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(54) **A STRUCTURAL MATERIAL PART OF A HIGH-SI MG-CONTAINING AL ALLOY AND THE MANUFACTURE METHOD THEREOF**

(57) The magnesium-contained high-silicon aluminum alloys for use as structural materials, including profiles, bars, sheets, and forgings, are manufactured by a process including the steps of: casting an alloy ingot by direct chill casting, preheating the ingot to disperse eutectic Si phase particles, and thermal-plastic processing and heat-treating to obtain the product with a final shape and a modified microstructure. The aluminum alloys contain 0.2~2.0wt% of Mg and 8~18wt% of Si, and have homogeneous and fine microstructure, wherein the aluminum matrix is equiaxed with an average grain size less than 6μm, and the silicon and second phase particles are dispersed with an average size less than 5μm. Without adding any modifiers, they are low-costly produced by incorporating the direct chill casting with thermal-plastic processing and heat treatment, which give rise to good plasticity and relatively high strength.

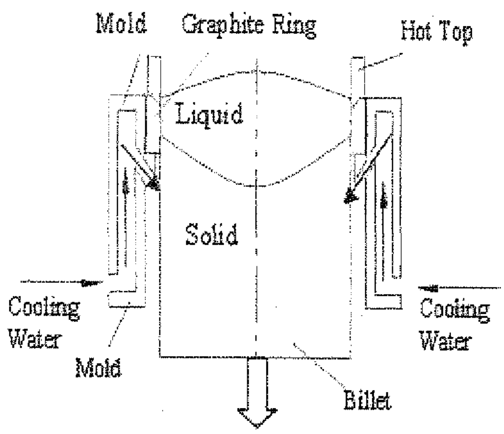

FIG. 1

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Description

Background of the Present Invention

Field of Invention

[0001] The present invention relates to aluminum alloys and their method of preparation, and more particularly to magnesium-contained high-silicon aluminum alloys for use as structural materials, and the manufacture method thereof.

Description of Related Arts

[0002] Aluminum-silicon alloys (Al-Si alloys), especially those with high silicon content, are widely used in car and aviation industries, due to their low density, high wear resistance, high anti-corrosiveness, and low thermal expansion coefficient. With the common solidification method for preparation of Al-Si alloys, there usually appear large silicon particles and eutectic plates, resulting in a dramatically increased brittleness of the alloys. Thus, it is difficult to improve the solidified microstructure and to obtain various shaped high-performance structural materials through subsequent plastic deformation, which poses a bottleneck for more general applications of these alloys. Traditionally, Al-Si alloys are categorized into the casting aluminum alloy series. In order to overcome their poor deformation ability, some new processing methods based on rapid solidification or powder metallurgy have been explored. However, the rapid solidification method can only allow preparation of tiny ingots with a diameter less than 10mm. If a large-sized Al-Si alloy ingot is desired, a further process is then required. As for the powder metallurgy method, it enables to obtain a relatively large-sized part, but suffers from a complicated process with high fabrication cost.

[0003] In the existing methods for casting pure aluminum or aluminum alloys, the direct chill (DC) casting is most common in use. The main concerns are focused on how to reduce the chemical composition segregation, refine the solidification microstructure, and improve the ingot surface quality. Based on the DC casting route, an efficient manufacture method has been developed by one of the present inventers to prepare large-sized ingots of high silicon-containing aluminum alloys without adding any modifiers like P, Na, and Sr, and received a China Invention Patent with the patent number ZL200510119550.6. The present inventers have further found out that while narrowing the range of the Si content (i.e. increasing the lower limit to 8% by weight and reducing the upper limit to 18% by weight of Si concentration, and adjusting the contents of Mg and other alloy elements, the above method can be incorporated with thermoplastic processing and subsequent heat treatment, so as to produce Mg-containing high-silicon aluminum alloys with relatively high plasticity and strength, including profiles, bars, sheets, and forgings, for use as advanced new structural materials.

Summary of the Present Invention

[0004] An object of the present invention is to provide high-silicon aluminum alloys (Al-Si alloys) that contain magnesium (Mg) and have good plasticity and high strength for use as structural materials, and the manufacture method thereof. Without adding any modifiers, the Al-Si alloys are manufactured at low cost with the direct chill casting followed by the thermoplastic process and heat treatment.

[0005] Accordingly, in order to accomplish the above object, the present invention presents the aluminum alloys containing Mg and high Si, which comprises profiles, bars, sheets, and forgings, wherein the aluminum alloys are made by a process comprising the steps of:

(a) casting an alloy ingot by a method of direct chill casting;

(b) preheat-treating the ingot to disperse eutectic Si phase particles; and

(c) thermal-plastic processing and heat-treating to obtain the alloy with a final shape and a modified microstructure, wherein the strengthening mechanisms of the alloy are referred to the grain refinement strengthening of aluminum matrix, the dispersion strengthening of silicon particles, and the precipitation strengthening of second phase particles.

[0006] The Mg-contained high-silicon aluminum alloys for use as structural materials contain 0.2~2.0wt% of Mg and 8~18wt% of Si, wherein they have an evenly refined microstructure: the aluminum matrix is fine equiaxed with an average grain size less than 6μm, and the silicon and second phase particles are dispersed with an average size less than 5μm.

[0007] The Mg-contained high-silicon aluminum alloys may contain at least one of Cu, Zn, Ni, Ti, and Fe elements, wherein a total weight percentage of the Cu, Zn, Ni, Ti, and Fe is less than 2wt%.

[0008] The step (a) of direct chill casting is subjected to the cast ingot preparation for a given Al-Si alloy, at a relative casting temperature of 150~30(1°C above the liquidus line, a casting speed of 100~200mm/min, and a cooling water flux of 5~15g/mm·s on the periphery of the solidified ingot, wherein no modifier is added to the alloy.

[0009] The step (b) of preheat-treating is subjected to the formation of dispersed eutectic Si phase particles in the ingot, at a heating rate of 10~30°C/min, a heating temperature of 450~520°C, and a holding time of 1~3 hours.

[0010] The preheat-treated ingot is subjected to a thermal-plastic processing in the step (c), at a hot-deformation temperature of 400~520°C, followed by cooling naturally or forcedly. The hot-deformed product is then heat-treated after the thermal-plastic processing.

[0011] For the product thermal-plastic processed with natural cooling, the heat treatment in the step (c) further comprises a step of solution treatment and a step of artificial aging process. The solution treatment is performed at a heating rate of 10~30°C/min, a solution treatment temperature of 500~540°C, and a solution treatment time of 0.5~3 hours, followed by quenching. The artificial aging process is performed at an aging temperature of 160~200°C, and an aging time of 1~10 hours.

[0012] For the product thermal-plastic processed with forced cooling, the heat treatment in the step (c) further comprises a step of artificial or natural aging treatment, wherein the artificial treatment is performed at an aging temperature of 160~200°C, and an aging time of 1~10 hours.

[0013] A hot rolling process is adapted in the step of thermal-plastic processing, wherein the ingot is hot deformed at a total rolling reduction of more than 40%.

[0014] A hot extrusion process is adapted in the step of thermal-plastic processing, wherein the ingot is hot deformed at an extrusion ratio of more than 15.

[0015] A hot forging process is adapted in the step of thermal-plastic processing, wherein the ingot is hot deformed at a forging ratio of more than 40%.

[0016] The present invention overcomes the cognition prejudice traditionally imposed on Al-Si alloys. Without adding any modifiers, an unexpected effect has been reached on the magnesium-contained high-silicon aluminum alloys prepared by incorporating conventional direct chill casting method with thermal-plastic process and heat treatment. They are typically of fine-dispersed silicon particles and second phase at equiaxed Al matrix, associated with a relatively high strength and good plasticity for potential use as structural materials

[0017] Fig. 14 gives a comparison of mechanical properties between the Al-Si extrusion alloys of the present invention and the China National Standard extrusion alloy 6063 at the T5 and T6 states, wherein the alloys of the present invention are Al-8.5Si-1.8Mg-0.27Fe, Al-12.7Si-0.7Mg-1.5Cu-0.3Ni-0.3Ti-0.3Fe, and Al-15.5Si-0.7Mg-0.27Fe, respectively.

[0018] Notably, the yield strength and tensile strength of the Al-8.5Si-1.8Mg-0.27Fe, Al-12.7Si-0.7Mg-1.5Cu-0.3Ni-0.3Ti-0.3Fe, and Al-15.5Si-0.7Mg-0.27Fe extrusion alloys at the T6 state are higher than the China National Standards for the extrusion alloy 6063 at the T6 state. The mechanical properties of these alloys at the extrusion state (T1), especially the elongation rate, are also higher than the China National Standards for the 6063 alloys at the T5 state.

[0019] As the most common aluminum extrusion alloys, the 6063 alloys have been widely used in architectures, vehicles, and decorations etc., which have great need in the existing market. Once the 6063 alloys are partially replaced by the magnesium-contained high-silicon aluminum alloys of the present invention, it will bring great economic benefits. In addition, the use of an increased amount of Si in the alloys can dramatically conserve the aluminum resource.

[0020] These and other objectives, features, and advantages of the present invention will become apparent from the following detailed descriptions, the accompanying drawings, and the appended claims.

Brief Description of the Drawings

[0021]

FIG. 1 is a perspective view of a device of direct chill casting according to preferred embodiments of the present invention.

FIG. 2 is a microstructure of ingot of Al-12.7Si-0.7Mg-0.3Fe alloy (#3) at cast condition during the direct chill casting process according to a first preferred embodiment of the present invention, wherein a casting temperature is 730°C, a casting rate is 180mm/min, and a cooling water flow rate is 8g/mm·s.

FIG. 3 is a high magnification microstructure of ingot of Al-12.7Si-0.7Mg-0.3Fe alloy (#3) at cast condition during the direct chill casting process according to the first preferred embodiment of the present invention, wherein a casting temperature is 730°C, a casting rate is 180mm/min, and a cooling flow rate of the surrounding water is 8g/mm·s.

FIG. 4 is a microstructure of Al-12.7Si-0.7Mg-0.3Fe alloy (#3) after pre-heated to 500°C for 2 hours, heat extruded at 470°C (having extraction ratio of 15) according to a second preferred embodiment of the present invention.

FIG. 5 is a T6 state microstructure of Al-12.7Si-0,7Mg-0.3Fe alloy (#3) after pre-heated to 500°C for 2 hours, heat extruded at 470°C (having extraction ratio of 15) according to a third preferred embodiment of the present invention, wherein said T6 state is at a solution temperature 540°C for one hour, and at an artificial aging temperature 200°C for 3 hours.

FIG. 6 is a microstructure of ingot of Al-15.5Si-0.7Mg-0.27Fe alloy (#5) at cast condition during the direct chill casting process according to the first preferred embodiment of the present invention, wherein a casting temperature is 800°C, a casting rate is 140mm/min, and a cooling water flow rate is 10g/mm·s.

FIG. 7 is a high magnification microstructure of ingot of Al-15.5Si-0.7Mg-0.27Fe alloy (#5) at cast condition during the direct chill casting process according to the first preferred embodiment of the present invention, wherein a casting temperature is 800°C, a casting rate is 140mm/min, and a cooling water flow rate is 10g/mm·s.

FIG. 8 is a microstructure of Al-15.5Si-0.7Mg-0.27Fe alloy (#5) after pre-heated to 500°C for 2 hours, heat extruded at 470°C (having extrusion ratio of 45) according to the second preferred embodiment of the present invention.

FIG. 9 is a microstructure of Al-1.5.5Si-0.71Mg-0.27Fe alloy (#5) after pre-heated to 500°C for 1 hour, heat rolled at 500°C (pressing amount of 60%) according to the second preferred embodiment of the present invention.

FIG. 10 is a T6 state microstructure of ingot of Al-15.5Si-0.7Mg-0.27Fe alloy (#5) after pre-heated to 500°C for 2 hours, heat extruded at 470°C (having extraction ratio of 45) according to the third preferred embodiment of the present invention, wherein said T6 state is at a solution temperature 520°C for 2 hours, and at an artificial aging temperature 180°C for 4 hours.

FIG. 11 is a T6 state microstructure of rectangular ingot of Al-15.5Si-0.7Mg-0.27Fe alloy (#5) after pre-heated to 500°C for 1 hour, heat rolling at 500°C (pressing amount of 60%) according to the third preferred embodiment of the present invention, wherein said T6 state is at a solution temperature 520°C for 3 hours, and at an artificial aging temperature 200°C for 4 hours.

FIG. 12 is a T6 state of high rate microstructure of Al-15.5Si-0.7Mg-0.27Fe alloy (#5) after pre-heated to 500°C for 2 hours, heat extruded at 470°C (having extrusion ratio of 45) according to the third preferred embodiment of the present invention, wherein said T6 state is at a solution temperature 520°C for 2 hours, and at an artificial aging temperature 180°C for 4 hours.

FIG. 13 is a microstructure of ingot of Al-17.5Si-0.7Mg-1.0Cu-0.27Fe alloy (#7) at cast condition during the direct chill casting process according to the first preferred embodiment of the present invention, wherein a casting temperature is 850°C, a casting rate is 120mm/min, and a cooling water flow rate is 10g/mm·s.

FIG. 14 is a table showing the comparisons mechanical properties of extrusion Si Al alloy of the present invention and the China standard extrusion of 6063 alloy.

FIG. 15 is a table showing the compositions of an alloy made from the ingot via the casting process.

FIG. 16 is a table showing the parameters of different alloys through casting process.

FIG. 17 is a table showing the parameters of the preheating process and extraction process of each of alloys.

FIG. 18 is a table showing the parameters of the preheating process and rolling process of each of alloys.

FIG. 19 is a table showing the parameters of the preheating process and forging process of each of alloys.

FIG. 20 is a table showing the parameters of the extrusion process for different alloys.

FIG. 21 is a table showing the parameters of the rolling process for different alloys.

FIG. 22 is a table showing the parameters of the forging process for different alloys.

FIG. 23 is a table showing the mechanical properties under variety of deformation processes and heat treatments situations.

Detailed Description of the Preferred Embodiment

[0022] Referring to Fig. 1 of the drawings, a step of casting ingot via the direct chill casting method according to a first preferred embodiment of the present invention is illustrated.

[0023] A device designed for the direct chill casting process is shown in Fig. 1 of the drawings, wherein the device comprises a cooling water inlet 1, a crystallizer 2, a hot top 4, and a graphite ring 5, wherein a raw material 3 of the ingot and a liquid metal 6 are separately received within a container of the device. A plurality of compositions of an alloy made from the ingot via the casting process is shown in Fig. 15. A plurality of parameters of the casting process is shown in Fig. 16.

[0024] Referring to Figs. 17, 18, and 19, a step of preheating, followed by hot extruding, or hot rolling, or hot forging the ingot according to a second preferred embodiment of the present invention is illustrated.

[0025] In the preheating process, the ingot is heated in an oven at a predetermined heating rate. After the predetermined temperature is reached, the ingot is held for a predetermined time. Then, a hot extrusion device, or a hot rolling device, or a hot forging device is used to complete a thermal-plastic processing. A plurality of parameters of the preheating and hot extruding for each of the alloys is shown in Fig. 17. A plurality of parameters of the preheating and hot rolling for each of the alloys is shown in Fig. 18. A plurality of parameters of the preheating and hot forging for each of the alloys is shown in Fig. 19.

[0026] Referring to Figs. 20, 21, 22, and 23, a step of heat treatment after hot deformation of the alloys, such as hot extrusion, hot rolling, and hot forging, according to a third preferred embodiment of the present invention is illustrated.

[0027] After the hot extrusion, hot rolling, or hot forging process of the ingot, the heat treatment is applied to the product at a predetermined temperature. A plurality of parameters of the hot extrusion, hot rolling, and hot forging processes are shown in Figs. 20, 21, and 22 respectively. A plurality of mechanical properties of the alloys after the heat treatments is shown in Fig. 23.

[0028] The present invention provides the industrial use of the Mg-contained high silicon aluminum alloys (Al-Si alloy), and the manufacture method thereof. Without adding any modifiers, the Al-Si alloys having good plasticity and relatively high strength are manufactured at low cost with the direct chill casting followed by the thermal-plastic process and heat treatment, for use as structural materials.

[0029] One skilled in the art will understand that the embodiment of the present invention as shown in the drawings and described above is exemplary only and not intended to be limiting.

[0030] It will thus be seen that the objects of the present invention have been fully and effectively accomplished. The embodiments have been shown and described for the purposes of illustrating the functional and structural principles of the present invention and is subject to change without departure from such principles. Therefore, this invention includes all modifications encompassed within the scope of the following claims.

Claims

1. A process for manufacturing aluminum alloy containing Mg and high silicon, which comprises sectional material, bar, sheet, and forging, comprises the steps of:

   (a) casting an ingot of said aluminum alloys by a method of direct chill casting;
   (b) preheat-treating said ingot to disperse eutectic Si phase particles; and
   (c) thermal-plastic processing and heat-treating to obtain said aluminum alloys with a final shape and a modified microstructure, wherein the strengthening mechanisms of said aluminum alloys refer to a grain refinement strengthening of aluminum matrix, a dispersion strengthening of silicon particles, and a precipitation strengthening of second phase particles, wherein said aluminum alloys contain 0.2~2.0 weight percentage (wt%) of Mg, 8~18wt% of Si, wherein said aluminum alloys have an evenly refined microstructure, and said aluminum matrix is equiaxed with an average grain size < 6μm, and said silicon and said second phase particles are dispersed with an average size < 5μm.

2. The process, according to claim 1, wherein said alloy of said structural material contains at least one of Cu, Zn, Ni, Ti, and Fe, wherein a total weight percentage of said Cu, Zn, Ni, Ti, and Fe is equal or less than 2wt%.

3. The process according to claim 1 or 2, wherein in the step (a), said direct chill casting is performed at a relative casting temperature of 150~300°C above the liquidus line of said aluminum alloys, a casting speed of 100~200mm/min, and a cooling water flux of 5~15g/mm·s on the periphery of said ingot, wherein no modifier is added in said direct chill casting; wherein, in the step (b), said ingot is preheated to disperse eutectic Si phase particles at a heating rate of 10~30°C/min, a heating temperature of 450~520°C, and a holding time of 1~3 hours, wherein said aluminum alloy is cooled naturally or is cooled forcedly, wherein said aluminum alloy is heat-treated after said thermal-plastic processing.

4. The process according to any one of claims 1-3 wherein the step (c) further comprises a step of solution treatment and a step of artificial aging treatment for said aluminum alloys after said thermal-plastic processing with natural cooling, wherein said solution treatment is performed at a heating rate of 10~30°C/min, a solution treatment temperature of 500~540°C, and a solution treatment time of 0.5~3 hours, wherein said artificial aging treatment is performed at an aging temperature of 160~200°C, and an aging time of 1~10 hours.

5. The process according to any one of claims 1-3 wherein the step (c) further comprises a step of artificial or natural aging treatment for forcedly cooling said aluminum alloy after said thermal-plastic processing, wherein said artificial aging treatment is performed at an aging temperature of 160~200°C, and an aging time of 1~10 hours.

6. The process according to any one of claims 1-3 wherein the step (c) further comprises a step of hot rolling in said thermal-plastic processing, wherein a total reduction amount ot said hot rolling is greater than 40%.

7. The process according to any one of claims 1-3 wherein the step (c) further comprises a step of hot extrusion in said thermal-plastic processing, wherein an extrusion ratio of said hot extrusion is greater than 15.

8. The process according to any one of claims 1-3 wherein the step (c) further comprises a step of hot

forging in said thermal-plastic processing, wherein a forging ratio of said hot forging is greater than 40%.

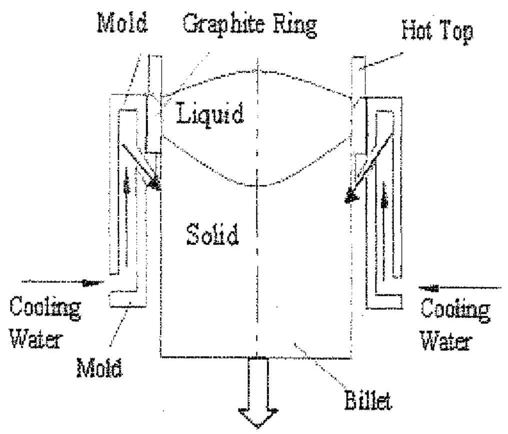
Mold
Graphite Ring
Hot Top
Liquid
Solid
Cooling
Water
Cooling
Water
Mold
Billet

FIG. 1


100 μm

FIG. 2

FIG. 3

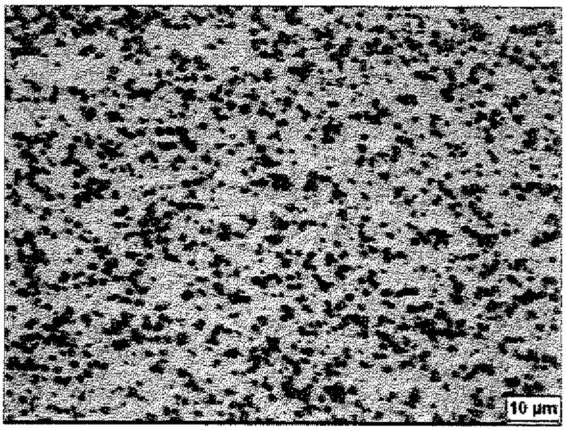

FIG. 4

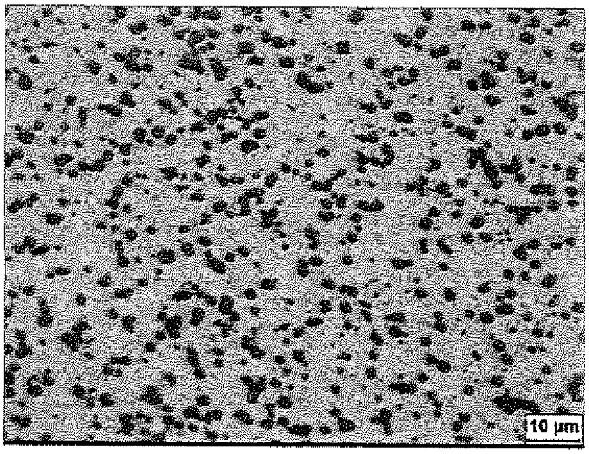

FIG. 5

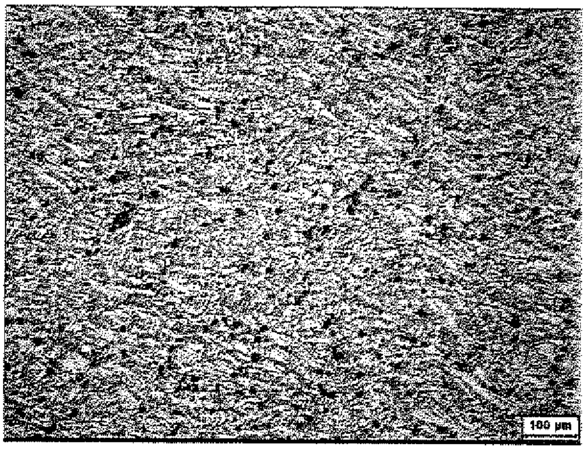

FIG. 6

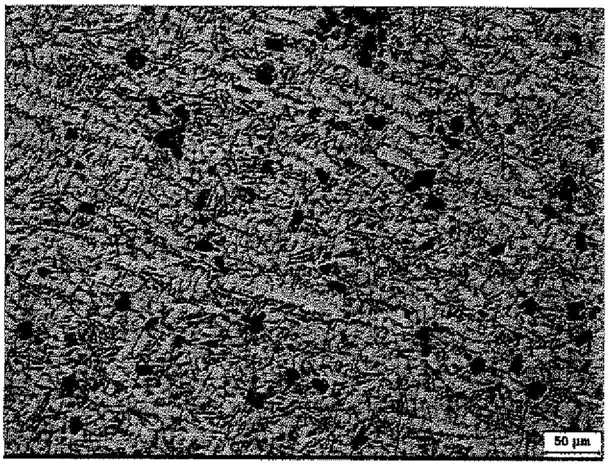

FIG. 7

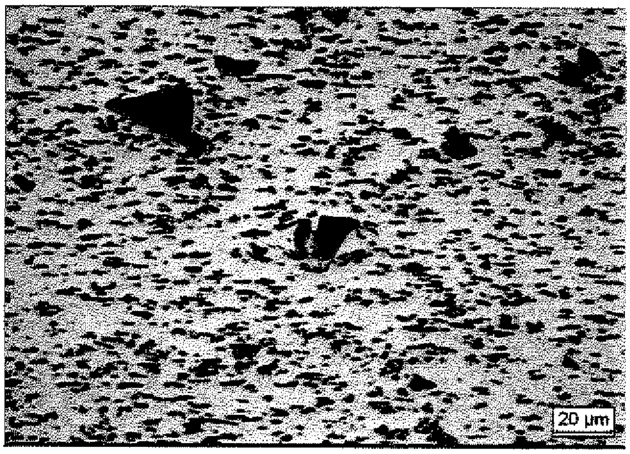

FIG. 8

FIG. 9

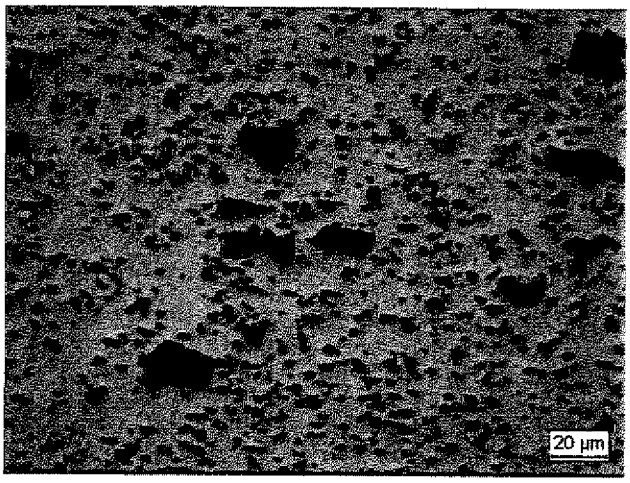

FIG. 10

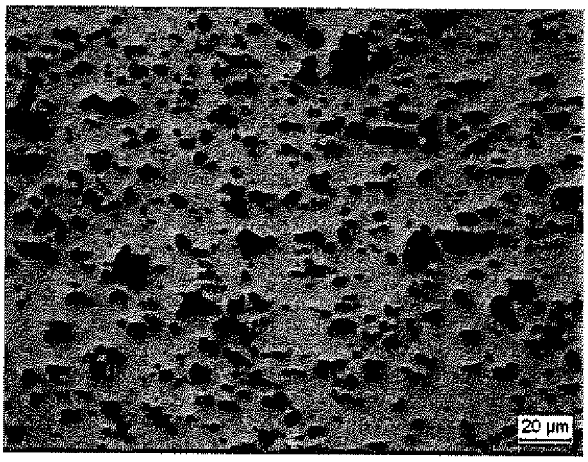

FIG. 11

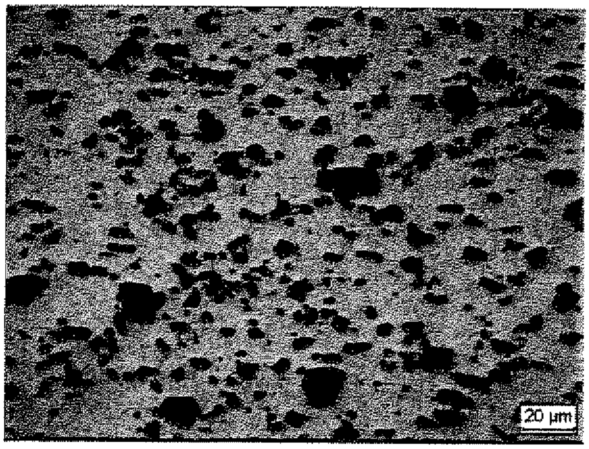

FIG. 12

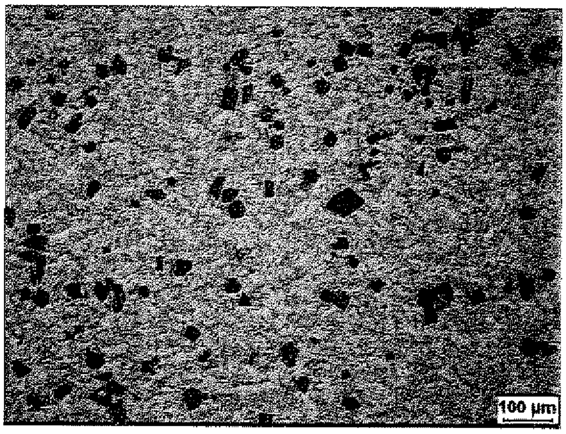

FIG. 13

Alloy	Status	Yield Strength(Mpa)	tensile strength(Mpa)	elongation rate(%)
Al-8.5Si-1.8Mg-0.27Fe	T1	175	252	13
Al-8.5Si-1.8Mg-0.27Fe	T6	296	344	7.2
Al-15.5Si-0.7Mg-0.27Fe	T1	120	232	11
Al-15.5Si-0.7Mg-0.27Fe	T6	280	325	7.5
Al-12.7Si-0.7Mg-1.5Cu-0.3Ni-0.3Ti-0.3Fe	T1	112	190	15
Al-12.7Si-0.7Mg-1.5Cu-0.3Ni-0.3Ti-0.3Fe	T6	268	347	9
6063 Al-(0.2-0.6)Si-(0.4-0.9)Mg	T5	110	160	8
6063 Al-(0.2-0.6)Si-(0.4-0.9)Mg	T6	180	205	8

FIG. 14

Alloy number	Si	Mg	Cu	Zn	Ni	Ti	Fe	Al
#1	8.5	0.7	0.5	0.3		0.3	0.27	Bal.
#2	8.8	1.8					0.27	Bal.
#3	12.7	0.7					0.3	Bal.
#4	12.7	1.2	1.5	0.3	0.3	0.3	0.3	Bal.
#5	15.5	0.7					0.27	Bal.
#6	15.5	1.8		0.8	0.5	0.3	0.27	Bal.
#7	17.5	0.7	1.0				0.27	Bal.
#8	17.5	1.0					0.27	Bal.

FIG. 15

Alloy number	Ingot sectional size (mm)	Casting temperature (°C)	Casting rate (min/min)	Cooling water rate (g/mm*s)
#1	Φ100	780	120	8
#1	600X50	780	180	8
#2	Φ100	780	120	8
#2	600X50	780	180	8
#3	Φ100	730	180	10
#3	600X50	730	180	10
#4	Φ100	730	140	8
#4	600X50	730	180	8
#5	Φ100	800	140	10
#5	600X50	850	180	10
#6	Φ100	800	160	12
#7	Φ60	850	120	10
#8	Φ60	850	180	14
#8	Φ100	850	180	14

FIG. 16

Alloy number	pre-treatment heating rate (°C/min)	pre-treatment temperature (°C)	pre-treatment time (hr)	extruction temperature (°C)	extruction rate	cooling method	deformation alloy number
#1	25	450	3	450	36	natural	1A
#2	20	450	3	450	36	natural	2A
#3	15	500	2	470	15	natural	3A
#4	15	500	2	470	15	enforcement	4A
#5	15	500	2	470	45	natural	5A
#7	10	500	4	480	30	enforcement	7A
#8	10	500	4	480	30	enforcement	8A

FIG. 17

Alloy number	pre-treatment heating rate (°C/min)	pre-treatment temperature (°C)	pre-treatment time (hr)	rolling temperature (°C)	rolling press rate (%)	cooling method	deformation alloy number
#1	20	450	3	450	50	natural	1B
#2	20	520	1	520	70	natural	2B
#3	20	500	2	500	60	natural	3B
#4	15	480	3	480	60	natural	4B
#4	15	520	1	520	70	natural	4B2
#5	15	500	3	500	60	natural	5B
#5	15	500	1	520	70	natural	5B2

FIG. 18

Alloy number	pre-treatment heating rate (°C/min)	pre-treatment temperature (°C)	pre-treatment time (hr)	forging temperature (°C)	forging rate(%)	cooling method	deformation alloy number
#2	25	500	2	500	65	natural	2C
#3	20	520	1	520	65	natural	3C
#5	15	500	2	500	50	natural	5C
#6	10	500	4	500	50	natural	6C
#6	15	490	4	490	50	natural	6C2
#7	10	500	4	500	50	natural	7C
#8	10	500	4	500	50	natural	8C

FIG. 19

deformation alloy number	Alloy number	heat treatment status	solution temperature (°C)	Soultion time(hr)	aritificial aging temperature (°C)	aritificial aging time (hr)	alloy number after heat treatment
1A	#1	T6	520	2	180	3	1AT6
3A	#3	T6	540	0.5	200	3	3AT6
4A	#4	T5			180	3	4AT6
5A	#5	T1					5AT1
5A	#6	T6	520	2	180	2	5AT6
7A	#7	T5			180	6	7AT5
8A	#8	T5			170	8	8AT5

FIG. 20

deformation alloy number	Alloy number	heat treatment status	solution temperature (°C)	Soultion time(hr)	aritificial aging temperature (°C)	aritificial aging time (hr)	alloy number after heat treatment
1B	#1	T6	500	3	160	8	1BT6
2B	#2	T5			180	3	2BT1
2B	#2	T6	520	2	160	10	2BT6
4B	#4	T7	540	0.5	200	8	4BT6
5B	#5	T8	520	1	200	4	5BT6
5B2	#5	T9	520	1	200	6	5BT26

FIG. 21

deformation alloy number	Alloy number	heat treatment status	solution temperature (°C)	Soultion time(hr)	aritificial aging temperature (°C)	aritificial aging time (hr)	alloy number after heat treatment
2C	#2	T6	520	3	180	6	2CT6
5C	#5	T6	540	0.5	200	4	5CT6
5C	#5	T1					5CT1
6C2	#6	T6	510	4	170	10	6C2T6
7C	#7	T6	510	3	200	2	7CT6
8C2	#8	T6	510	4	180	8	8C2

FIG. 22

Number of Alloy after heat treatment	yield strength $\sigma_{0.2}$ (MPa)	tensile strength $\sigma_{0.2}$ (MPa)	elongation rate(%)
1AT6	293	379	14.6
2AT6	302	378	12.5
2BT6	294	360	11.7
4AT5	290	375	10.4
4AT6	305	380	9.2
5AT1	120	232	10
5AT6	280	325	7.5
5BT6	300	366	7.6
6C2T6	260	343	6
7AT5	240	265	1.8
7CT6	285	327	2.5
8C2T6	296	339	2.8

FIG. 23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2008/001246

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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: C22C, C22F

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)

WPI, EPODOC, PAJ, CPRS, CNKI: Al, alumin?um, Mg, magnesium, Si, silicon, cast+, DC, direct chill+, thermal, thermo, plastic+, extrud+, extrusion, suppress+, squeeze+, compress+, heat+, isometric, cubic, equiaxial, equiaxis, crystal+, grain+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	CN1555423A (SHOWA DENKO KK) 15 Dec.2004 (15.12.2004)	
X	claim 71, description pages 4-6, 14 and 19	1,2
A	Whole document	3-8
A	CN1546708A (UNIV DONGHUA) 17 Nov.2004 (17.11.2004) whole document	1-8
D,A	CN1789456A (UNIV NORTHEASTERN) 21 Jun.2006 (21.06.2006) whole document Cited in the application	1-8
A	JP5-331604A (NIPPON LIGHT METAL CO) 14 Dec.1993 (14.12.1993) claim 1	1-8

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 Sept.2008 (08.09.2008)	**09 Oct. 2008 (09.10.2008)**

Name and mailing address of the ISA/CN	Authorized officer
The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	PANG Limin Telephone No. (86-10)62084751

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2008/001246

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP64-17834A (SHOWA DENKO KK et al.) 20 Jan.1989 (20.01.1989) whole document	1-8
A	US4068645A (COMALCO ALUMINIUM LTD) 17 Jan.1978 (17.01.1978) whole document	1-8
A	JP8-3701A (MITSUBISHI ALUMINIUM CO LTD) 09 Jan.1996 (09.01.1996) whole document	1-8
A	JP62-83453A (AISHIN KEIKINZOKU KK et al.) 16 Apr.1987 (16.04.1987) whole document	1-8
A	JP10-96039A (SUMITOMO LIGHT METAL IND CO) 14 Apr.1998 (14.04.1998) whole document	1-8

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2008/001246

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN1555423A	15.12.2004	WO03010349A1	06.02.2003
		US2003143102A1	31.07.2003
		EP1413636A1	28.04.2004
		AU2002323939A1	17.02.2003
		JP2003515695T	18.11.2004
		US2006027291A1	09.02.2006
		CA2454509 A	06.02.2003
CN1546708A	17.11.2004	CN1298878C	07.02.2007
CN1789456A	21.06.2006	CN100392129C	04.06.2008
JP5-331604A	14.12.1993	JP3318966B2	26.08.2002
JP64-17834A	20.01.1989	DE3823476A	19.01.1989
		US4973363A	27.11.1990
		DE3823476C2	27.07.1995
		JP2506115B2	12.06.1996
US4068645A	17.01.1978	DE2418389A	31.10.1974
		SE7404892A	21.11.1974
		FR2225534A	13.12.1974
		JP50116313A	11.09.1975
		GB1437144A	26.05.1976
		CA1017601A	20.09.1977
		FR2225534B	08.11.1974
		AU475116B	16.10.1975
JP8-3701A	09.01.1996	NONE	
JP62-83453A	16.04.1987	JP4018024B	26.03.1992
		JP1744090C	25.03.1993
JP10-96039A	14.04.1998	JP3835629B2	18.10.2006

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INTERNATIONAL SEARCH REPORT

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Continuation of: second sheet, A. CLASSIFICATION OF SUBJECT MATTER:

C22C21/02 (2006.01)i
C22C21/00 (2006.01)i
C22F1/043 (2006.01)i
C22F1/04 (2006.01)i

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