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(54) **ALUMINUM ALLOY AND PREPARATION METHOD THEREFOR**

(57) An aluminum alloy and a preparation method thereof are provided. In percentage by mass, the aluminum alloy includes: 8-11% of Si, 2-3% of Cu, 0.7-1.1% of Mg, 0.7-1.5% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.02-0.1% of Ti, 0.01-0.02% of Ga, 0.004-0.02% of B, 0-2% of Zn, and the balance of Al and less than 0.1% of other elements.

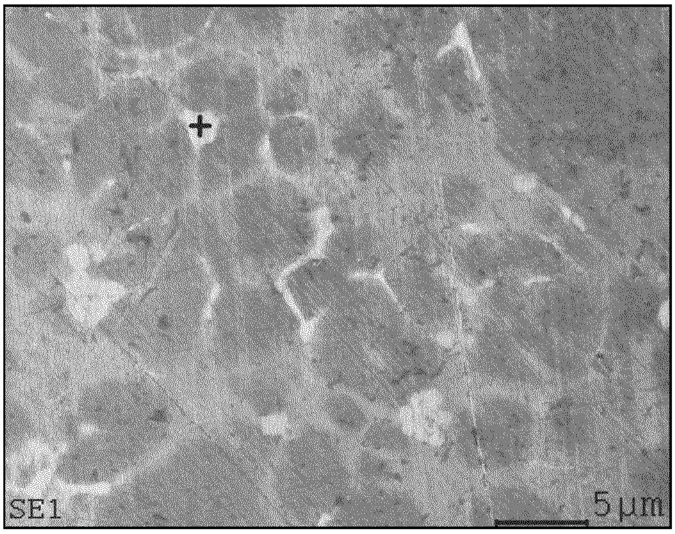

FIG. 2

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present disclosure claims priority to and benefits of Chinese Patent Application No. 201911174477.0 filed on November 26, 2019, which is incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates to the technical field of die-casting aluminum alloy, and more specifically, to an aluminum alloy and a preparation method thereof.

BACKGROUND

[0003] Die casting is a precision casting process that is characterized by forcing molten metal under high pressure into a metal mold cavity with a complex shape. Die castings are characterized by a very small dimensional tolerance and a high surface precision. In most cases, die castings can be directly assembled for use without turning.

[0004] Die casting of aluminum alloys has high requirements on their mechanical properties, such as yield strength, tensile strength, elongation, and melt fluidity. During die casting, existing die-casting aluminum alloy materials are highly dependent on the accuracy of control conditions for the formation process and are greatly affected by slight variation in process parameters, so that it is difficult to give consideration to the requirements of both the strength and elongation for die casting.

SUMMARY

[0005] To resolve the problem that it is difficult to give consideration to process requirements for existing die-casting aluminum alloy materials, the present disclosure discloses an aluminum alloy and a preparation method.

[0006] The technical solutions adopted by the present disclosure to resolve the foregoing technical problem are as follows:

[0007] According to an aspect, the present disclosure provides an aluminum alloy. In percentage by mass, the aluminum alloy includes: 8-11% of Si, 2-3% of Cu, 0.7-1.1% of Mg, 0.7-1.5% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.02-0.1% of Ti, 0.01-0.02% of Ga, 0.004-0.02% of B, 0-2% of Zn, and the balance of Al and less than 0.1% of other elements.

[0008] In some embodiments, in percentage by mass, the aluminum alloy includes: 9-10.8% of Si, 2.5-2.8% of Cu, 0.7-1.1% of Mg, 0.9-1.3% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.03-0.1% of Ti, 0.01-0.015% of Ga, 0.004-0.01% of B, 0-2% of Zn, and the balance of Al and less than 0.1% of other elements.

[0009] According to the aluminum alloy in some embodiments of the present disclosure, the mass ratio of Ti to B is (5-10):1.

[0010] According to the aluminum alloy in some embodiments of the present disclosure, the content of Ga in percentage by mass is greater than the content of Sr in percentage by mass.

[0011] According to the aluminum alloy in some embodiments of the present disclosure, the content of Si and the content of Cu satisfy the following condition: $Wt(Si) = (Wt(Cu) - 0.2) \times (3\text{-}5)$.

[0012] According to the aluminum alloy in some embodiments of the present disclosure, the content of Mn and the content of Cu satisfy the following condition: $Wt(Cu) = (Wt(Mn) - 0.3) \times (2.5\text{-}4)$.

[0013] According to the aluminum alloy in some embodiments of the present disclosure, the other elements include one or more of Zr, Ni, Ce, Sc, and Er.

[0014] According to another aspect, the present disclosure provides a method for preparing the foregoing aluminum alloy. The method includes the following steps: weighing out various raw materials in required proportions based on proportions of all elements in the aluminum alloy, melting the raw materials in a melting furnace to obtain a molten metal, and subjecting the molten metal to slag removal and refining and degassing, and then casting, to obtain an aluminum alloy ingot.

[0015] According to the method in some embodiments of the present disclosure, the slag removal includes adding a slag remover into the molten metal, the slag remover including one or more of an aluminum alloy slag remover agent NF-1 and an aluminum alloy slag-removal agent DSG.

[0016] According to the method in some embodiments of the present disclosure, the refining is carried out at 700-710°C, and the refining includes adding a refining agent into the molten metal, the refining agent including one or more of hexafluoroethane and an aluminum refining agent ZS-AJ01C.

[0017] According to the method in some embodiments of the present disclosure, the method further includes die casting the aluminum alloy ingot for formation.

[0018] According to the method in some embodiments of the present disclosure, the method includes carrying out artificial aging on the die-cast aluminum alloy.

[0019] According to the method in some embodiments of the present disclosure, the artificial aging is carried out at 100-200°C for 1.5-3 h.

[0020] By adjusting proportions of all strengthening elements in the aluminum alloy, the aluminum alloy provided in the present disclosure has high yield strength and thermal conductivity, and ensures good elongation without sacrificing the strength. For the aluminum alloy in the present disclosure, the yield strength is about 240-260 MPa, the tensile strength is about 380-410 MPa, the elongation is 3-6%, and the thermal conductivity is about 130-142 W/(k•m). In addition, the aluminum alloy material has low process requirements, and has good process adaptability in die casting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a metallographic image of an aluminum alloy prepared in Example 1 of the present disclosure;
FIG. 2 is an SEM image of an aluminum alloy prepared in Example 1 of the present disclosure; and
FIG. 3 is an SEM-diffraction spectrum of the area marked with the cross in FIG. 2.

DETAILED DESCRIPTION

[0022] To make the technical problems to be resolved by the present disclosure, technical solutions, and beneficial effects more comprehensible, the following further describes the present disclosure in detail with reference to the accompanying drawings and embodiments. It should be understood that the specific embodiments described herein are merely used for explaining the present disclosure instead of limiting the present disclosure.

[0023] According to an aspect, the present disclosure provides an aluminum alloy. In percentage by mass, the aluminum alloy includes: 8-11% of Si, 2-3% of Cu, 0.7-1.1% of Mg, 0.7-1.5% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.02-0.1% of Ti, 0.01-0.02% of Ga, 0.004-0.02% of B, 0-2% of Zn, and the balance of Al and less than 0.1% of other elements.

[0024] By adjusting proportions of all strengthening elements in the aluminum alloy, the aluminum alloy provided in the present disclosure has high yield strength and thermal conductivity, and ensures good elongation without sacrificing the strength. For the aluminum alloy in the present disclosure, the yield strength is about 240-260 MPa (for example, 240 MPa, 242 MPa, 245 MPa, 248 MPa, 250 MPa, 251 MPa, 253 MPa, 255 MPa, 258 MPa, or 260 MPa), the tensile strength is about 380-410 MPa (for example, 380 MPa, 385 MPa, 390 MPa, 395 MPa, 400 MPa, 405 MPa, or 410 MPa), the elongation is about 3-6% (for example, 3%, 3.5%, 4%, 4.5%, 5%, 5.5%, or 6%), and the thermal conductivity is about 130-142 W/(k•m) (for example, 130 W/(k•m), 132 W/(k•m), 135 W/(k•m), 138 W/(k•m), 140 W/(k•m), or 142 W/(k•m)). In addition, the aluminum alloy material has low process requirements, and has good process adaptability in die casting.

[0025] In some embodiments, in percentage by mass, the aluminum alloy includes: 9-10.8% of Si, 2.5-2.8% of Cu, 0.7-1.1% of Mg, 0.9-1.3% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.03-0.1% of Ti, 0.01-0.015% of Ga, 0.004-0.01% of B, 0-2% of Zn, and the balance of Al and less than 0.1% of other elements.

[0026] In some other embodiments, the aluminum alloy is composed of the following components in percentage by mass: 9-10.8% of Si, 2.5-2.8% of Cu, 0.7-1.1% of Mg, 0.9-1.3% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.03-0.1% of Ti, 0.01-0.015% of Ga, 0.004-0.01% of B, 0-2% of Zn, and the balance of Al.

[0027] In some embodiments, the content of Si is 9%, 9.8%, 10%, 10.5%, or 10.8%, the content of Cu is 2.5%, 2.6%, or 2.8%, the content of Mg is 0.7%, 0.8%, 0.9%, 1%, or 1.1%, the content of Mn is 0.9%, 1%, 1.1%, 1.2%, or 1.3%, the content of Sr is 0.01%, 0.013%, 0.015%, or 0.02%, the content of Cr is 0.01%, 0.013%, or 0.015%, the content of Fe is 0, 0.1%, 0.2%, 0.3%, or 0.4%, the content of Ti is 0.03%, 0.04%, 0.05%, or 0.06%, the content of Ga is 0.01%, 0.013%, or 0.015%, the content of B is 0.004%, 0.005%, 0.006%, 0.007%, or 0.008%, and the content of Zn is 0, 0.3%, 0.6%, 0.9%, 1.3%, 1.7%, or 2%.

[0028] In the materials involved in the present disclosure, Si and Al form eutectic Si and primary Si. Dispersed primary Si and fine α-Al grains are formed under the effect of Sr, increasing the strength and fluidity of the aluminum alloy.

[0029] According to the aluminum alloy in some embodiments of the present disclosure, Cu is solubilized into Al to form a solid solution phase, and precipitated Al_2Cu strengthening phase is dispersed on the grain boundary.

[0030] According to the aluminum alloy in some embodiments of the present disclosure, with the increase of Mg content, the yield strength increases and the elongation decreases gradually. When the Mg content is more than 0.7%, a dispersion strengthening phase (with a particle size below 10 μm) mainly composed of Al_2Cu is precipitated. With the increase of the Mg content, the area occupied by this phase in the aluminum alloy gradually increases. When the Mg content is more than 1.1%, the grains of this phase in the aluminum alloy will increase sharply, and the elongation will decrease greatly.

[0031] According to the aluminum alloy in some embodiments of the present disclosure, Mn and Cr are solubilized into the aluminum alloy matrix to inhibit the grain growth of primary Si and α-Al, so that the primary Si is dispersed among grains.

[0032] According to the aluminum alloy in some embodiments of the present disclosure, Ti and B are dispersed among the grains, so that primary Si can uniformly distribute into α-Al, which greatly inhibits the growth of α-Al (the particle size of α-Al is reduced by one-third compared with that in the aluminum alloy without the addition of Ti and B).

[0033] According to the aluminum alloy in some embodiments of the present disclosure, an excessively high content of Zn is easily solubilized into the aluminum alloy, thereby affecting the solubilization of Cu, Mn, and Mg, which will affect the precipitated second phase and greatly change the thermal conductivity of the aluminum alloy.

[0034] According to the aluminum alloy in some embodiments of the present disclosure, an excessively high content of Fe will make the aluminum alloy brittle and thus affect the elongation of the aluminum alloy.

[0035] The mechanical properties, thermal conductivity, and elongation of the aluminum alloy are the result of the combined effect of the foregoing elements. Any element that deviates from the scope provided by the present disclosure deviates from the disclosure intent of the present disclosure, resulting in a reduction in mechanical properties, thermal conductivity, or elongation of the aluminum alloy, thereby detrimental to the use of the aluminum alloy as a die-casting material.

[0036] According to the aluminum alloy in some embodiments of the present disclosure, the mass ratio of Ti to B is (5-10):1, for example 5:1, 6:1, 7:1, 8:1, 9:1, or 10:1. It was found through further experiments that Ti and B in this ratio ensure the high strength and thermal conductivity of the aluminum alloy. The reason is that Ti within this content range is uniformly distributed around the eutectic Si, increasing the strength of the aluminum alloy, and the addition of B in this ratio ensures the high strength with good thermal conductivity.

[0037] According to the aluminum alloy in some embodiments of the present disclosure, the content of Ga in percentage by mass is greater than the content of Sr in percentage by mass.

[0038] According to the aluminum alloy in some embodiments of the present disclosure, the content of Si and the content of Cu satisfy the following condition: Wt(Si) = (Wt(Cu) - 0.2) $\times$ (3-5). Under this condition, the formed eutectic Si and Al_2Cu inhibit the growth of the α-Al grains, which become small in diameter.

[0039] According to the aluminum alloy in some embodiments of the present disclosure, the content of Mn and the content of Cu satisfy the following condition: Wt(Cu) = (Wt(Mn) - 0.3) $\times$ (2.5-4). Under this condition, through the induction of Ti-B, Si, Cu, and Mn form a new spherical Si_7Mn_6Cu phase uniformly distributed at the grain boundary, greatly increasing the strength and elongation of the aluminum alloy.

[0040] Under the foregoing conditions, a high-strength α solid solution is formed in the aluminum alloy. In this case, Ti, Ga, and B form a fine strengthening phase evenly distributed between the eutectic Si and α solid solution, which greatly increases the yield strength of the aluminum alloy while ensuring the elongation of the aluminum alloy.

[0041] According to the aluminum alloy in some embodiments of the present disclosure, the other elements include one or more of Zr, Ni, Ce, Sc, and Er. Zr, Ni, Ce, Sc, and Er are harmful elements that need to be reduced as impurities from the aluminum alloy as much as possible. In some specific embodiments, the aluminum alloy does not include the other elements.

[0042] For example, as an impurity element, the solubilization of Ni into α solid solution of the alloy will have a greater impact on Cu, Mn, and Mg, resulting in severe segregation, thereby making the aluminum alloy brittle. Zr, Ce, Er, and Sc form a second phase that cannot be solubilized in the aluminum alloy, so that the distribution of composition of the aluminum alloy is uneven, making the aluminum alloy brittle.

[0043] According to another aspect, the present disclosure provides a method for preparing the foregoing aluminum alloy. The method includes the following steps: weighing out various raw materials in required proportions based on proportions of all elements in the aluminum alloy, melting the raw materials in a melting furnace to obtain a molten metal, and subjecting the molten metal to slag removal and refining and degassing, and then casting, to obtain an aluminum alloy ingot. The raw materials include an Al-containing material, a Si-containing material, a Mgcontaining material, a Fe-containing material, a Sr-containing material, a Ti-containing material, a B-containing material, a Cu-containing material, a Mn-containing material, a Ga-containing material, a Cr-containing material, and a Zn-containing material. The raw materials are selected from alloys or elements containing the foregoing elements.

[0044] In some embodiments, the slag removal includes adding a slag remover into the molten metal, the slag remover including one or more of an aluminum alloy slag remover agent NF-1 and an aluminum alloy slag-removal agent DSG.

[0045] In some embodiments, the refining is carried out at 700-710°C (specifically 700°C, 701°C, 702°C, 703°C, 704°C, 705°C, 706°C, 707°C, 708°C, 709°C, or 710°C). The refining includes adding a refining agent into the molten metal and stirring. The refining agent includes one or more of hexafluoroethane and an aluminum refining agent ZS-AJ01C.

[0046] According to the method in some embodiments of the present disclosure, the method further includes die casting the aluminum alloy ingot for formation.

[0047] In some embodiments, the casting is carried out at 680-720°C (for example 680°C, 690°C, 700°C, 710°C, or

720°C).

[0048] In some embodiments, artificial aging is carried out on the die-cast aluminum alloy at 100-200°C (for example 100°C, 110°C, 120°C, 130°C, 140°C, 150°C, 160°C, 170°C, 180°C, 190°C, or 200°C) for 1.5-3 h (for example 1.5 h, 2 h, 2.5 h, or 3 h).

[0049] The aluminum alloy is precipitation-hardened by the artificial aging, and the precipitation hardening effect can be observed by testing the mechanical properties of the aluminum alloy. The precipitation of Al_2Cu phase is accelerated at 100-200°C, increasing the strength of the grain boundary, thereby increasing the strength and hardness of the alloy.

[0050] The present disclosure is further described through the following examples.

Table 1

	Si	Cu	Mn	Mg	Ti	Sr	Cr	Fe	Ga	B	Zn	Inevitable impurities and Al
Example 1	9.5	2.7	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 2	10	2.7	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 3	10.5	2.7	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 4	10	2.5	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 5	10	2.6	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 6	10	2.8	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 7	10	2.5	0.9	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 9	10	2.5	1.1	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 10	10	2.5	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 11	10.5	2.5	0.95	0.8	0.04	0.013	0.012	0	0.014	0.005	0	
Example 12	10.5	2.5	1	0.9	0.04	0.013	0.012	0	0.014	0.005	0	
Example 13	10.5	2.5	0.95	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 14	10.5	2.5	1.1	0.8	0.03	0.013	0.012	0	0.014	0.004	0	
Example 15	10.5	2.5	1.1	0.8	0.07	0.013	0.012	0	0.014	0.005	0	
Example 16	10.5	2.5	1.1	0.8	0.08	0.013	0.012	0	0.014	0.005	0	
Example 17	10.5	2.5	1.1	0.8	0.05	0.013	0.012	0	0.014	0.005	0	
Example 18	10.5	2.5	1.1	0.8	0.03	0.013	0.012	0	0.014	0.005	0	
Example 19	10.5	2.5	1.1	0.8	0.03	0.013	0.01	0	0.014	0.005	0	
Example 20	10.5	2.5	1.1	0.8	0.03	0.013	0.015	0.1	0.014	0.005	0	
Example 21	10.5	2.5	1.1	0.8	0.05	0.013	0.012	0.2	0.014	0.005	0.5	
Example 22	10.5	2.5	1.1	0.8	0.05	0.013	0.012	0.3	0.014	0.005	1	
Example 23	8.5	2.7	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 24	10	2.2	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 25	10	2.8	1.4	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 27	10.5	2.5	1.1	0.8	0.03	0.015	0.012	0	0.02	0.005	0	

(continued)

	Si	Cu	Mn	Mg	Ti	Sr	Cr	Fe	Ga	B	Zn	Inevitable impurities and Al
Example 28	10.5	2.5	1.1	1	0.02	0.013	0.012	0	0.014	0.005	0	
Example 29	10.5	2.5	1.1	1	0.1	0.013	0.012	0	0.014	0.005	0	
Example 30	10.5	2.5	1.1	1	0.04	0.013	0.012	0	0.01	0.005	0	
Example 31	10.5	2	1.1	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 32	8	3	1.1	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 33	10.5	2.5	0.8	1	0.04	0.013	0.012	0	0.014	0.005	0	
Example 34	10.5	2.5	1.5	1	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 1	7.8	2.7	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 2	12	2.7	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 3	10	1.8	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 4	10	3.5	1.2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 5	10	2.5	0.5	1	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 6	10	2.5	2	1	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 7	10	2.5	1	1	0.04	0.013	0.012	0	0	0.005	0	
Comparative Example 8	10.5	2.5	1	0.5	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 9	10.5	2.5	1	1.5	0.04	0.013	0.012	0	0.014	0.005	0	
Comparative Example 10	10.5	2.5	1	0.7	0.15	0.013	0.012	0	0.014	0.005	0	
Comparative Example 11	10.5	2.5	1	0.7	0.03	0.005	0.012	0	0.01	0.005	0	
Comparative Example 12	10.5	2.5	1	0.7	0.03	0.013	0	0	0.014	0.005	0	
Comparative Example 13	10.5	2.5	1.1	0.7	0.05	0.013	0.012	0	0.014	0.005	2.3	
Note: Each composition in Table 1 is in percentage by weight, and the total weight of inevitable impurity elements is less than 0.1%.												

Example 1

[0051] This example is used to describe the aluminum alloy and the preparation method thereof in the present disclosure, including the following steps:
[0052] As shown in Table 1, the components of the aluminum alloy in percentage by mass include: 9.5% of Si, 2.7% of Cu, 1% of Mg, 1.2% of Mn, 0.013% of Sr, 0.012% of Cr, 0% of Fe, 0.04% of Ti, 0.014% of Ga, 0.005% of B, 0% of Zn, and the balance of Al and less than 0.1% of inevitable impurities. The required mass of intermediate alloys or metal elements was calculated based on the mass of the foregoing components of the aluminum alloy, the intermediate alloys or metal elements were melted in a melting furnace to obtain a molten metal, and the molten metal was subjected to slag removal by using a slag remover and was subjected to refining and degassing by using a refining agent at 700-710°C, and then was cast to obtain an aluminum alloy ingot. The aluminum alloy ingot was naturally aged for 7 d to obtain an aluminum alloy.

Examples 2-34

[0053] Examples 2-34 are used to describe the aluminum alloy and the preparation method thereof in the present disclosure, including most of the steps in Example 1, and the difference is as follows:
[0054] The compositions of the aluminum alloy in Examples 2-34 are shown in Table 1, the required mass of intermediate alloys or metal elements was calculated based on the mass of the foregoing components of the aluminum alloy, the intermediate alloys or metal elements were melted in a melting furnace to obtain a molten metal, and the molten metal was subjected to slag removal by using a slag remover and was subjected to refining and degassing by using a refining agent at 700-710°C, and then was cast to obtain an aluminum alloy ingot. The aluminum alloy ingot was naturally aged for 7 d to obtain an aluminum alloy.

Comparative Example 1

[0055] This comparative example is used to compare with the aluminum alloy and the preparation method thereof in the present disclosure, including the following steps:
[0056] As shown in Table 1, the components of the aluminum alloy in percentage by mass include: 7.8% of Si, 2.7% of Cu, 1% of Mg, 1.2% of Mn, 0.013% of Sr, 0.012% of Cr, 0% of Fe, 0.04% of Ti, 0.014% of Ga, 0.005% of B, 0% of Zn, and the balance of Al and less than 0.1% of inevitable impurities. The required mass of intermediate alloys or metal elements was calculated based on the mass of the foregoing components of the aluminum alloy, the intermediate alloys or metal elements were melted in a melting furnace to obtain a molten metal, and the molten metal was subjected to slag removal by using a slag remover and was subjected to refining and degassing by using a refining agent at 700-710°C, and then was cast to obtain an aluminum alloy ingot. The aluminum alloy ingot was naturally aged for 7 d to obtain an aluminum alloy.

Comparative Examples 2-13

[0057] Comparative Examples 2-13 are used to compare with the aluminum alloy and the preparation method thereof in the present disclosure, including most of the steps in Example 1, and the difference is as follows:
The compositions of the aluminum alloy in Comparative Examples 2-13 are shown in Table 1, the required mass of intermediate alloys or metal elements was calculated based on the mass of the foregoing components of the aluminum alloy, the intermediate alloys or metal elements were melted in a melting furnace to obtain a molten metal, and the molten metal was subjected to slag removal by using a slag remover and was subjected to refining and degassing by using a refining agent at 700-710°C, and then was cast to obtain an aluminum alloy ingot. The aluminum alloy ingot was naturally aged for 7 d to obtain an aluminum alloy.

Performance Test

[0058] The aluminum alloy prepared in Example 1 was imaged by using a scanning electron microscope (SEM) to obtain SEM images shown in FIG. 1 and FIG. 2. The area marked with the cross in FIG. 2 was subjected to diffraction to obtain an SEM-diffraction spectrum shown in FIG. 3. The EDS spectrum was analyzed to obtain the composition of the area marked with the cross in FIG. 2, as shown in Table 2.

Table 2

Element	wt%	at%
CK	02.52	05.94
OK	01.42	02.52
MgK	00.81	00.95
AlK	71.05	74.60
SiK	07.69	07.76
MnK	12.40	06.39
CuK	04.11	01.83
Matrix	Correction	ZAF

[0059] It can be learned that a spherical Si_7Mn_6Cu phase is formed herein in FIG. 2 and is evenly distributed at the grain boundary, increasing the strength and elongation of the aluminum alloy.

[0060] The aluminum alloys prepared in Examples 1-34 and Comparative Examples 1-13 were subjected to the following performance tests:

Tensile test: The yield strength, tensile strength, and elongation were tested according to GBT 228.1-2010 Metallic Materials Tensile Testing Part 1: Room Temperature Test Methods.

[0061] Thermal conductivity test: A thermally conductive ingot wafer of ϕ 12.7×3 mm was prepared as a to-be-tested piece, and graphite was evenly sprayed on both sides of the to-be-tested piece to form a coating. The coated piece was tested by using a laser thermal conductivity instrument. The laser thermal conductivity test was carried out in accordance with ASTM E1461 Standard Test Method for Thermal Diffusivity by the Flash Method.

[0062] The test results are shown in Table 3.

Table 3

	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Die-casting formability	Thermal conductivity of ingot W/(m•k)
Example 1	243	415	5.12	Excellent	137
Example 2	251	418	4.83	Excellent	138
Example 3	255	411	4.53	Excellent	135
Example 4	248	410	4.54	Excellent	132
Example 5	249	413	4.2	Excellent	134
Example 6	252	410	4.48	Excellent	133
Example 7	248	412	4.52	Excellent	138
Example 8	249	418	5.03	Excellent	136
Example 9	251	417	4.93	Excellent	134
Example 10	253	418	4.28	Excellent	132
Example 11	243	418	5.21	Excellent	138
Example 12	249	418	5.02	Excellent	136
Example 13	254	415	4.35	Excellent	135
Example 14	245	413	4.2	Excellent	135
Example 15	251	410	4.35	Excellent	133
Example 16	250	407	4.38	Excellent	135
Example 17	251	421	5.02	Excellent	133
Example 18	245	411	4.82	Excellent	138

(continued)

	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Die-casting formability	Thermal conductivity of ingot W/(m•k)
Example 19	245	410	4.53	Excellent	136
Example 20	245	413	4.82	Excellent	135
Example 21	247	412	4.35	Excellent	133
Example 22	252	410	4.32	Excellent	132
Example 23	242	403	4.5	Good	135
Example 24	241	405	4.68	Good	136
Example 25	252	401	3.52	Good	130
Example 26	242	398	4.25	Excellent	137
Example 27	243	405	4.52	Excellent	134
Example 28	241	403	4.32	Excellent	132
Example 29	241	405	4.35	Excellent	130
Example 30	251	395	3.8	Excellent	131
Example 31	242	395	3.2	Excellent	131
Example 32	241	385	3.1	Good	131
Example 33	241	386	3.92	Good	132
Example 34	252	392	3.53	Excellent	130
Comparative Example 1	241	373	2.8	Average	121
Comparative Example 2	252	382	2.3	Good	118
Comparative Example 3	235	375	3.1	Good	118
Comparative Example 4	252	379	2.23	Average	115
Comparative Example 5	235	381	2.82	Average	127
Comparative Example 6	261	370	2.31	Average	115
Comparative Example 7	241	373	2.85	Good	123
Comparative Example 8	223	372	3.5	Good	135
Comparative Example 9	261	371	2.22	Average	115
Comparative Example 10	236	370	3.38	Good	121
Comparative Example 11	238	372	3.26	Good	123
Comparative Example 12	237	369	3.17	Good	125

(continued)

	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Die-casting formability	Thermal conductivity of ingot W/(m•k)
Comparative Example 13	237	372	3.18	Good	123

[0063] It can be learned by comparing the test results of Examples 1-34 with the test results of Comparative Examples 1-13 that, the mechanical strength, thermal conductivity, elongation, and die-casting formability of the aluminum alloy provided in the present disclosure is better than the aluminum alloys beyond the element range provided in the present disclosure. And the aluminum alloy provided in the present disclosure can meet the requirements of the die-casting process.

[0064] The foregoing descriptions are merely embodiments of the present disclosure, but are not intended to limit the present disclosure. Any modification, equivalent replacement, or improvement made within the spirit and principle of the present disclosure shall fall within the protection scope of the present disclosure.

Claims

1. An aluminum alloy, in percentage by mass, the aluminum alloy comprising:
8-11% of Si, 2-3% of Cu, 0.7-1.1% of Mg, 0.7-1.5% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.02-0.1% of Ti, 0.01-0.02% of Ga, 0.004-0.02% of B, 0-2% of Zn, and the balance of Al and less than 0.1% of other elements.

2. The aluminum alloy according to claim 1, in percentage by mass, the aluminum alloy comprising:
9-10.8% of Si, 2.5-2.8% of Cu, 0.7-1.1% of Mg, 0.9-1.3% of Mn, 0.01-0.015% of Sr, 0.01-0.015% of Cr, 0-0.4% of Fe, 0.03-0.1% of Ti, 0.01-0.015% of Ga, 0.004-0.01% of B, 0-2% of Zn, and the balance of Al and less than 0.1% of other elements.

3. The aluminum alloy according to claim 1 or 2, wherein in the aluminum alloy, a mass ratio of Ti to B is (5-10):1.

4. The aluminum alloy according to any one of claims 1 to 3, wherein in the aluminum alloy, a content of Ga in percentage by mass is greater than a content of Sr in percentage by mass.

5. The aluminum alloy according to any one of claims 1 to 4, wherein in the aluminum alloy, a content of Si and a content of Cu satisfy the following condition:

$$Wt(Si) = (Wt(Cu) - 0.2) \times (3\text{-}5).$$

6. The aluminum alloy according to any one of claims 1 to 5, wherein in the aluminum alloy, a content of Mn and a content of Cu satisfy the following condition:

$$Wt(Cu) = (Wt(Mn) - 0.3) \times (2.5\text{-}4).$$

7. The aluminum alloy according to any one of claims 1 to 6, wherein the other elements comprise one or more of Zr, Ni, Ce, Sc, and Er.

8. A method for preparing the aluminum alloy according to any one of claims 1 to 7, comprising the following steps:
weighing out various raw materials in required proportions based on proportions of all elements in the aluminum alloy, melting the raw materials in a melting furnace to obtain a molten metal, and subjecting the molten metal to slag removal and refining and degassing, and then casting, to obtain an aluminum alloy ingot.

9. The method according to claim 8, wherein the slag removal comprises adding a slag remover into the molten metal, the slag remover comprising one or more of an aluminum alloy slag remover agent NF-1 and an aluminum alloy

slag-removal agent DSG.

10. The method according to claim 8 or 9, wherein the refining is carried out at 700-710°C, and the refining comprises adding a refining agent into the molten metal, the refining agent comprising one or more of hexafluoroethane and an aluminum refining agent ZS-AJ01C.

11. The method according to any one of claims 8 to 10, further comprising:
die casting the aluminum alloy ingot for formation.

12. The method according to claim 11, comprising carrying out artificial aging on the die-cast aluminum alloy.

13. The method according to claim 12, wherein the artificial aging is carried out at 100-200°C for 1.5-3 h.

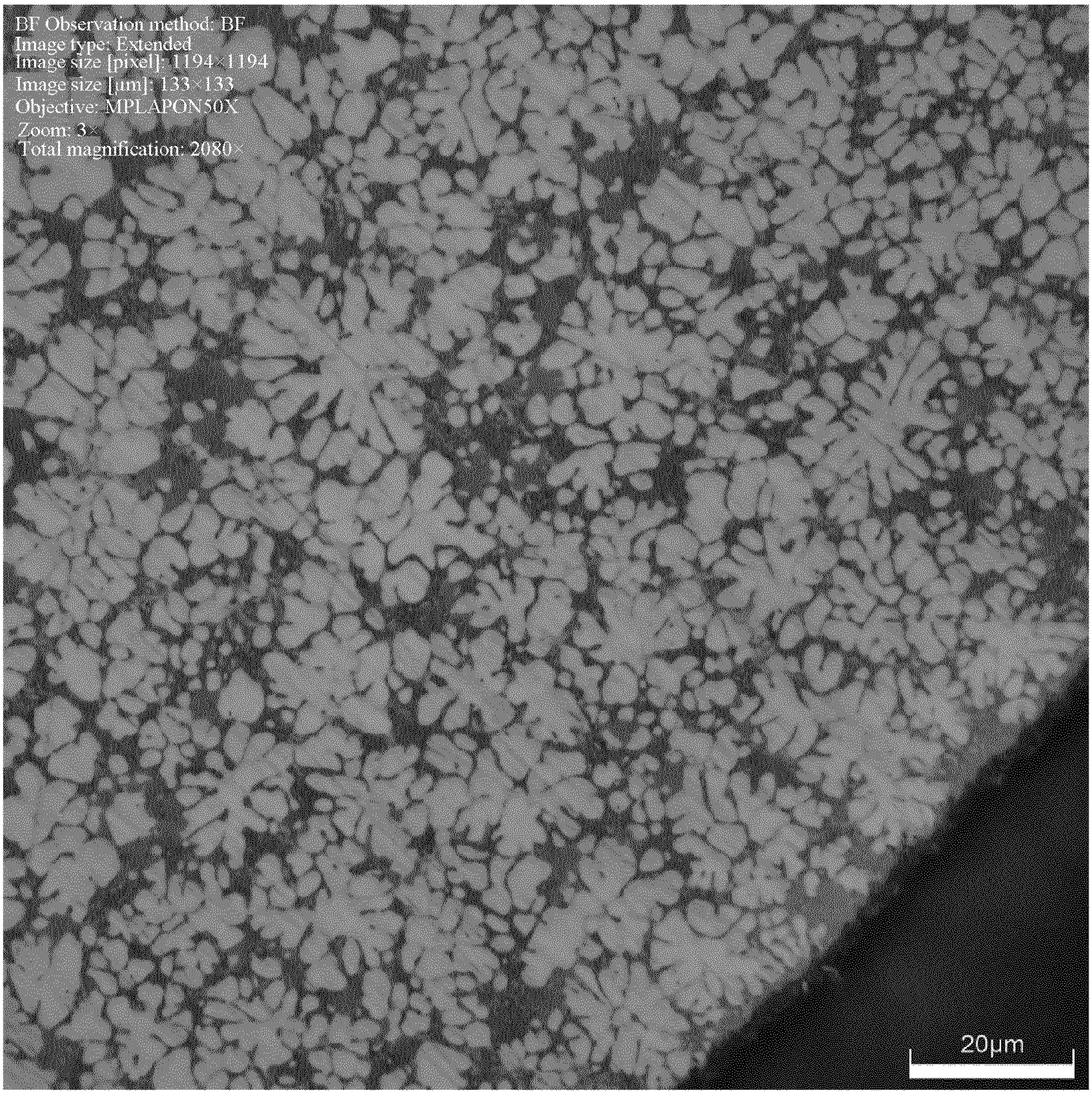
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Image type: Extended
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Zoom: 3×
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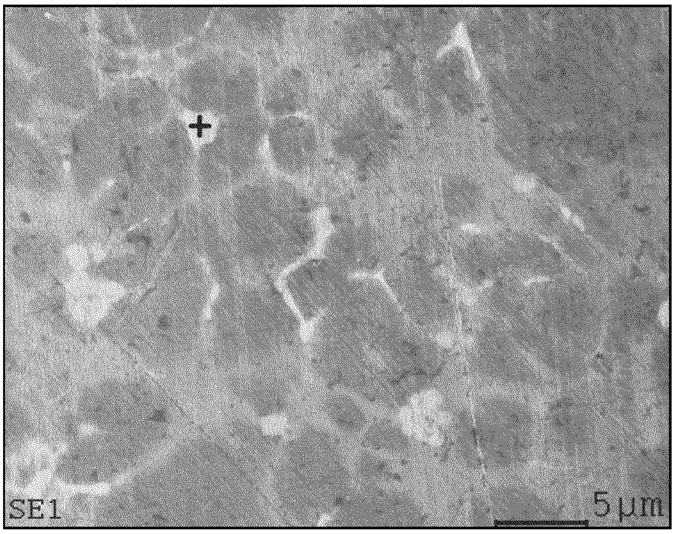
FIG. 1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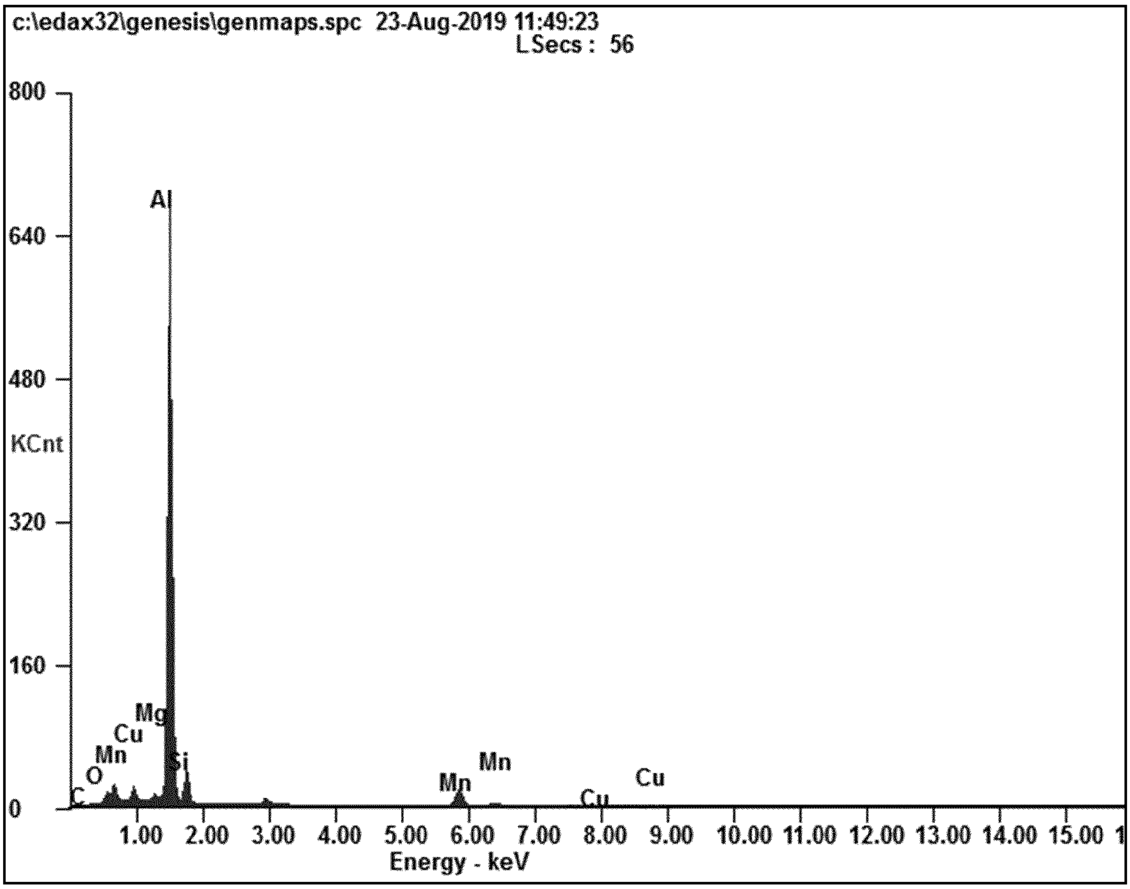
5 µm

FIG. 2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640
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O
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Mn
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Cu
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00 13.00 14.00 15.00
Energy - keV

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/081455

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/02(2006.01)i； C22C 1/02(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)

C22C

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)

DWPI, CNABS, CNKI, VEN: 铝合金, 硅, 铜, 镁, 锰, 锶, 铬, 钛, 镓, 硼, 精炼, Al alloy, Si, silicon, Cu, copper, Mg, magnesium, Mn, manganese, Sr, strontiam, Cr, chromium, Ti, titanium, Ga, gallium, B, boron, refining

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 106119626 A (SUZHOU MEIKE KASI AUTOMOTIVE TECHNOLOGY CO., LTD.) 16 November 2016 (2016-11-16) claims 1-8	1-13
Y	CN 1537961 A (RHEINFELDEN ALUMINIURN GMBH) 20 October 2004 (2004-10-20) claim 1	1-13
A	CN 1410572 A (XINAN ALUMINIUM INDUSTRY (GROUP) CO. LTD.) 16 April 2003 (2003-04-16) entire document	1-13
A	JP S59100249 A (SHOWA ALUMINIUM CO., LTD.) 09 June 1984 (1984-06-09) entire document	1-3

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

* Special categories of cited documents:
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- "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
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- "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
13 August 2020	**21 August 2020**

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Facsimile No. **(86-10)62019451**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/081455

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	106119626	A	16 November 2016	None			
CN	1537961	A	20 October 2004	BR	PI0400079	B1	01 November 2011
				EP	1443122	A1	04 August 2004
				SI	EP1443122	T1	31 December 2009
				KR	101205169	B1	27 November 2012
				JP	2004225160	A	12 August 2004
				CA	2455426	C	13 December 2011
				DE	502004009801	D1	10 September 2009
				KR	20040068021	A	30 July 2004
				BR	PI0400079	A	28 December 2004
				NO	20040286	L	26 July 2004
				DK	1443122	T3	30 November 2009
				NO	20040286	A	26 July 2004
				SI	1443122	T1	31 December 2009
				PT	1443122	E	20 October 2009
				EP	1443122	B1	29 July 2009
				ES	2330332	T3	09 December 2009
				AT	437972	T	15 August 2009
				US	2004170523	A1	02 September 2004
				JP	4970709	B2	11 July 2012
				CA	2455426	A1	23 July 2004
				US	6824737	B2	30 November 2004
				NO	337610	B1	09 May 2016
				CN	1320144	C	06 June 2007
				BR	0400079	A	28 December 2004
CN	1410572	A	16 April 2003	CN	1250758	C	12 April 2006
JP	S59100249	A	09 June 1984	JP	H0319291	B2	14 March 1991

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- CN 201911174477 **[0001]**