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(54) DIE-CASTING ALUMINUM ALLOY, ALUMINUM ALLOY DIE-CAST MATERIAL, AND METHOD FOR MANUFACTURING SAME

(57) The present invention relates to a die-cast aluminum alloy, an aluminum alloy die-cast material, and a method for manufacturing the same for a large heat sink with excellent thermal conductivity and castability and a tool/container in which heat dissipation properties are required. The die-cast aluminum alloy comprises Si: 9.5 % by mass or more and 12 % by mass or less, Fe: 0.3 % by mass or more and 1.0 % by mass or less, and Mg: 0.15 % by mass or more and 0.35 % by mass or less, the remainder being Al and unavoidable impurities.

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Description

TECHNICAL FIELD

[0001] The present invention belongs to the technical field of alloy materials, and relates to a die-cast aluminum alloy with excellent thermal conductivity and castability, and relates to a die-cast aluminum alloy for a large heat sink and a tool/container in which heat dissipation properties are required, an aluminum alloy die-cast material, and a method for manufacturing the same.

PRIOR ART

[0002] In recent years, there has been a demand for electrification of automobiles, high performance electrical and electronic equipment, and improvement in communication speed, and many semiconductors and motors are used to achieve them. Increasing the performance of semiconductors and motors increases the amount of heat generated, but in order to guarantee these performances, it is necessary to remove the generated heat. Therefore, it is desired to improve the thermal conductivity of the heat sink and the container itself. In particular, with the construction of 5G base stations, the production volume of heat sinks for the base station facilities of communication equipment is increasing. For the production of heat sinks for the base station facilities, it is necessary to provide aluminum alloys which have good conductivities of electricity and heat and can be formed into large sizes.

[0003] On the other hand, Patent Literature 1 discloses an Al-Si alloy which contains 13 wt% or more and 80 wt% or less of Si and having low thermal expansion and high thermal conductivity. In order to obtain a material with low thermal expansion, although a composition containing a large amount of Si is required, when the content of Si is increased, since the melting point rises, it is difficult to die cast. Therefore, in Patent Literature 1, the alloy is quenched at a rate of 300 to 800 K/sec and die casted.

[0004] Further, Patent Literature 2 discloses an aluminum alloy material for a heat sink which contains Si: 4.0 to 14.0 wt% and Fe: 0.2 to 1.0 wt% and having excellent thermal conductivity. Since the thermal conductivity decreases when the amount of Si in the alloy increases, in order to solve this problem, in Patent Literature 2, the contents of the components in the alloy are optimized. However, in the examples of the invention shown in Table 1 of Patent Literature 2, only the examples of the invention examples in which the contents of Si are 6.0, 9.0, and 13.0 wt% are disclosed, and the content of Si more than those is not optimized. Therefore, there is still room for improvement in the thermal conductivity and castability of the aluminum alloy materials for a heat sink.

[0005] Furthermore, Patent Literature 3 discloses an aluminum alloy member which contains 8 % by mass (hereinafter %) $< Si < 11\%$, $0.2\% < Mg < 0.3\%$, $0.3\% < Fe < 0.7\%$, $0.15\% < Mn < 0.35\%$, $1 < Fe + Mn \times 2$, $0.005\% < Sr < 0.020\%$, $Cu < 0.2\%$, $Zn < 0.2\%$. The alloy member is held at 200 °C < T < 250 °C for 0.1 to 1 hour after the casting, and has a tensile yield strength of 200 MPa or more at room temperature, but a thermal conductivity is merely 145 W/m ·K or more. Therefore, there is still room for improvement in the thermal conductivity.

CITATION LIST

PATENT LITERATURE

[0006]

Patent Literature 1: JP2001-288526A
Patent Literature 2: JP2002-105571A
Patent Literature 3: JP2013-204087A

Summary of the Invention

Technical Problem

[0007] In view of the problems in the prior art as described above, the object of the present invention is to provide a die-cast aluminum alloy with more excellent thermal conductivity and castability for a large heat sink and an instrument/container in which heat dissipation properties are required, an aluminum alloy die-cast material, and a method for manufacturing the same.

Solution to Problem

[0008] The present invention relates to a die-casting aluminum alloy including, based on the total mass of the aluminum alloy, Si: 9.5 % by mass or more and 12 % by mass or less, Fe: 0.3 % by mass or more and 1.0 % by mass or less, and Mg: 0.15 % by mass or more and 0.35 % by mass or less, the remainder being Al and unavoidable impurities.

[0009] It is preferable that the die-cast aluminum alloy of the present invention further includes, based on the total mass of the aluminum alloy, at least one element selected from the group consist of

Sr: 0.005 % by mass or more and 0.040 % by mass or less,
Na: 0.002 % by mass or more and 0.020 % by mass or less,
K: 0.002% by mass or more and 0.020% by mass or less,
Be: 0.005% by mass or more and 0.050% by mass or less,
Ca: 0.005% by mass or more and 0.050% by mass or less, and
Ba: 0.005% by mass or more and 0.050% by mass or less, and

$$([Na] / 2 + [K] / 2 + [Be] / 5 + [Ca] / 5 + [Sr] /5+[Ba] / 5) / ([P] / 5) > 3.5.$$

[0010] Further, it is preferable that the die-cast aluminum alloy of the present invention does not contain any of Mn, Ti and Zr.

[0011] In a preferred embodiment, in the die-cast aluminum alloy of the present invention, a content of Si is 10 % by mass or more and 11 % by mass or less, a content of Fe is 0.4 % by mass or more and 0.8 % by mass or less, a content of Mg is 0.2 % by mass or more and 0.3 % by mass or less, a content of Sr is 0.010 % by mass or more and 0.030 % by mass or less, or a content of Ca is 0.005% by mass or more and 0.020 % by mass or less.

[0012] In a specific embodiment, the die-cast aluminum alloy of the present invention is used for heat sinks and instruments/containers that require heat dissipation, especially for large heat sinks.

[0013] Further, the present invention also provides an aluminum alloy die-cast material composed of the die-cast aluminum alloy of the present invention. The aluminum alloy die-cast material of the present invention has a yield strength of 130 MPa or more and a thermal conductivity of 170 W/m K or more, preferably a yield strength of 140 MPa or more and a thermal conductivity of 180 W/m K or more, and an elongation of 5% or more.

[0014] In a specific embodiment, the aluminum alloy die-cast material of the present invention is used for heat sinks and instruments/containers that require heat dissipation.

[0015] Further, the present invention also provides a method for manufacturing an aluminum die-cast material by molding the aluminum alloy by a die-cast method, cooling to a temperature of 200 °C or less at a cooling rate of 100 °C/sec or more, and then, without subjecting to solutionizing treatment, subjecting to aging treatment under the conditions of 200 to 240 °C for 1 to 6 hours.

[0016] In a preferred embodiment, the condition of the aging treatment is 200 to 220 °C for 4 to 6 hours.

[0017] Furthermore, the present invention also provides a heat sink and an instrument/container that require heat dissipation which are composed of the die-cast aluminum alloy of the present invention, or manufactured by the method for manufacturing the aluminum alloy die-cast material of the present invention.

Effect of the invention

[0018] The die-cast aluminum alloy provided by the present invention or the aluminum alloy die-cast material manufactured by the manufacturing method of the present invention has more excellent thermal conductivity and castability, and is applied to the manufacture of a large heat sink with more excellent thermal conductivity and castability, and the instrument/container that require heat dissipation.

Brief explanation of the drawing

[0019]

FIG. 1 is a micrograph (× 2000) showing the microstructure of the die-cast aluminum alloy of the present invention.

Embodiments for achieving the invention

[0020] In the following, representative embodiments of the die-cast aluminum alloy, the aluminum alloy die-cast material, and the manufacturing method thereof according to the present invention will be described in detail, but the present invention is not limited thereto. Further, in the present invention, the meaning of not containing a certain element refers to intentionally not adding a certain element, and does not exclude cases where the element is contained as an impurity. In addition, the content ranges "A to B" and "A or more and B or less" both indicate that the contents shown for A and B themselves are also included.

1. Die-cast aluminum alloy

[0021] The die-cast aluminum alloy of the present invention contains, based on the total mass of the aluminum alloy, Si: 9.5 % by mass or more and 12 % by mass or less, Fe: 0.3 % by mass or more and 1.0 % by mass or less, and Mg: 0.15 % by mass or more and 0.35 % by mass or less, the remainder being Al and unavoidable impurities. Each component will be described in detail in the following.

(1) Essential additive element

Si: 9.5 to 12 % by mass

[0022] Si has the effect of improving castability. When casting a product having a complicated shape or a thin portion such as a heat sink or a large container, it is necessary to add 9.5% by mass or more of Si to the alloy from the viewpoint of castability. Si also has the effect of improving the mechanical strength, wear resistance and vibration damping properties of casting products. However, as the amount of Si increases, the thermal conductivity and extensibility of the alloy decrease, and when the content of Si exceeds 12% by mass or more, the thermal conductivity is remarkably lowered, and the desired heat dissipation characteristics as a heat sink and an instrument/container cannot be satisfied, and in addition, since the machinability is also deteriorated, it is desirable to set to 12% by mass or less. Therefore, the content of Si is 9.5% by mass or more and 12% by mass or less, preferably 10% by mass or more and 11% by mass or less, and more preferably 10.5% by mass or more and 11% by mass or less.

Fe: 0.3 to 1.0% by mass

[0023] Fe improves the mechanical strength of the aluminum alloy, and also has the effect of preventing seizure of the mold when casting by die casting. This effect becomes remarkable when Fe is contained in an amount of 0.3% by mass or more. However, even if 1.0% by mass or more of Fe is added, the effect cannot be expected to be further improved. Further, the thermal conductivity and extensibility decrease with an increase in Fe. Therefore, the content of Fe is 0.3% by mass or more and 1.0% by mass or less, preferably 0.4% by mass or more and 0.8% by mass or less, and more preferably 0.6% by mass or more and 0.7% by mass or less.

Mg: 0.15 to 0.35% by mass

[0024] Mg reacts with Si in the matrix phase to form an Mg-Si-based compound which is precipitated at the aging treatment, and thus reduces the solid solution amount of Si in the matrix phase, which results in improvement of the thermal conductivity. Furthermore, the addition of Mg improves the mechanical strength. This effect becomes remarkable when the content of Mg is 0.15% by mass or more, but on the other hand, when adding Mg in an amount of 0.35% by mass or more, the thermal conductivity decreases significantly. Therefore, the content of Mg is 0.15% by mass or more and 0.35% by mass or less, preferably 0.2% by mass or more and 0.3% by mass or less, and more preferably 0.2% by mass or more and 0.25% by mass or less.

(2) Optional additive element

Sr: 0.005 to 0.040% by mass

[0025] Sr is an element that has an improvement effect on eutectic Si and improves thermal conductivity. Further, the mechanical properties are improved at the aging heat treatment. At this time, the heat treatment may not be required depending on the required properties of the casting product. However, when the content exceeds 0.040% by mass, since the degassing ability of the molten metal is lowered, and a brittle Al-Sr-based compound is formed to decrease the toughness, the content is set to 0.040% by mass or less. The content of Sr is 0.005% by mass or more and 0.040% by mass or less, preferably 0.010% by mass or more and 0.030% by mass or less, and more preferably 0.010% by mass or more and 0.020% by mass or less.

Na: 0.002 to 0.020% by mass

[0026] Na is an element that has an improvement effect on eutectic Si and improves thermal conductivity. In particular, when the content of Na in the alloy is 0.002% by mass or more and 0.020% by mass or less, preferably 0.002% by mass or more and 0.010% by mass or less, and more preferably 0.005% by mass or more and 0.010% by mass or less, the above effects can be exhibited more effectively.

K: 0.002 to 0.020% by mass

[0027] K is an element that has an improvement effect on eutectic Si and improves thermal conductivity. In particular, when the content of K in the alloy is 0.002% by mass or more and 0.020% by mass or less, preferably 0.002% by mass or more and 0.010% by mass or less, and more preferably 0.005% by mass or more and 0.010% by mass or less, the above effects can be exhibited more effectively.

Be: 0.005 to 0.050 % by mass

[0028] Be is an element that has an improvement effect on eutectic Si and improves thermal conductivity. In particular, when the content of Be in the alloy is 0.002% by mass or more and 0.050% by mass or less, preferably 0.005% by mass or more and 0.050% by mass or less, and more preferably 0.005% by mass or more and 0.010% by mass or less, the above effects can be exhibited more effectively.

Ca: 0.005 to 0.050% by mass

[0029] Ca is an element that has an improvement effect on eutectic Si and improves thermal conductivity. In particular, when the content of Ca in the alloy is 0.002% by mass or more and 0.050% by mass or less, preferably 0.005% by mass or more and 0.050% by mass or less, more preferably 0.005% by mass or more and 0.020% by mass or less, and furthermore preferably 0.010% by mass or more and 0.020% by mass or less, the above effects can be exhibited more effectively.

Ba: 0.005 to 0.050 % by mass

[0030] Ba is an element that has an improvement effect on eutectic Si and improves thermal conductivity. In particular, when the content of Ba in the alloy is 0.002% by mass or more and 0.050% by mass or less, preferably 0.005% by mass or more and 0.050% by mass or less, and more preferably 0.005% by mass or more and 0.010% by mass or less, the above effects can be exhibited more effectively.

(3) Ratio of trace element

[0031] All of the above Sr, Na, K, Be, Ca and Ba are trace elements which are added if necessary in the die-cast aluminum alloy of the present invention. Further, P is an element that inhibits the effects of these elements. When the ratio of the content of other elements and P satisfies $([Na] / 2 + [K] / 2 + [Be] / 5 + [Ca] / 5 + [Sr] / 5 + [Ba] / 5) / ([P] / 5) > 3.5$, the eutectic Si can be improved, thereby improving the thermal conductivity. The ratio is preferably greater than 5, more preferably greater than 6, furthermore preferably greater than 7. When the ratio is less than 3.5, the above effects are reduced.

(4) Unavoidable impurities

[0032] In addition to the above alloy components, the die-cast aluminum alloy of the present invention may contain unavoidable impurities, and if necessary, may contain components added for improving other characteristics such as improving strength and improving corrosion resistance. Examples of these components include Cu, Mo, Zn, Ni, Co, Mn, Zr, Cr, Ti, Sn and In, but since there is a risk that these components make the thermal conductivity lower, the total content of the unavoidable impurities should be 0.15% by mass or less.

2. Method for manufacturing aluminum alloy die-cast material

[0033] In the following, the characteristic contents of the method for manufacturing an aluminum alloy die-cast material according to the present invention will be described in detail.

(1) Solutionizing treatment

[0034] Solutionizing treatment is performed at 480 to 540 °C for 1 to 10 hours, followed by quenching. By performing the solutionizing treatment under these conditions, it is possible to realize that the micro-macro segregation observed in the cast structure is relaxed, the variation in thermal conductivity and mechanical strength is reduced, the solutionization of the Mg-Si-based precipitate in the matrix phase is accelerated, precipitate a supersaturated solid solution of transition elements such as Fe is precipitated to improve the thermal conductivity, and further by spheroidizing the Si particles to improve extensibility and plastic workability.

[0035] When the treatment temperature is less than 480 °C or the holding time is less than 1 hour, the above effect is insufficient, but to the contrary, when the treatment temperature is higher than 540 °C or the holding time is longer than 10 hours, due to the occurrence of localized melting, there raises a possibility to lower the strength. In order to further obtain the effect of the solutionizing treatment, it is preferable that the treatment temperature is set to higher than 500 °C.

[0036] When performing the solutionizing treatment, although the properties such as strength, thermal conduction, and elongation are improved, in general high-speed, high-pressure die-cast process, there is a case that air or a gas generated from lubricants and release agents is caught in the casting material. In such a case, if the solutionizing treatment is performed after the die casting, blisters (bubbles) or distortion will occur. Therefore, usually the solutionizing treatment is not performed after the high-speed, high-pressure die casting. When the solutionizing treatment is not performed, it is preferable to cool down to 200 °C after casting at a cooling rate of 100 °C/sec or more.

(2) Aging treatment

The aging treatment is performed at 200 to 240 °C for 1 to 6 hours.

[0037] By the aging treatment, Si and Mg which are solid-dissolved in the matrix phase are precipitated as a Mg-Si-based compound to reduce the amounts of Si and Mg solid-dissolved in the matrix phase, and thus it is possible to improve the thermal conductivity of the alloy. Further, the precipitated Mg-Si-based compound improves the mechanical strength of the alloy. When the aging condition is less than 200 °C or less than 1 hour, since the amount of precipitation of the Mg-Si-based compound is relatively small, the improvement of thermal conductivity is small. On the other hand, when exceeding 240 °C or 6 hours, overaging occurs and the strength is lowered. The heat treatment conditions can be selected in consideration of industrial production restrictions, but, considering the balance between the thermal conductivity and strength, the desirable range is 200 to 240 °C for 1 to 6 hours, the preferable range is 200 to 240 °C for 2 to 6 hours, the more preferable range is 200 to 220 °C for 4 to 6 hours.

[0038] Although the typical embodiments of the present invention have been described above, the present invention is not limited to these, and various design changes are possible, and all of these design changes are included in the technical scope of the present invention.

EXAMPLES

[0039] Various aluminum alloys having the compositions shown in Table 1 and Table 2 were prepared. Specifically, the molten metal was obtained by melting at 760°C, subjected to degassing and slag removal treatment, and then the trace components were adjusted.

A plate material of 110 × 110 × 3 mm was produced from the aluminum alloy with a 350-ton cold chamber die casting machine (Number: TOYO Ds-350EX) at a casting temperature of 750 °C and a mold temperature of 180 °C.

[Table 1]

	Si	Fe	Mg	Cu	Mn	Ti	Zr	Sr	Na	K	Be	Ca	Ba	P	Al	Trace element ratio	0.2%proof stress (MPa)	Elongation (%)	Thermal conductivity (W/mk)	Castability	Seizure resistance
Ex.1	9.5	0.3	0.2	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	140	8	187	○	△
Ex.2	9.5	1.0	0.2	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	144	6	181	○	○
Ex.3	10.5	0.3	0.2	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	140	7	185	○	△
Ex.4	10.5	0.6	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	144	6	181	○	○
Ex.5	10.5	0.6	0.25	-	-	-	-	-	-	-	-	0.02	-	-	Bal.	-	144	6	180	○	○
Ex.6	10.5	0.6	0.25	-	-	-	-	0.02	-	-	-	-	-	0.003	Bal.	6.7	144	6	183	○	○
Ex.7	10.5	0.6	0.25	-	-	-	-	0.01	-	-	-	0.01	-	0.003	Bal.	6.7	143	6	184	○	○
Ex.8	10.5	0.6	0.25	-	-	-	-	-	0.005	0.005	0.005	-	-	0.003	Bal.	10.0	144	6	183	○	○
Ex.9	10.5	0.6	0.25	-	-	-	-	-	0.005	-	-	-	0.005	0.003	Bal.	5.8	143	6	182	○	○
Ex.10	10.5	1.0	0.15	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	142	6	180	○	○
Ex.11	12.0	0.3	0.35	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	147	5	182	○	△
Ex.12	12.0	0.6	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	145	5	180	○	○

[Table 2]

	Si	Fe	Mg	Cu	Mn	Ti	Zr	Sr	Na	K	Be	Ca	Ba	P	Al	Trace element ratio	0.2%proof stress (MPa)	Elongation (%)	Thermal conductivity (W/mk)	Castability	Seizure resistance	Others
Com. Ex.1	7.0	0.6	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	142	9	188	×	○	-
Com. Ex.2	9.0	0.6	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	143	7	183	×	○	-
Com. Ex.3	10.5	0.3	0.1	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	136	7	187	○	△	-
Com. Ex.4	10.5	0.15	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	141	7	180	○	×	-
Com. Ex.5	10.5	0.6	0.25	-	-	-	-	-	-	-	-	-	-	-	Bal.	≈0	144	2	175	○	○	-
Com. Ex.6	13.0	0.6	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	145	4	180	○	○	bad machinability
Com. Ex.7	13.5	0.6	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	146	4	179	○	○	bad machinability
Com. Ex.8	10.5	0.6	0.5	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	155	5	179	○	○	-
Com. Ex.9	10.5	1.2	0.25	-	-	-	-	0.02	-	-	-	-	-	-	Bal.	-	148	5	177	○	○	-
Com. Ex.10	10.5	0.6	0.25	-	0.2	-	-	0.02	-	-	-	-	-	-	Bal.	-	144	6	175	○	○	-
Com. Ex.11	10.5	0.6	0.25	-	-	0.2	-	0.02	-	-	-	-	-	-	Bal.	-	144	6	172	○	○	-
Com. Ex.12	10.5	0.6	0.25	-	-	-	0.2	0.02	-	-	-	-	-	-	Bal.	-	144	6	174	○	○	-
Com. Ex.13	10.5	0.6	0.25	-	-	-	-	0.005	-	-	-	-	-	0.003	Bal.	1.7	142	2	179	○	○	-

Com. Ex.14	10.5	0.6	0.25	-	-	-	-	0.005	-	-	-	0.005	-	0.005	Bal.	2.0	144	2	178	○	○	-
Com. Ex.15	10.5	0.6	0.25	-	-	-	-	0.003	-	-	-	0.003	-	0.003	Bal.	2.0	141	2	178	○	○	-
Com. Ex.16	10.5	0.6	0.25	-	-	-	-	-	0.005	0.005	0.005	-	-	0.010	Bal.	3.0	140	2	179	○	○	-
Com. Ex.17	10.5	0.6	0.25	-	-	-	-	-	0.001	0.001	0.001	-	-	0.003	Bal.	2.0	144	2	179	○	○	-
Com. Ex.18	10.5	0.6	0.25	-	-	-	-	-	0.001	-	-	-	0.001	0.003	Bal.	1.2	142	2	178	○	○	-
Com. Ex.19	12.0	0.5	-	-	-	-	-	-	-	-	-	-	-	-	Bal.	-	134	2	169	○	○	-
Com. Ex.20	10.8	0.8	-	2.5	-	-	-	-	-	-	-	-	-	-	Bal.	-	185	2	105	○	○	-

[0040] The obtained die-cast plate was subjected to the aging treatment at 200 °C for 4 hours in a flow-type heat treatment furnace (Model: Asahi Kagaku H-60), and then various test pieces were produced. Further, each characteristic was measured for each test piece based on the following experimental method. The obtained results are shown in Tables 1 and 2.

[Tensile test]

[0041] Based on Japanese Industrial Standards JIS Z2241, a tensile test was conducted by using an AMSLER-type universal testing machine (Shimadzu 100kN Autograph) to measure 0.2% proof stress and elongation.

[Thermal conductivity]

[0042] Thermal conductivity was measured by the laser flash method based on Japanese Industrial Standards JIS R 1611-1997.

[Seizure resistance]

[0043] The seizure resistance was evaluated in 3 stages according to the condition of the casting surface just above the gate part of the die-cast plate. The case of seizure was evaluated as " x ", the case where there was discoloration of the mold was evaluated as "△", and the case where there was no abnormality in the casting surface was evaluated as "○".

[Castability]

[0044] As for the castability, if the relative porosity differs by 1% or more from the difference in specific gravity between the 20 mm portion in the vicinity of the gate portion (gate side) and the 20 mm portion in the vicinity of the overflow portion (half gate side), it will be false and marked with " x ". A test piece having a relative porosity of less than 1% will be acceptable and marked with "○".

[0045] Specifically, the relative porosity is determined by the following three Equations (1) to (3). The specific gravity of the sample obtained from the gate side portion and the half gate side portion is calculated by Equation (1), and the porosity of the sample is calculated by Equation (2). The standard specific gravity, that is, the theoretical specific gravity refers to the specific gravity of a casting that does not have casting defects such as pores (cavity). Finally, the relative porosity is calculated by Equation (3).

$$\text{Specific gravity} = \text{Weight in air} / (\text{Weight in air} - \text{Weight in water}) \times \text{Specific gravity of water} \qquad (1)$$

$$\text{Porosity} = (\text{Standard specific gravity} - \text{Specific gravity of sample}) / \text{Specific gravity of sample} \times 100 \qquad (2)$$

$$\text{Relative porosity} = |\text{Gate side porosity} - \text{Half gate side porosity}| \qquad (3)$$

[0046] The alloy compositions and the evaluation results are shown in the following Table 1 and Table 2. Further, FIG. 1 shows a micrograph (photonic magnification: 2000) showing the microstructure.

[0047] The blanks in Table 1 and Table 2 indicates that the corresponding element is below the detection limit. Noting specifically, the blanks corresponding to Mn, Ti, and Zr indicate that the contents of Mn, Ti, and Zr are each less than 0.01% by mass. The blanks corresponding to Sr, Na, K, Be, Ca, and Ba indicate that the content of Sr, Na, K, Be, Ca, and Ba is less than 0.0005% by mass, respectively. The elements of blank are not added intentionally and are unlikely to be included. In addition, in the blank corresponding to P, the content of P is 0.002% by mass or less. "Trace element ratio" in Table 1 and Table 2 indicates a value of ([Na] / 2 + [K] / 2 + [Be] / 5 + [Ca] / 5 + [Sr] / 5 + [Ba] / 5) / ([P] /5).

[0048] As can be seen from the above Table 1, the 0.2% proof stresses of Examples 1 to 12 of the present invention are all 140 MPa or more, and the thermal conductivities are all 180 W/m·K or more. Further, in Example 6 of FIG. 1, finely improved eutectic Si can be confirmed.

[0049] On the other hand, as shown in Table 2 or FIG. 1, since the content of Si in Comparative Example 1 is as low as 7.0% by mass, the castability thereof is poor. Since the content of Si of Comparative Example 2 is 9.0% by mass, which is still lower than the lower limit of the range of the present invention, the castability therof is poor.

[0050] Since the content of Mg of Comparative Example 3 is as low as 0.1% by mass, the 0.2% proof stress thereof is less than 140 MPa. Since the content of Fe of Comparative Example 4 is as low as 0.15% by mass, the seizure resistance thereof is poor. Since Comparative Example 5 does not contain any trace elements including Sr, and the ratio of the trace elements is close to 0, the thermal conductivity thereof is less than 180 W/m K and the elongation thereof is less than 5%.

[0051] Since the content of Si of Comparative Example 6 is 13.0% by mass, which is too high, the elongation and machinability thereof are poor. Since the content of Si in Comparative Example 7 is too high at 13.5% by mass, coarse eutectic Si crystallizes, which resulting in poor elongation and machinability, and the thermal conductivity is less than 180 W/m ·K.

[0052] Since the content of Mg of Comparative Example 8 is as high as 0.5% by mass, the thermal conductivity thereof is less than 180 W/m K. Since the content of Fe of Comparative Example 9 is as high as 1.2% by mass, the thermal conductivity thereof is less than 180 W/m ·K. Further, the acicular Al-Fe-Si-based compound is crystallized, and elongation is also insufficient.

[0053] Since Comparative Example 10 contains 0.2% by mass of Mn, Comparative Example 11 contains 0.2% by mass of Ti, and Comparative Example 12 contains 0.2% by mass of Zr, the thermal conductivities of Comparative Examples 10 to 12 are all lower than 180 W/m K.

[0054] Since Comparative Example 13 has the ratio of trace element of lower than 3.5, the eutectic Si is larger than that of Example 6 in Table 1, the thermal conductivity thereof is less than 180 W/m K , and the elongation is also insufficient. Since Comparative Examples 14 to 18 have the ratio of trace elements is all lower than 3.5 as in Comparative Example 13, the thermal conductivities are less than 180 W/m K and the elongation are also insufficient.

[0055] Comparative Example 19 has a composition equivalent to that of JIS-ADC 1 alloy. Since Mg is not contained and also any trace elements including Sr are not contained, the 0.2% proof stress thereof is less than 140 MPa, the thermal conductivity thereof is also less than 180 W/m ·K, and the elongation thereof is less than 5%. Comparative Example 20 has a composition equivalent to that of JIS-ADC 12 alloy. Since Mg is not contained and Cu is contained in 2.5% by mass, the thermal conductivity thereof is as low as 105 W/m K and the elongation thereof is also insufficient.

[0056] The alloy having the composition shown in Example 6 in Table 1 was subjected to the aging treatment under various conditions shown in Table 3, and the 0.2% proof stress and thermal conductivity were measured for the corresponding test pieces. The results are shown in Table 3.

[Table 3]

Aging temperature (°C)	Aging time (h)	0.2% Proof stress (MPa)	Thermal conductivity (W/m · K)
180	6	164	176
200	4	156	182
200	6	155	183
220	2	150	181
220	4	147	183
220	6	146	184
240	1	142	182
240	2	141	183
240	8	131	183
260	1	138	184
300	1	129	188
300	2	127	190
300	4	123	191

[0057] As can be seen from Table 3, the 0.2% proof stress at 200 °C for 4 hours, 200 °C for 6 hours, 220 °C for 4 hours, 220 °C for 6 hours, 240 °C for 1 hour, and 240 °C for 2 hours are all 140 MPa or more, and the thermal conductivities thereof are all 180 W/m ·K or more.

[0058] The embodiments and specific examples of the present invention are described in detail, but the present invention is not limited to the above specific embodiments and application fields. The above specific embodiments are only general and guidance, and are not intended to limit the present invention. Based on the suggestions of the present description, a person skilled in the art can make various embodiments without departing from the protection scope of the claims of the present invention, which all fall within the protection scope of the present invention.

Claims

1. A die-cast aluminum alloy comprising, based on the total mass of the aluminum alloy,

   Si: 9.5 % by mass or more and 12 % by mass or less,
   Fe: 0.3 % by mass or more and 1.0 % by mass or less, and
   Mg: 0.15 % by mass or more and 0.35 % by mass or less,
   the remainder being Al and unavoidable impurities.

2. The die-cast aluminum alloy according to claim 1, wherein, based on the total mass of the aluminum alloy, at least one element selected from the group consist of

   Sr: 0.005 % by mass or more and 0.040 % by mass or less,
   Na: 0.002 % by mass or more and 0.020 % by mass or less,
   K: 0.002% by mass or more and 0.020% by mass or less,
   Be: 0.005% by mass or more and 0.050% by mass or less,
   Ca: 0.005% by mass or more and 0.050% by mass or less, and
   Ba: 0.005% by mass or more and 0.050% by mass or less, and

$$([Na] / 2 + [K] / 2 + [Be] / 5 + [Ca] / 5 + [Sr] /5 + [Ba] / 5) / ([P] / 5) > 3.5.$$

3. The die-cast aluminum alloy according to claim 1 or 2, which does not contain any of Mn, Ti and Zr.

4. The die-cast aluminum alloy according to claim 1 or 2, wherein the content of Si is 10% by mass or more and 11% by mass or less.

5. The die-cast aluminum alloy according to claim 1 or 2, wherein the content of Fe is 0.4% by mass or more and 0.8% by mass or less.

6. The die-cast aluminum alloy according to claim 1 or 2, wherein the content of Mg is 0.2% by mass or more and 0.3% by mass or less.

7. The die-cast aluminum alloy according to claim 1 or 2, wherein the content of Sr is 0.010% by mass or more and 0.030% by mass or less.

8. The die-cast aluminum alloy according to claim 1 or 2, wherein the content of Ca is 0.005% by mass or more and 0.020% by mass or less.

9. The die-cast aluminum alloy according to claim 1 or 2, which is used for heat sinks and instruments/containers that require heat dissipation.

10. An aluminum alloy die-cast material which is composed of the die-cast aluminum alloy according to any one of claims 1 to 9, wherein

    the yield strength is 130 MPa or more and
    the thermal conductivity is 170 W/m ·K or more.

11. The aluminum alloy die-cast material according to claim 10, wherein

    the yield strength is 140 MPa or more, and
    the thermal conductivity is 180 W/m K or more.

12. The aluminum alloy die-cast material according to claim 10 or 11, wherein the elongation is 5% or more.

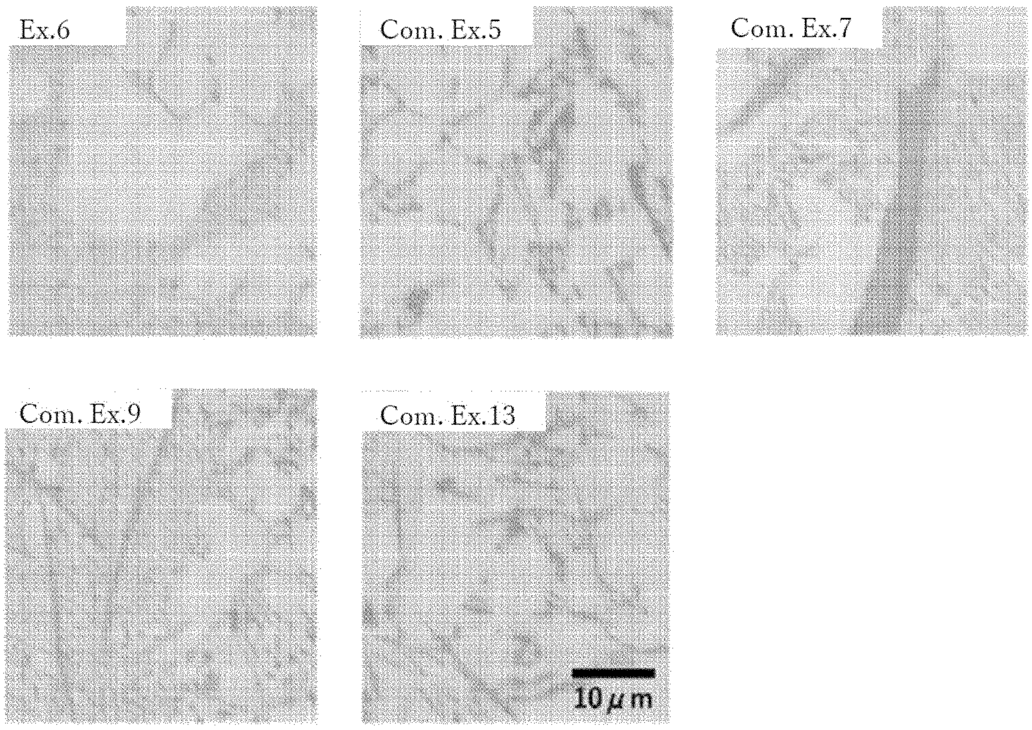
13. The aluminum alloy die-cast material according to claim 10 or 11, which is a heat sink and an instrument/container that require heat dissipation.

14. A method for manufacturing an aluminum alloy die-cast material, comprising molding the aluminum alloy according to any one of claims 1 to 9 by a die-cast method, cooling to a temperature of 200 °C or less at a cooling rate of 100 °C/sec or more, and without subjecting to solutionizing treatment, subjecting to aging treatment under the conditions of 200 to 240 °C for 1 to 6 hours.

15. The method for manufacturing an aluminum alloy die-cast material according to claim 14, wherein the condition of the aging treatment is at 200 to 220 °C for 4 to 6 hours.

16. A heat sink and an instrument/container that require heat dissipation, which comprises the die-cast aluminum alloy according to any one of claims 1 to 9, and is manufactured by the manufacturing method according to claim 14 or 15.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/015329

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. C22C21/02(2006.01)i, C22F1/043(2006.01)i, C22F1/00(2006.01)n
FI: C22C21/02, C22F1/043, C22F1/00 602, C22F1/00 611, C22F1/00 630A, C22F1/00 630K, C22F1/00 650F, C22F1/00 651A, C22F1/00 681, C22F1/00 682, C22F1/00 691B, C22F1/00 691C, C22F1/00 692A, C22F1/00 692B

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)
Int. Cl. C22C21/02-21/04, C22F1/043, C22F1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	CN 108866396 A (GUANGZHOU ZHIYUAN NEW MATERIAL TECH CO., LTD.) 23 November 2018, claims 1-10, paragraphs [0046]-[0082], table 1	1, 3-7, 9-11, 13, 16 2, 8, 14-15 12
X Y A	JP 2006-063420 A (RYOKA MACS CORP.) 09 March 2006, claims 1-4, paragraphs [0014], [0015], [0020]-[0022], table 2	1, 3-6, 9, 14-16 2, 7-8 10-13
Y	JP 2004-269937 A (SUMITOMO LIGHT METAL INDUSTRIES, LTD.) 30 September 2004, claim 1, paragraphs [0014]-[0017]	2, 7

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

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Date of the actual completion of the international search
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/015329

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2010-144253 A (NIPPON LIGHT METAL CO., LTD.) 01 July 2010, claims 3-4, paragraphs [0009], [0018]	14-15
A	JP 09-272957 A (NIPPON LIGHT METAL CO., LTD.) 21 October 1997, paragraph [0009]	1-16

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/015329

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CN 108866396 A	23.11.2018	(Family: none)	
JP 2006-063420 A	09.03.2006	(Family: none)	
JP 2004-269937 A	30.09.2004	(Family: none)	
JP 08-134578 A	28.05.1996	(Family: none)	
JP 2010-144253 A	01.07.2010	(Family: none)	
JP 09-272957 A	21.10.1997	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2002105571 A **[0006]**
- JP 2013204087 A **[0006]**