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(54) **MAGNETIC NANOPARTICLE, AND PREPARATION METHOD THEREFOR AND USE THEREOF**

(57) The present application provides a magnetic nanoparticle, and a preparation method therefor and a use thereof. The chemical formula of the magnetic nanoparticle is $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, wherein $0 \le x \le 0.3$, $0 \le y \le 0.3$, $0 \le z \le 0.25$, and x, y and z are not 0 at the same time; and the average particle size of the magnetic nanoparticle is 20-40 nm. The magnetic nanoparticle in the present application has a small particle size and exhibit excellent magnetic properties, and can be used in magnetic storage devices to further meet needs for storage of massive data in the information age.

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Description

TECHNICAL FIELD

[0001] The present application relates to the technical field of magnetic materials, for example, a magnetic nanoparticle, a preparation method therefor and use thereof.

BACKGROUND

[0002] In recent years, as magnetic recording devices have increasingly evolved toward higher recording density, magnetic materials are required to have better magnetic properties.

[0003] Although having magnetic properties not as good as rare-earth permanent magnets, hexagonal ferrite permanent magnets possess numerous advantages such as abundant resources, simple preparation processes, and low costs. They are widely used in the fields of motors, sensors, and magnetic storage, and their consumption is the highest in permanent magnet materials currently. When used in magnetic storage devices, hexagonal ferrite permanent magnets exhibit high temperature resistance, corrosion resistance, and oxidation resistance, making them particularly suitable for magnetic storage devices in long-term use. In the current era of informatization and digitalization, a large amount of "warm data" and "cold data" need long-term storage. Therefore, hexagonal ferrite-based magnetic storage media have attracted widespread attention.

[0004] CN102076629A discloses a reinforced hexagonal ferrite magnetic material, wherein the magnetic material is doped with alkali metal.

[0005] CN109836147A discloses a permanent magnet ferrite and a preparation method therefor. Based on the total mass of the permanent magnet ferrite, the permanent magnet ferrite consists of 55wt% or more of a Sr-based ferrite material and 45wt% or less of a Ca-based ferrite material. The Sr-based ferrite material has a main phase represented by $Sr_{1-x}La_xFe^{3+}{}_{2n-y}Co_yO_{19}$, and the Ca-based ferrite material has a main phase represented by $Ca_x(Sr+Ba)_yLa_{1-x-y}Fe^{3+}{}_{2n-z}Co_zO_{19}$.

[0006] In the above solutions, the ferrite materials have a large particle size and poor magnetic properties. The low magnetic properties of the ferrite material lead to a low magnetic storage density, failing to meet the storage demands of massive data in the information age, and thus becoming the main obstacle limiting ferrites' widespread application.

SUMMARY

[0007] The following is a summary of subject matter that is described in greater detail herein. This summary is not intended to be limiting as to the scope of the claims.

[0008] The present application provides a magnetic nanoparticle, a preparation method therefor and use thereof. The magnetic nanoparticle of the present application has a small particle size and exhibits excellent magnetic properties. When used in magnetic storage devices, the magnetic nanoparticle can further meet the storage demands for massive data in the information age.

[0009] In a first aspect, the present application provides a magnetic nanoparticle, and a chemical formula of the magnetic nanoparticle is $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$; wherein $0 \le x \le 0.3$, $0 \le y \le 0.3$, $0 \le z \le 0.25$, at least one of x, y and z is not equal to 0, and an average particle size of the magnetic nanoparticle is 20-40 nm, for example, 20 nm, 25 nm, 30 nm, 35 nm, or 40 nm.

[0010] The magnetic nanoparticle of the present application has a nanocrystalline structure (with an average particle size of less than 50 nm). Due to the nanocrystalline structure, coercivity of the material increases as the grain size decreases. In particular, when the grain size is less than 50 nm, adjacent grains will have strong exchange-coupling interaction, significantly enhancing the remanence of the material. Furthermore, the magnetic particle has a chemical composition represented by $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, possessing excellent magnetic properties, and supporting the development of magnetic storage devices towards high-density recording.

[0011] In an embodiment, particles having a particle size of 10-40 nm (for example, 10 nm, 15 nm, 20 nm, 25 nm, 30 nm, or 40 nm) account for 90% or more of the magnetic nanoparticle.

[0012] In an embodiment, particles having a particle size >40 nm (for example, 40.5 nm, 41 nm, 43 nm, 45 nm, 48 nm, or 49 nm) account for 5% or less of the magnetic nanoparticle, for example, 1%, 2%, 3%, 4%, or 5%.

[0013] In an embodiment, particles having a particle size <10 nm (for example, 9 nm, 8 nm, 7 nm, 6 nm, 5 nm, or 3 nm) account for 5% or less of the magnetic nanoparticle, for example, 1%, 2%, 3%, 4%, or 5%.

[0014] In the magnetic nanoparticles of the present application, the sum of the proportions of particles having a particle size of 10-40 nm, particles having a particle size >40 nm, and particles having a particle size <10 nm is 100%. For example, the proportion of particles having a particle size of 10-40 nm is 95%, the proportion of particles having a particle size >40 nm is 3%, and the proportion of particles having a particle size <10 nm is 2%.

[0015] In an embodiment, when both y and z are not 0, y and z have a relationship: $1 \leq y/z \leq 1.5$, for example, 1, 1.1, 1.2, 1.36, 1.4, or 1.5.

[0016] In a second aspect, the present application provides a preparation method for the magnetic nanoparticle as described in the first aspect, and the preparation method comprises the following steps:

(1) mixing a main material A and a main material B proportionally to obtain a mixed material, wherein the main material A comprises $SrCO_3$ and Fe_2O_3, and the main material B comprises any one or a combination of at least two of $BaCO_3$, La_2O_3, or Co_2O_3; and then mixing the mixed material with H_3BO_3 and $SrCl_2$, grinding and performing a calcination treatment;

(2) subjecting a material obtained from the calcination treatment to a melting treatment and introducing the material onto a water-cooled roller to obtain an amorphous thin sheet; and

(3) subjecting the amorphous thin sheet to a thermal crystallization treatment and then a washing treatment to obtain the magnetic nanoparticle.

[0017] During the preparation process of the magnetic nanoparticle in the present application, the addition of H_3BO_3 and $SrCl_2$ can assist to melt the mixture and also regulate the viscosity of the molten liquid, thereby affecting the thickness of the amorphous thin sheets and their cooling rate on the roller, and ultimately influencing the microstructure and properties of the material.

[0018] In an embodiment, a mass of H_3BO_3 in step (1) is 15-25% of a mass of the mixed material, for example, 15%, 18%, 20%, 22%, or 25%.

[0019] In an embodiment, a mass of $SrCl_2$ is 10-20% of the mass of the mixed material, for example, 10%, 12%, 15%, 18%, or 20%.

[0020] In an embodiment, a method for the grinding in step (1) comprises ball milling.

[0021] In an embodiment, the calcination treatment is performed at a temperature of 900-1100°C, for example, 900°C, 950°C, 1000°C, 1050°C, or 1100°C.

[0022] In an embodiment, the calcination treatment is performed for a period of 1-3 h, for example, 1 h, 1.5 h, 2 h, 2.5 h, or 3 h.

[0023] The calcination treatment in the present application allows various elements to diffuse into each other in the solid state, thereby preventing the molten material from non-uniform distribution caused by density differences in the subsequent melting process, which would otherwise lead to insufficient atomic diffusion and elemental segregation.

[0024] In an embodiment, the melting treatment in step (2) is performed at a temperature of 1350-1500°C, for example, 1350°C, 1380°C, 1400°C, 1450°C, or 1500°C.

[0025] In an embodiment, the introduction specifically comprises pouring a liquid obtained from the melting treatment into a tubular container equipped with a nozzle, and applying pressure by air introduction to force the liquid to flow through the nozzle.

[0026] In an embodiment, a rotational speed of the water-cooled roller is 20-30 m/s, for example, 20 m/s, 22 m/s, 25 m/s, 28 m/s, or 30 m/s.

[0027] In an embodiment, the thermal crystallization treatment in step (3) is performed at a temperature of 550-650°C, for example, 550°C, 580°C, 600°C, 620°C, or 650°C.

[0028] In the present application, the crystal grains and particle sizes can be adjusted by controlling the crystallization temperature and time. If the temperature is too low, the grain size will be too small, and thereby to much paramagnetic particles will be generated, and also one signle particle may include multiple tiny grains, endowing the material with polycrystalline structure. If the temperature is too high, the grains will excessively grow and overly large particles will affect the magnetic properties.

[0029] In an embodiment, the thermal crystallization is performed for a period of 4-6 h, for example, 4 h, 4.5 h, 5 h, 5.5 h, or 6 h.

[0030] In an embodiment, the washing treatment in step (3) comprises placing a material obtained from the thermal crystallization into water, adding an acid and repeatedly dissolving until all non-magnetic materials in the material are dissolved and washed away, then settling a remaining material and repeatedly washing with alcohol.

[0031] In an embodiment, a drying treatment is performed after the washing.

[0032] In an embodiment, the drying treatment is performed at a temperature of 100-110°C, for example, 100°C, 102°C, 105°C, 108°C, or 110°C.

[0033] In a third aspect, the present application provides use of the magnetic nanoparticle as described in the first aspect. The magnetic nanoparticle is used in magnetic storage devices.

[0034] Compared with the related art, the present application has the following beneficial effects.

(1) During the preparation process of the magnetic nanoparticle in the present application, the addition of H_3BO_3 and $SrCl_2$ can assist to melt the mixture and also regulate the viscosity of the molten liquid, thereby affecting the thickness of the amorphous thin sheets and their cooling rate on the roller, and ultimately influencing the microstructure and properties of the material.

(2) The magnetic nanoparticle of the present application has a nanocrystalline structure (with an average particle size of less than 50 nm). Due to the nanocrystalline structure, coercivity of the material increases as the grain size decreases. In particular, when the grain size is less than 50 nm, adjacent grains will have strong exchange-coupling interaction, significantly enhancing the remanence of the material. Furthermore, the magnetic particle has a chemical composition represented by $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, possessing excellent magnetic properties, and supporting the development of magnetic storage devices towards high-density recording.

(3) The magnetic nanoparticle of the present application maintains an average particle size of 30 nm or less, exhibits an Ms of 77.3 emu/g or more, an Mr of 45.1 emu/g or more, and a Hcj of 4.15 kOe or more, and demonstrates excellent magnetic properties.

[0035] Other aspects will be appreciated upon reading and understanding the detailed description.

DETAILED DESCRIPTION

[0036] The technical solutions of the present application are further described below in terms of specific embodiments. It should be clear to those skilled in the art that the embodiments are merely used for a better understanding of the present application and should not be regarded as a specific limitation to the present application.

Example 1

[0037] This example provides a magnetic nanoparticle, and a preparation method for the magnetic nanoparticle is as follows.

(1) $SrCO_3$, $BaCO_3$, La_2O_3, Fe_2O_3, and Co_2O_3 were proportioned such that the atomic ratios of various elements satisfied $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, wherein x = 0, y = 0.3, and z = 0.25, and y/z = 1.2. Then, H_3BO_3 and $SrCl_2$ were added to the mixture by 25% and 10%, respectively, relative to the weight of the mixture. Then the mixture was placed into a ball mill jar, added with deionized water, and subjected to ball milling for 5 h, wherein a weight ratio of material to balls to water was 1:10:1.5. The mixed material, together with the solution, was poured into a container and then dried by heating at 110°C. The dried powder was placed into a muffle furnace and calcined at 1000°C for 2 h.

(2) The calcined product was placed into a crucible, heated to 1400°C to melt, and then poured into a tubular container equipped with a nozzle. Simultaneously, air was introduced to apply pressure, forcing the liquid to flow through the nozzle onto a water-cooled roller rotating at a high speed (25 m/s), so as to obtain thin sheets with an amorphous microstructure.

(3) The amorphous thin sheets were crystallized by heating at 600°C for 5 h. The crystallized thin sheets were then immersed in water, added with hydrochloric acid and repeatedly dissolved until the residual non-magnetic SrO, BaO, La_2O_3, Fe_2O_3, Co_2O_3, H_3BO_3, and $SrCl_2$ in the thin sheets were completely dissolved and washed away. The remaining product was settled, repeatedly washed with alcohol, and then dried at 110°C to obtain the magnetic nanoparticles. The magnetic powder had an average particle size of 23 nm, wherein particles with a particle size of 10-40 nm accounted for 95%, particles with a particle size of >40 nm accounted for 2%, and particles with a particle size of <10 nm accounted for 3%.

Example 2

[0038] This example provides a magnetic nanoparticle, and a preparation method for the magnetic nanoparticle is as follows.

(1) $SrCO_3$, $BaCO_3$, La_2O_3, Fe_2O_3, and Co_2O_3 were proportioned such that the atomic ratios of various elements satisfied $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, wherein x = 0, y = 0.3, and z = 0.25, and y/z = 1.2. Then, H_3BO_3 and $SrCl_2$ were added to the mixture by 15% and 20%, respectively, relative to the weight of the mixture. Then the mixture was placed into a ball mill jar, added with deionized water, and subjected to ball milling for 5 h, wherein a weight ratio of material to

balls to water was 1:10:1.5. The mixed material, together with the solution, was poured into a container and then dried by heating at 110°C. The dried powder was placed into a muffle furnace and calcined at 900°C for 3 h.

(2) The calcined product was placed into a crucible, heated to 1350°C to melt, and then poured into a tubular container equipped with a nozzle. Simultaneously, air was introduced to apply pressure, forcing the liquid to flow through the nozzle onto a water-cooled roller rotating at a high speed (20 m/s), so as to obtain thin sheets with an amorphous microstructure.

(3) The amorphous thin sheets were crystallized by heating at 550°C for 6 h. The crystallized thin sheets were then immersed in water, added with hydrochloric acid and repeatedly dissolved until the residual non-magnetic SrO, BaO, La_2O_3, Fe_2O_3, Co_2O_3, H_3BO_3, and $SrCl_2$ in the thin sheets were completely dissolved and washed away. The remaining product was settled, repeatedly washed with alcohol, and then dried at 110°C to obtain the magnetic nanoparticles. The magnetic powder had an average particle size of 28 nm, wherein particles with a particle size of 10-40 nm accounted for 93%, particles with a particle size of >40 nm accounted for 3%, and particles with a particle size of <10 nm accounted for 4%.

Example 3

[0039] This example provides a magnetic nanoparticle, and a preparation method for the magnetic nanoparticle is as follows.

(1) $SrCO_3$, $BaCO_3$, La_2O_3, Fe_2O_3, and Co_2O_3 were proportioned such that the atomic ratios of various elements satisfied $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, wherein x = 0, y = 0.3, and z = 0.2, and y/z = 1.5. Then, H_3BO_3 and $SrCl_2$ were added to the mixture by 15% and 10%, respectively, relative to the weight of the mixture. Then the mixture was placed into a ball mill jar, added with deionized water, and subjected to ball milling for 5 h, wherein a weight ratio of material to balls to water was 1:10:1.5. The mixed material, together with the solution, was poured into a container and then dried by heating at 110°C. The dried powder was placed into a muffle furnace and calcined at 1100°C for 1 h.

(2) The calcined product was placed into a crucible, heated to 1500°C to melt, and then poured into a tubular container equipped with a nozzle. Simultaneously, air was introduced to apply pressure, forcing the liquid to flow through the nozzle onto a water-cooled roller rotating at a high speed (30 m/s), so as to obtain thin sheets with an amorphous microstructure.

(3) The amorphous thin sheets were crystallized by heating at 650°C for 4 h. The crystallized thin sheets were then immersed in water, added with hydrochloric acid and repeatedly dissolved until the residual non-magnetic SrO, BaO, La_2O_3, Fe_2O_3, Co_2O_3, H_3BO_3, and $SrCl_2$ in the thin sheets were completely dissolved and washed away. The remaining product was settled, repeatedly washed with alcohol, and then dried at 110°C to obtain the magnetic nanoparticles. The magnetic powder had an average particle size of 23 nm, wherein particles with a particle size of 10-40 nm accounted for 96%, particles with a particle size of >40 nm accounted for 2%, and particles with a particle size of <10 nm accounted for 2%.

Example 4

[0040] This example differs from Example 1 only in that the additive amount of H_3BO_3 was 10% of the mixture. Other conditions and parameters were exactly the same as those in Example 1.

Example 5

[0041] This example differs from Example 1 only in that the additive amount of H_3BO_3 was 30% of the mixture. Other conditions and parameters were exactly the same as those in Example 1.

Example 6

[0042] This example differs from Example 1 only in that the additive amount of $SrCl_2$ was 5% of the mixture. Other conditions and parameters were exactly the same as those in Example 1.

Example 7

[0043] This example differs from Example 1 only in that the additive amount of $SrCl_2$ was 25% of the mixture. Other conditions and parameters were exactly the same as those in Example 1.

Comparative Example 1

[0044]

(1) $SrCO_3$, $BaCO_3$, La_2O_3, Fe_2O_3, and Co_2O_3 were proportioned such that the atomic ratios of various elements satisfied $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, wherein x = 0, y = 0.3, and z = 0.25, and y/z = 1.2. Then, H_3BO_3 and $SrCl_2$ were added to the mixture by 15% and 20%, respectively, relative to the weight of the mixture. Then the mixture was placed into a ball mill jar, added with deionized water, and subjected to ball milling for 5 h, wherein a weight ratio of material to balls to water was 1:10:1.5. The mixed material, together with the solution, was poured into a container and then dried by heating at 110°C. The dried powder was placed into a muffle furnace and calcined at 900°C for 3 h.

(2) The calcined material was immersed in water, added with hydrochloric acid and repeatedly dissolved until the residual non-magnetic SrO, BaO, La_2O_3, Fe_2O_3, Co_2O_3, H_3BO_3, and $SrCl_2$ in the material were completely dissolved and washed away. The remaining product was settled, repeatedly washed with alcohol, and then dried at 110°C to obtain the ferrite magnetic powder particles. The magnetic powder had an average particle size of 0.9 μm, and the size was significantly larger than the particle size of magnetic powder in Examples.

Comparative Example 2

[0045] This comparative example differs from Example 1 only in that $SrCl_2$ was not added. Other conditions and parameters were exactly the same as those in Example 1.

Comparative Example 3

[0046] This comparative example differs from Example 1 only in that x = 0, y = 0, and z = 0. Other conditions and parameters were exactly the same as those in Example 1.

Performance test

[0047] The magnetic materials obtained in Examples and Comparative Examples were analyzed by VSM to measure the saturation magnetization (Ms), remanence (Mr), and coercivity (Hcj). The test results are shown in Table 1.

Table 1

	Ms (emu/g)	Mr (emu/g)	Hcj (kOe)
Example 1	77.3	45.1	4.15
Example 2	77.9	45.7	4.33
Example 3	79.2	47.5	4.56
Example 4	74.5	44.7	4.02
Example 5	73.1	44.1	3.93
Example 6	74.7	44.9	4.59
Example 7	77.6	44.5	3.71
Comparative Example 1	66.5	36.7	3.21
Comparative Example 2	73.1	40.5	3.51
Comparative Example 3	75.2	39.3	3.56

[0048] As shown in Table 1, Examples 1-3, it can be seen that the magnetic nanoparticle of the present application maintains an average particle size of 30 nm or less, exhibits an Ms of 77.3 emu/g or more, an Mr of 45.1 emu/g or more, and a Hcj of 4.15 kOe or more, and demonstrates excellent magnetic properties.

[0049] From the comparison of Example 1 and Examples 4-5, it can be seen that, during the preparation process of the magnetic nanoparticle of the present application, the additive amount of H_3BO_3 affects the performance of the magnetic nanoparticle. When the additive amount of H_3BO_3 is controlled within 15-25% by mass of the mixture, the prepared magnetic nanoparticles exhibit good performance. If the additive amount of boric acid is too low, the melt viscosity becomes too high, resulting in poor dispersion on the roller and an unfavorable particle size distribution, leading to low Ms, Mr, and Hcj values. If the additive amount of boric acid is too high, the melt viscosity becomes too low, resulting in an excessive number of paramagnetic particles smaller than 10 nm in the magnetic powder, and the Ms, Mr, and Hcj values are also unsatisfactory.

[0050] From the comparison of Example 1 and Examples 6-7, it can be seen that, during the preparation process of the magnetic nanoparticle of the present application, the additive amount of $SrCl_2$ affects the performance of the magnetic nanoparticle. When the additive amount of $SrCl_2$ is controlled within 10-20% by mass of the mixture, the prepared magnetic nanoparticles exhibit good performance. If the additive amount of $SrCl_2$ is too low, the particles exhibit a relatively good Hcj, but the Ms and Mr values are low. If the additive amount of $SrCl_2$ is too high, the Ms and Mr values increase slightly, but the Hcj is low.

[0051] From the comparison of Example 1 and Comparative Example 1, it can be seen that the magnetic nanoparticle of the present application has a nanocrystalline structure (with an average particle size of less than 50 nm). Due to the nanocrystalline structure, coercivity of the material increases as the grain size decreases. In particular, when the grain size is less than 50 nm, adjacent grains will have strong exchange-coupling interaction, significantly enhancing the remanence of the material. Furthermore, the magnetic particle has a chemical composition represented by $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$, possessing excellent magnetic properties, and supporting the development of magnetic storage devices towards high-density recording.

[0052] From the comparison of Example 1 and Comparative Example 2, it can be seen that without $SrCl_2$, the Ms, Mr and Hcj of the material will all decrease.

[0053] From the comparison of Example 1 and Comparative Example 3, it can be seen that in the absence of Ba, La, and Co in the magnetic nanoparticles of the present application, the Ms, Mr, and Hcj of the material all decrease to varying degrees. Although the particle size is relatively small, the magnetic properties deteriorate, making the material unsuitable for high-density recording in magnetic storage devices.

[0054] The applicant declares that the above description is only specific embodiments of the present application, but the protection scope of the present application is not limited to this. Those skilled in the art should understand that any variations or substitutions that may be easily conceived by any person skilled in the art within the technical scope disclosed in the present application shall fall within the protection scope and disclosure scope of the present application.

Claims

1. A magnetic nanoparticle, wherein a chemical formula of the magnetic nanoparticle is $Sr_{1-x-y}Ba_xLa_yFe_{12-z}Co_zO_{19}$; wherein $0 \le x \le 0.3$, $0 \le y \le 0.3$, $0 \le z \le 0.25$, at least one of x, y and z is not equal to 0, and an average particle size of the magnetic nanoparticle is 20-40 nm.

2. The magnetic nanoparticle according to claim 1, wherein particles having a particle size of 10-40 nm account for 90% or more of the magnetic nanoparticle.

3. The magnetic nanoparticle according to claim 1 or 2, wherein particles having a particle size >40 nm account for 5% or less of the magnetic nanoparticle.

4. The magnetic nanoparticle according to any one of claims 1-3, wherein particles having a particle size <10 nm account for 5% or less of the magnetic nanoparticle.

5. The magnetic nanoparticle according to any one of claims 1-4, wherein in a case both y and z are not 0, y and z have a relationship: $1 \le y/z \le 1.5$.

6. A preparation method for the magnetic nanoparticle according to any one of claims 1-5, which comprises the following steps:

   (1) mixing a main material A and a main material B proportionally to obtain a mixed material, wherein the main material A comprises $SrCO_3$ and Fe_2O_3, and the main material B comprises any one or a combination of at least two of $BaCO_3$, La_2O_3, or Co_2O_3; and then mixing the mixed material with H_3BO_3 and $SrCl_2$, grinding and performing a calcination treatment;

(2) subjecting a material obtained from the calcination treatment to a melting treatment and introducing the material onto a water-cooled roller to obtain an amorphous thin sheet; and
(3) subjecting the amorphous thin sheet to a thermal crystallization treatment and then a washing treatment to obtain the magnetic nanoparticle.

7. The preparation method according to claim 6, wherein a mass of H_3BO_3 in step (1) is 15-25% of a mass of the mixed material.

8. The preparation method according to claim 6 or 7, wherein a mass of $SrCl_2$ is 10-20% of the mass of the mixed material.

9. The preparation method according to any one of claims 6-8, wherein a method for the grinding in step (1) comprises ball milling.

10. The preparation method according to any one of claims 6-9, wherein the calcination treatment is performed at a temperature of 900-1100°C;
optionally, the calcination treatment is performed for a period of 1-3 h.

11. The preparation method according to any one of claims 6-10, wherein the melting treatment in step (2) is performed at a temperature of 1350-1500°C.

12. The preparation method according to any one of claims 6-11, wherein the introduction specifically comprises pouring a liquid obtained from the melting treatment into a tubular container equipped with a nozzle, and applying pressure by air introduction to force the liquid to flow through the nozzle;
optionally, a rotational speed of the water-cooled roller is 20-30 m/s.

13. The preparation method according to any one of claims 6-12, wherein the thermal crystallization treatment in step (3) is performed at a temperature of 550-650°C;
optionally, the thermal crystallization treatment is performed for a period of 4-6 h.

14. The preparation method according to any one of claims 6-13, wherein the washing treatment in step (3) comprises placing a material obtained from the thermal crystallization into water, adding an acid and repeatedly dissolving until all non-magnetic materials in the material are dissolved and washed away, then settling a remaining material and repeatedly washing with alcohol;

optionally, a drying treatment is performed after the washing;
optionally, the drying treatment is performed at a temperature of 100-110°C.

15. Use of the magnetic nanoparticle according to any one of claims 1-5, wherein the magnetic nanoparticle is used in magnetic storage devices.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/073777

A. CLASSIFICATION OF SUBJECT MATTER

H01F 1/032(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)

IPC: 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)

CNABS; CNTXT; CNKI; VEN; ENTXT; IEEE: 永磁, 纳米, 颗粒, 粒子, 钡, 锶, 镧, H3BO3, SrCl2, Sr, Ba, La, magnetic, nm, nano+, particle, ferrite

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 101372417 A (QINGHAI INSTITUTE OF SALT LAKES, CHINESE ACADEMY OF SCIENCES) 25 February 2009 (2009-02-25) description, page 5, lines 16-30	1-5, 15
A	CN 106187144 A (CHENGDU UNIVERSITY OF INFORMATION TECHNOLOGY et al.) 07 December 2016 (2016-12-07) entire document	1-15
A	CN 108585053 A (WUHAN UNIVERSITY OF TECHNOLOGY) 28 September 2018 (2018-09-28) entire document	1-15
A	US 2016167978 A1 (OCEAN TEAM GROUP A/S) 16 June 2016 (2016-06-16) entire document	1-15

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
16 April 2024	**19 April 2024**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/073777

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 101372417 A	25 February 2009	None	
CN 106187144 A	07 December 2016	None	
CN 108585053 A	28 September 2018	None	
US 2016167978 A1	16 June 2016	AU 2014305109 A1	07 June 2018
		AU 2014305109 B2	23 January 2020
		CA 2955068 A1	12 February 2015
		CA 2955068 C	11 May 2021
		US 2016184871 A1	30 June 2016
		US 10144041 B2	04 December 2018
		EP 3030358 A1	15 June 2016
		EP 3030358 A4	19 April 2017
		EP 3030358 B1	29 September 2021
		WO 2015018419 A1	12 February 2015
		MX 2016001583 A	07 September 2016
		MX 362268 B	10 January 2019
		BR 112016002419 A2	01 August 2017

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Patent documents cited in the description

- CN 102076629 A **[0004]**
- CN 109836147 A **[0005]**