder, 1.5 wt. % of epoxy resin and 0.3 wt. % of zinc stearate and then the mixture is dried in the help of alcohol as co-solvent. The molding of magnetic powder core is pressed under the pressure of 2 GPa. The magnetic powder core is annealed under vacuum situation. The annealing temperature is 440° C. and annealing time is 60 minutes. The epoxy resin and estrodur compounds are used to spray and paint the surface of magnetic powder core. The thickness of spray painting layer is 100 μm.

[0096] The properties of amorphous alloy magnetic powder core prepared by said method mentioned above are also listed in Table 4. It can be seen from Table 4 that, except that composition 20 is in a crystallization process and properties of magnetic powder core deteriorate, other compositions all have more excellent magnetic properties and magnetic permeability is not less than 45.

[0097] The coercive force of alloy with other compositions (except 10 and Comparison 1) is below 60 A/m, the average magnetic permeability is over 35 which is 98% or more than the magnetic permeability at 100 kHz and 90% or more at 1 MHz, wherein the quality factor is over 60 at 1 MHz.

TABLE 4

	Powder characteristic			Properties of powder core						
No.	Oxygen content (ppm)	Loose packed density (g/cm^3)	structure	H_c (A/m)	$\mu_{10\ kHz}$	$\mu_{100\ kHz}$	$\mu_{1\ MHz}$	$Q_{10\ kHz}$	$Q_{100\ kHz}$	$Q_{1\ MHz}$
11	2600	2.8.0	Amorphous	46	48	48	47	7	34	72
12	2900	2.9	Amorphous	37	60	60	58	8	38	85
13	2500	2.8	Amorphous	40	65	65	64	7	35	80
14	3000	2.8	Amorphous	41	65	65	64	6	33	75
15	2700	2.6	Amorphous	49	60	60	59	6	30	72
16	2800	2.6	Amorphous	50	53	53	52	6	32	75
17	3300	2.5	Amorphous	47	49	49	48	5	27	64
18	3000	2.7	Amorphous	54	45	45	44	4.5	28	68
19	3200	2.7	Amorphous	52	46	46	45	4.5	28	67
20	2800	2.7	crystallized	118	12	12	12	5	7	34

Embodiment 4

[0098] In said embodiment, amorphous Fe—Co—Ni—Sn—Al—P—C—B—Si series alloy powder is prepared by non-vacuum gas atomization method. The raw materials are Fe, Co, Ni, Cr, Sn, Al, P—Fe alloy, graphite, B—Fe alloy and Si.

[0099] The nominal compositions of said embodiment are listed in Table 5. The lists of glass transition temperature of corresponding alloy, crystallization temperature, melting point, approximate glass transition temperature and width of super cooled liquid region are also listed in Table 5 respectively. As shown in this table, except that composition 25 cannot be fully formed into amorphous materials, alloy with other compositions of said series alloy all has high reduced glass transition temperature. The minimum is 0.58 and the maximum is 0.60. The width of super cooled liquid region is over 20K.

TABLE 5

Series No.	Compositions of alloy by atomic percentage	T_g/K	T_x/K	T_m/K	T_g/T_m	$(T_x - T_g)$/K
21	$Fe_{71}Co_2Sn_2Al_4P_{10}C_2B_5Si_4$	703	740	1208	0.58	37
22	$Fe_{71}Ni_2Cr_1AL_4P_{11}C_2B_6Si_2$	715	745	1197	0.60	30
23	$Fe_{72.5}Co_1Ni_1Sn_3Al_2P_{11.5}C_5B_2Si_2$	708	746	1223	0.58	38
24	$Fe_{63}Ni_3Co_3Cr_{0.5}Al_4P_{13}C_2B_3Si_6$	720	743	1183	0.61	23
25	$Fe_{63}Ni_5Co_3Cr_2Sn_4Al_1P_{10}C_4B_2Si_4$	—	—	1215	—	—

[0100] In the amorphous alloy powder with the components mentioned above, the oxygen content and the loose packed density of amorphous alloy powder of −350 mess are given in Table 6. As can be seen in this table, the average loose packed density of said series alloy is not less than 3.6 g/cm^3 and the average oxygen content is below 2000 ppm.

[0101] The amorphous alloy powder of −350 mess obtained by screening the amorphous alloy powder with the composition mentioned above is isothermal annealed for 30 minutes at a temperature of 400° C., wherein annealing process is in vacuum protection. Said amorphous alloy powder uniformly mixes with 1 wt. % of SiO_2 powder, 2 wt. % of epoxy resin and 0.3 wt. % of zinc stearate and then the mixture is dried in the help of alcohol as co-solvent. The molding of magnetic powder core is pressed under the pressure of 2.4 GPa. The magnetic powder core is annealed under vacuum situation. The annealing temperature is 440° C. and annealing time is 60 minutes. The epoxy resin and estrodur compounds are used to spray and paint the surface of magnetic powder core. The thickness of spray painting layer is 100 μm.

[0102] The properties of amorphous alloy magnetic powder core prepared by said method mentioned above are given in Table 6. It can be concluded from Table 6 that, except that composition 25 is in a crystallization process and properties of magnetic powder core deteriorate, the coercive force of alloy with other components is below 40 A/m, the average magnetic permeability is over 60 which is 98% or more than the magnetic permeability at 100 kHz and 90% or more at 1 MHz, wherein the quality factor is over 60 at 1 MHz.

TABLE 6

Series No.	Oxygen content (ppm)	Loose packed density (g/cm^3)	Structure	H_c (A/m)	$\mu_{10\,kHz}$	$\mu_{100\,kHz}$	$\mu_{1\,MHz}$	$Q_{10\,kHz}$	$Q_{100\,kHz}$	$Q_{1\,MHz}$
21	1500	3.6	amorphous	32	72	72	70	9	45	98
22	1200	3.7	amorphous	28	70	70	68	9	40	88
23	1250	3.7	amorphous	26	68	68	66	9	40	92
24	1100	3.7	amorphous	25	75	75	73	9	41	96
25	800	3.7	crystallization	68	13	13	13	6	9	42

Embodiment 5

[0103] Amorphous alloy powder is prepared by the same method as embodiment 1. The procedures for preparing magnetic powder core are also the same. The only difference is the change of temperature of heat treatment.

[0104] FIG. **7** shows the dependence of magnetic permeability on annealing temperature at 100 kHz. As shown in the figure, the magnetic permeability of said magnetic powder core increases with the increasing of the temperature of heat treatment and the maximum value is obtained at 440° C. then the magnetic permeability decreases with the increasing of annealing temperature. The maximum magnetic permeability is about 50.

[0105] FIG. **8** shows the dependence of quality factor on annealing temperature at 100kHz and 1 MHz.

[0106] The dependence of the quality factor on annealing temperature is similar to that of magnetic permeability. The difference is that the maximum quality factor of magnetic powder core appears under the annealing temperature of 380° C. The maximum quality factor is about 75 at 100 kHz; the maximum quality factor is about 35 at 1 MHz.

[0107] FIG. **9** shows the dependence of coercive force H, on annealing temperature corresponding to the static magnetic hysteresis loop of magnetic powder core under maximum magnetic field of 2000 A/m. As shown in the figure, the change trend of coercive force is completely opposite to that of magnetic peameability and the minimum coercive force is about 44 A/m.

We claim:

1. An amorphous alloy powder exhibiting excellent soft magnetic properties in high frequency range characterized by a composition in atomic percent of the following formula: $(Fe_{1-x}M_x)_{100-a-b-c}P_aT_bD_c$, wherein M represents at least one element of Co and Ni; T is over three elements selected from Al, C, B and Si, D is at least one element selected from Sn, Cr, Mn, Mo, W, V, Nb, Ta, Ti, Zr, Hf, Pt, Pd and Au, the subscripts x, a, b, and c satisfy the relationships of $0.0 \leqq x \leqq 0.16$, $8 \leqq a \leqq 15$, $10 \leqq b \leqq 25$ and $0.5 \leqq c \leqq 6$.

2. An amorphous alloy powder according to claim 1, the subscripts x, a, b, and c preferably satisfy the relationships of $0.01 \leqq x \leqq 0.12$, $9 \leqq a \leqq 12$, $10 \leqq b \leqq 23$ and $1 \leqq c \leqq 5$.

3. An amorphous alloy powder according to claim 1, the subscripts a, b, and c preferably satisfy the relationship of $22 \leqq (a+b+c) \leqq 38$.

4. An amorphous alloy powder according to claim 1, characterized in that, the reduced glass transition temperature of said amorphous alloy powder $T_{rg} \geqq 0.53$, wherein $T_{rg}=T_g/T_m$, T_g represents glass transition temperature and T_m represents melting point of the alloy.

5. An amorphous alloy powder according to claim 1, characterized in that, the supercooled liquid region of said amorphous alloy powder $\Delta T_x \geqq 20K$, wherein $\Delta T_x=T_x-T_g$, T_x represents crystallization temperature.

6. An amorphous alloy powder according to claim 1, characterized in that the oxygen content of the powder in said amorphous alloy powder is below 4000 ppm.

7. A method for making amorphous alloy powder exhibiting excellent soft magnetic properties in high frequency characterized in that the alloy powder with composition according to claim 1 is made by atomization method, wherein said atomization maybe water atomization and/or gas atomization, while said gas atomization may be vacuum gas atomization, non-vacuum gas atomization, adjustable gas atomization or their combination.

8. The method for making amorphous alloy powder according to claim 7, characterized in that the loose packed density of the powder ρ satisfies the relation: $\rho>2.4$ g/cm^3.

9. An amorphous magnetic powder core exhibiting excellent soft magnetic properties in high frequency range characterized by comprised the components by weight percentage as follows: 0.2%-7% of insulating agent, 0.01%-5% of adhesives, 0.01%-2% of lubricants and the rest is said amorphous alloy powder according to claim 1.

10. The amorphous magnetic powder core according to claim 9, characterized in that said insulating agent is one or a combination selected from the following groups of substances:

Oxide powder selected from SiO_2, CaO, Al_2O_3 and TiO_2,

Salts selected from silicates and phosphates,

Mineral powder selected from mica powder and kaolinite, and

surface film produced by chemical deposition or self-oxidation.

11. The amorphous magnetic powder core according to claim 9, characterized in that, said adhesives are organic adhesives and/or inorganic adhesives, wherein the organic adhesives are at least one selected from epoxy resins, the inorganic adhesives are at least one selected from phosphates.

12. The amorphous magnetic powder core according to claim 9, characterized in that, said lubricants are one or a combination selected from stearates and talc powder.

13. The amorphous magnetic powder core of amorphous alloy powder according to claim 9, characterized in that, the magnetic properties satisfy the requirements of one, several or their combination of the followings:

Magnetic permeability is no less than 35,

Quality factor Q is not less than 30 at 1 MHz,

Per unit of initial permeability is no less than 98% at 100 kHz, no less than 90% at 1 MHz;

Coercive force H_c corresponding with static magnetic hysteresis loop in maximum magnetic field of 2000 A/m is less than 70 A/m.

14. A method for making an amorphous magnetic powder core exhibiting excellent soft magnetic properties in high frequency range characterized in that the process includes the following steps:

(a) Using said amorphous alloy powder according to claim 1 and a required content of insulating agent, adhesives and lubricants, mixing themof and then drying them to obtain dry powder,

(b) Compacting said dried powder in a mold under a pressure of 500 MPa-3000 MPa to form a magnetic powder core,

(c) Annealing said molded magnetic powder core below the crystallization temperature of said amorphous alloy.

15. The method for making amorphous magnetic powder core according to claim 14, characterized in that after step (c), preferably further including: (d) spray painting magnetic powder core and (e) testing the properties of magnetic powder core.

16. The method for making amorphous magnetic powder core according to claim 14, characterized in that in step (c), the temperature for annealing said magnetic powder core is between (T_x−100° C.) and T_x, wherein T_x represents crystallization temperature; annealing time is from 5 minutes to 300 minutes, the atmosphere is one of vacuum, nitrogen and argon.

17. The method for making amorphous magnetic powder core according to claim 14, characterized in that in step (c), the annealing temperature is preferably between (T_x−70° C.) and (T_x−20° C.), wherein T_x represents crystallization temperature of said alloy.

18. The method for making amorphous magnetic powder core according to claim 14, characterized in that the magnetic properties of magnetic powder core obtained shall satisfy the requirements of at least one, or the combination of the following:

Magnetic permeability is no less than 35;

Quality factor Q is not less than 30 at 1 MHz;

Per unit initial permeability is not less than 98% at 100 kHz, not less than 90% or more at 1 MHz;

Coercive force H_c corresponding with static magnetic hysteresis loop in maximum magnetic field of 2000 A/m is less than 70 A/m.

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