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(54) **AL-ZN-CU ALLOY AND MANUFACTURING METHOD THEREOF**

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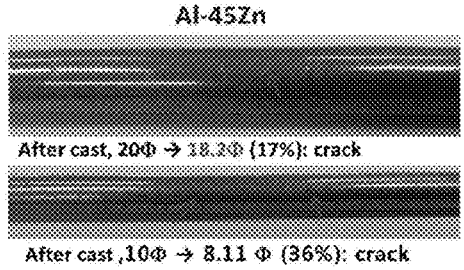
C22F 1/053 (2006.01)

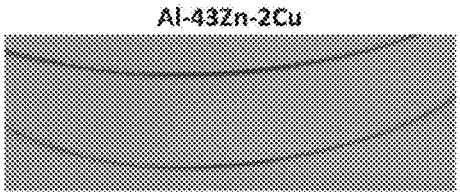
(52) **U.S. Cl.**

CPC ***C22C 21/10*** (2013.01); ***C22F 1/053*** (2013.01)

(57) **ABSTRACT**

The present invention relates to an Al—Zn—Cu alloy comprising: 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy, wherein a tensile strength is 230 to 450 MPa and an elongation is 2.75 to 10% in the cast state. According to the present invention, it is possible to provide an Al—Zn—Cu alloy having improved casting property, strength and elongation at the same time.





Moldability comparison according to the sectional area reduction rate in the cold forming process

Reduction rate of the cross-sectional area	10%	20%	35%	50%	75%
Al-45Zn	O	O	X	X	X
Al-45Zn-2Cu	O	O	O	O	O

FIG. 1

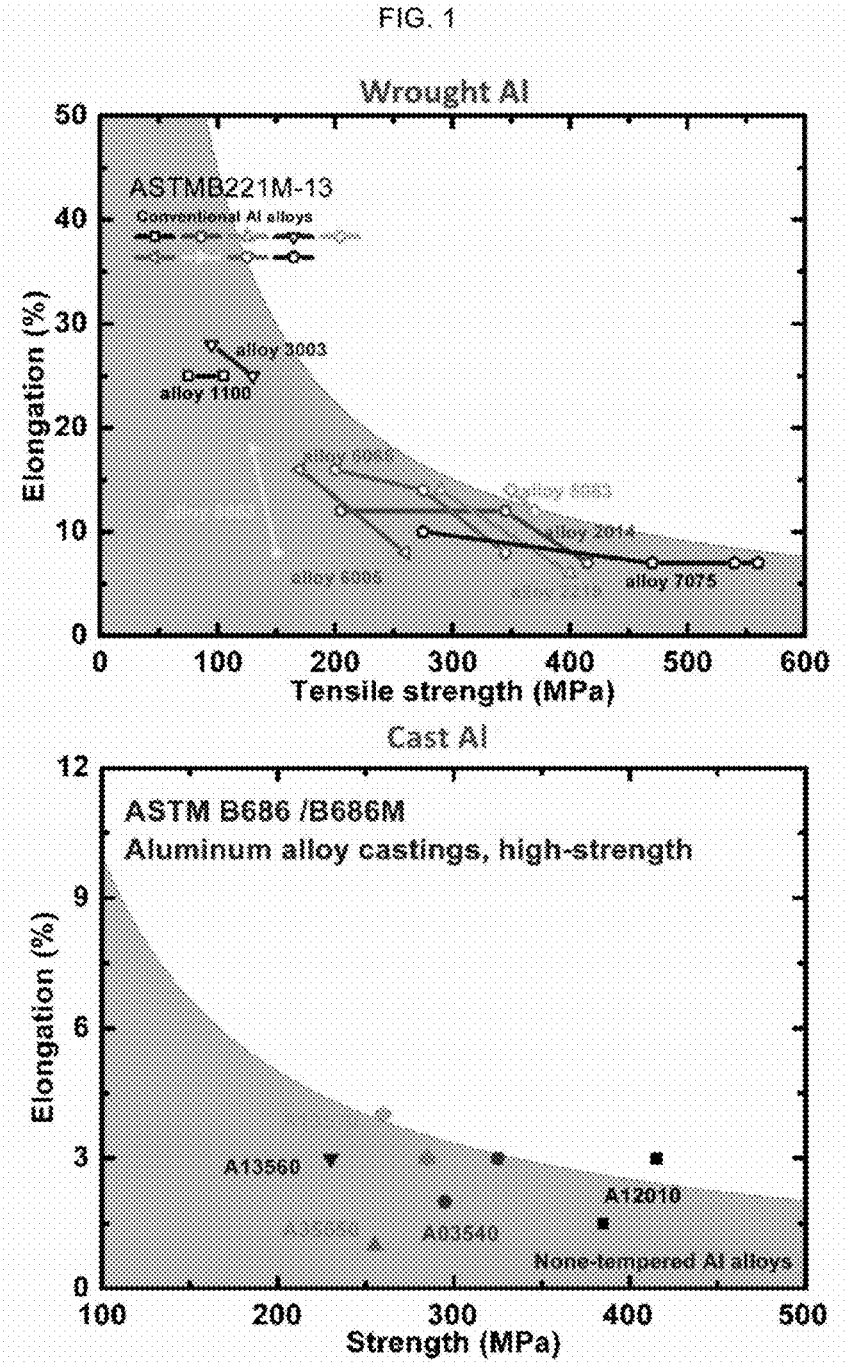
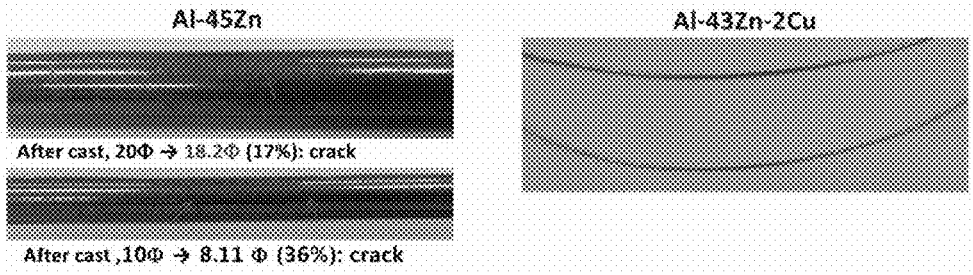

Wrought Al
ASTMB221M-13
Conventional Al alloys
alloy 3003
alloy 1100
alloy 2014
alloy 7075
Elongation (%)
Tensile strength (MPa)
Cast Al
ASTM B686 /B686M
Aluminum alloy castings, high-strength
A13560
A12010
A03540
None-tempered Al alloys
Elongation (%)
Strength (MPa)

FIG. 2



Moldability comparison according to the sectional area reduction rate in the cold forming process

Reduction rate of the cross-sectional area	10%	20%	35%	50%	75%
Al-45Zn	O	O	X	X	X
Al-45Zn-2Cu	O	O	O	O	O

FIG. 3

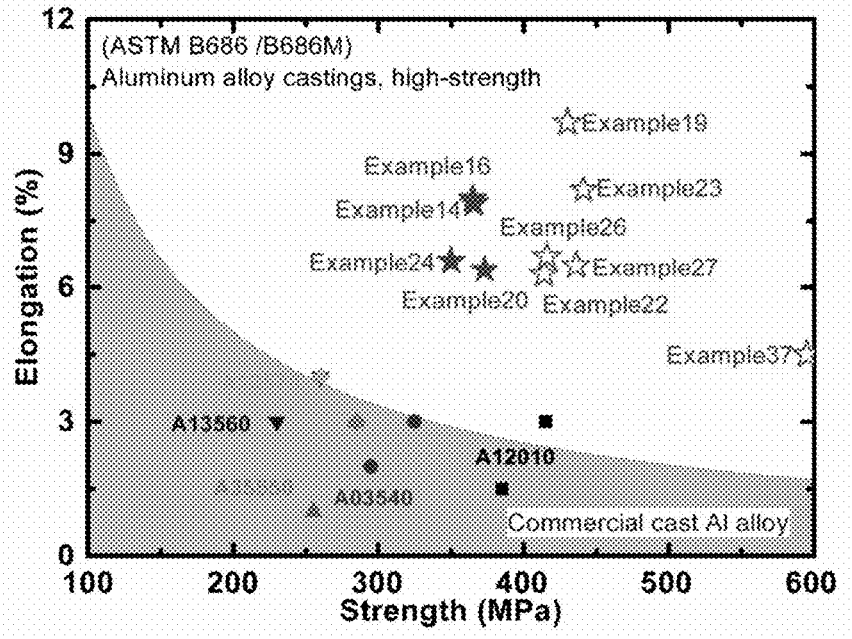


FIG. 4

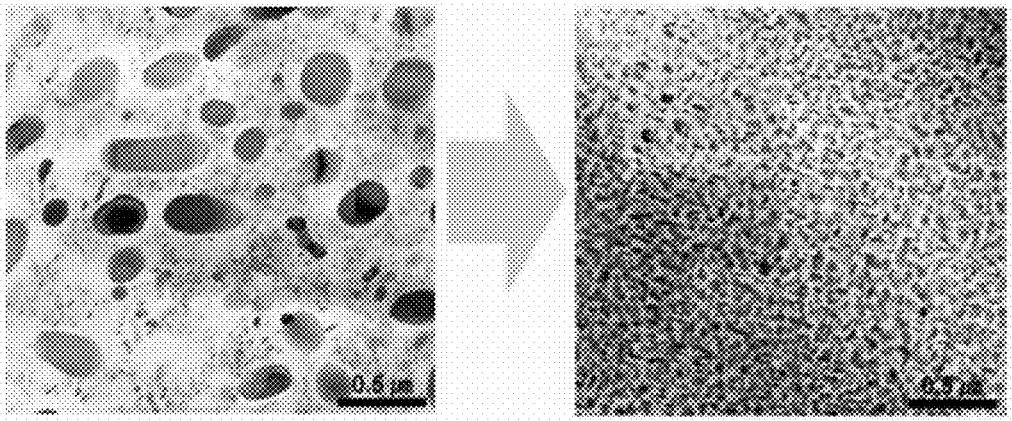


FIG. 5

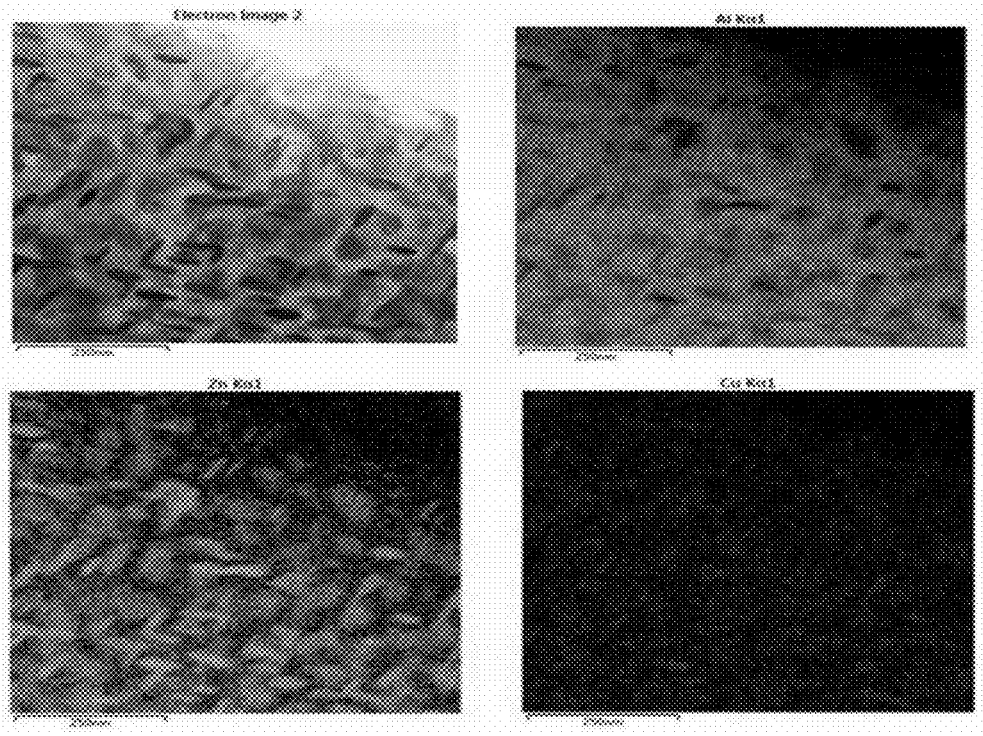
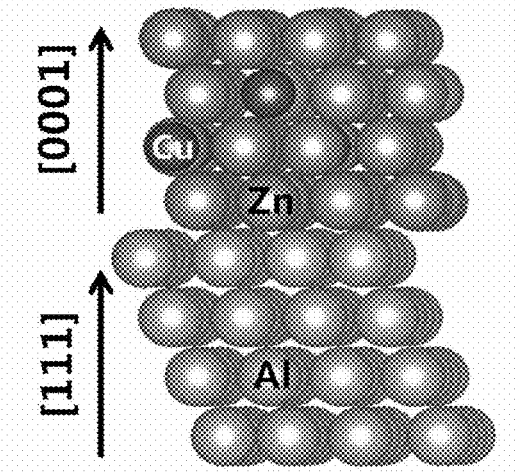


FIG. 6



The interface of Al/Zn-Cu alloy

FIG. 7A

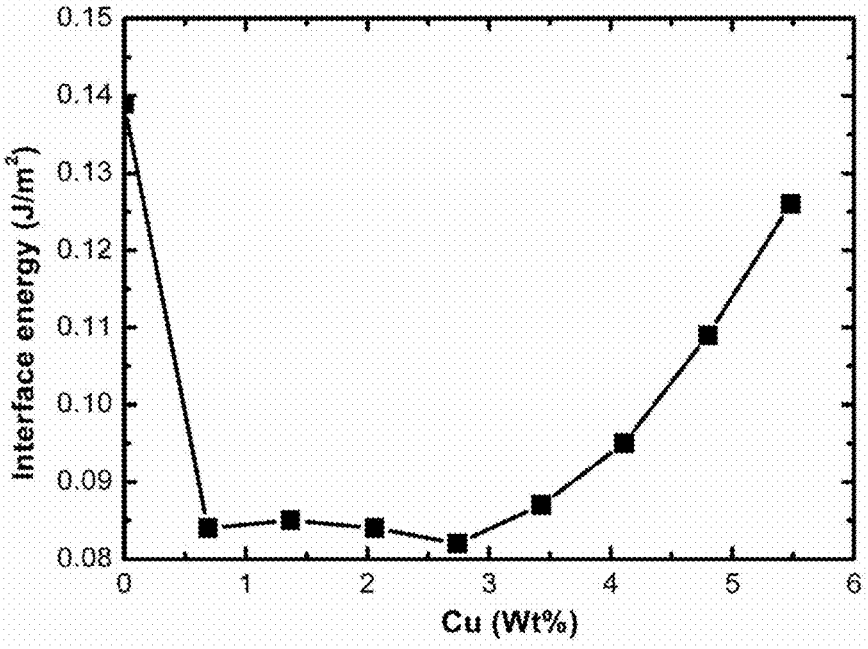


FIG. 7B

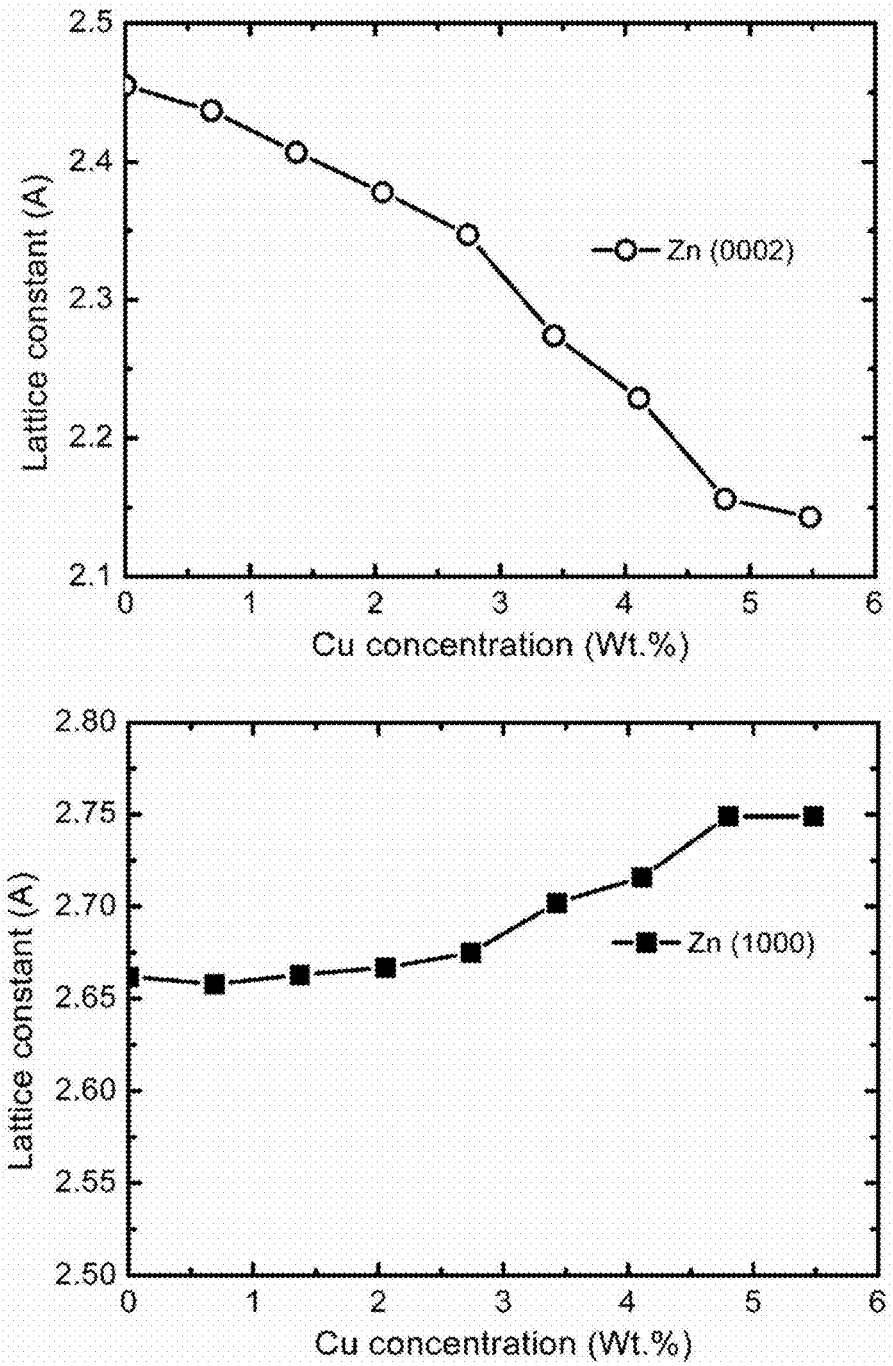

Lattice constant (A)
2.5
2.4
2.3
2.2
2.1
0
1
2
3
4
5
6
Cu concentration (Wt.%)
Zn (0002)
Lattice constant (A)
2.80
2.75
2.70
2.65
2.60
2.55
2.50
0
1
2
3
4
5
6
Cu concentration (Wt.%)
Zn (1000)

FIG. 8A

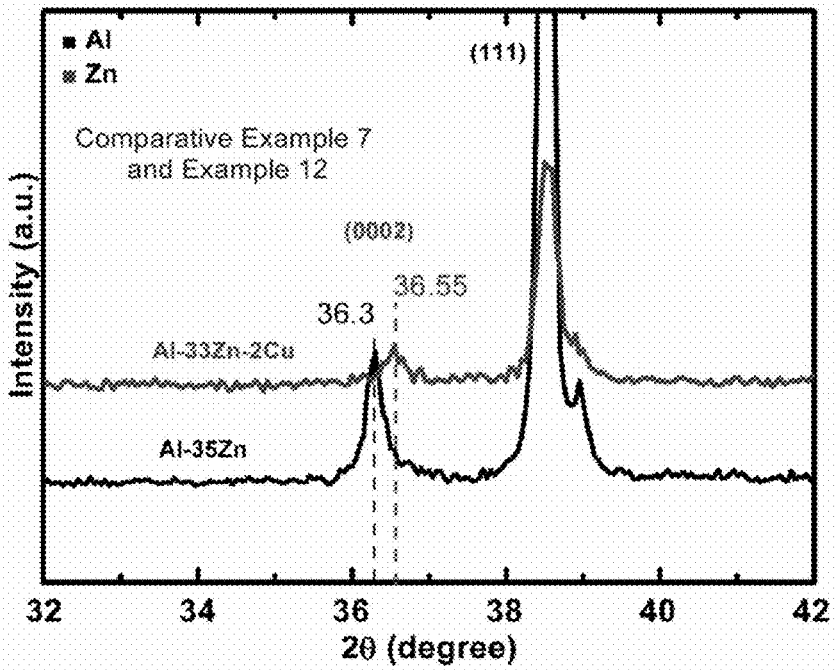

■ Al
※ Zn
(111)
Comparative Example 7
and Example 12
(0002)
36.55
36.3
Al-33Zn-2Cu
Al-35Zn
Intensity (a.u.)
32
34
36
38
40
42
2θ (degree)

FIG. 8B

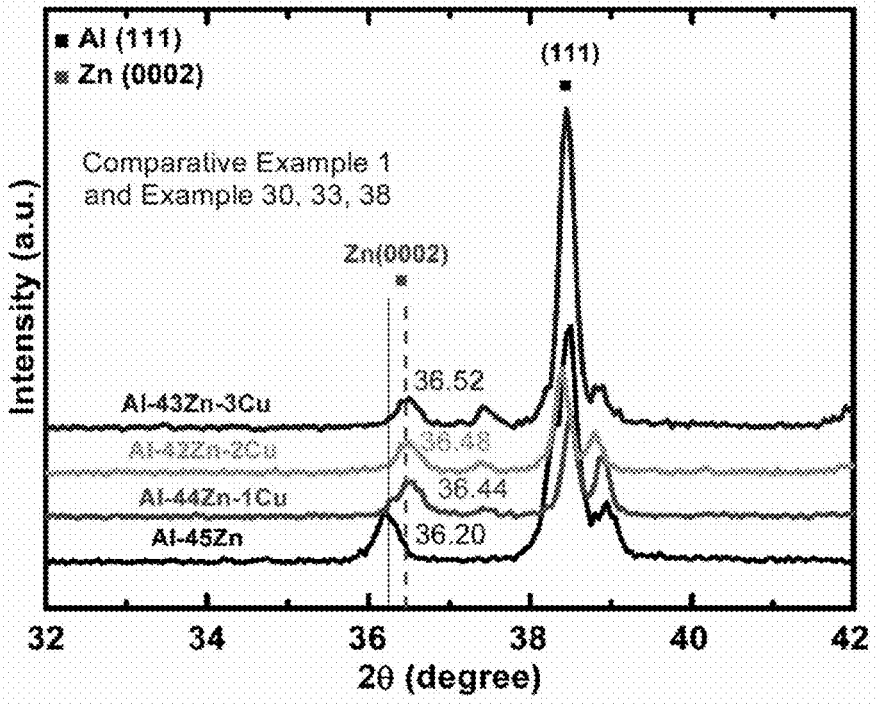

■ Al (111)
※ Zn (0002)
(111)
Comparative Example 1
and Example 30, 33, 38
Zn(0002)
36.52
Al-43Zn-3Cu
Al-42Zn-2Cu
36.48
Al-44Zn-1Cu
36.44
Al-45Zn
36.20
Intensity (a.u.)
32
34
36
38
40
42
2θ (degree)

FIG. 9A

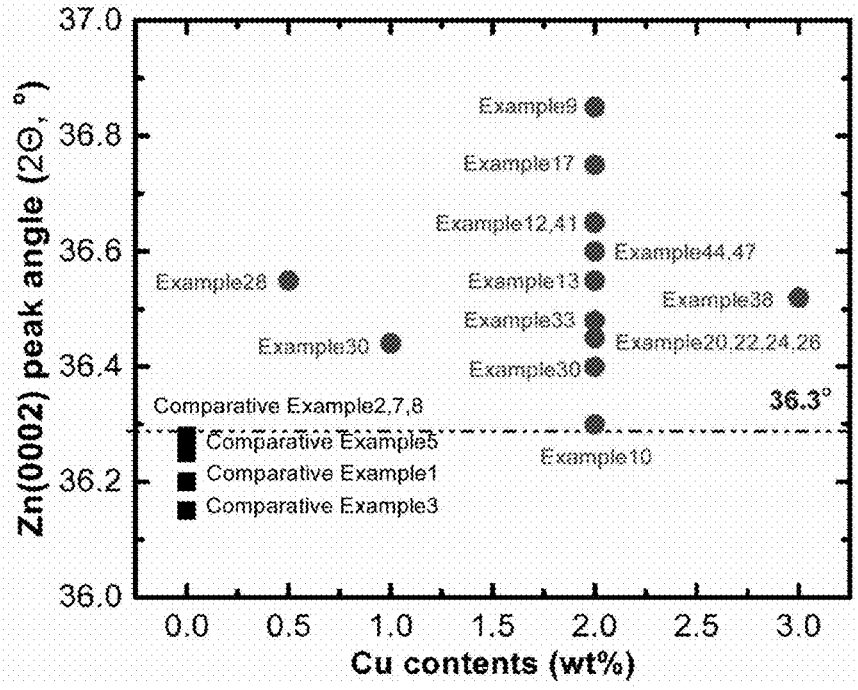

Zn(0002) peak angle (2Θ, °)
37.0
36.8
36.6
36.4
36.2
36.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Cu contents (wt%)
Example9
Example17
Example12,41
Example44,47
Example28
Example13
Example38
Example33
Example30
Example20,22,24,26
Example30
Comparative Example2,7,8
36.3°
Comparative Example5
Comparative Example1
Comparative Example3
Example10

FIG. 9B

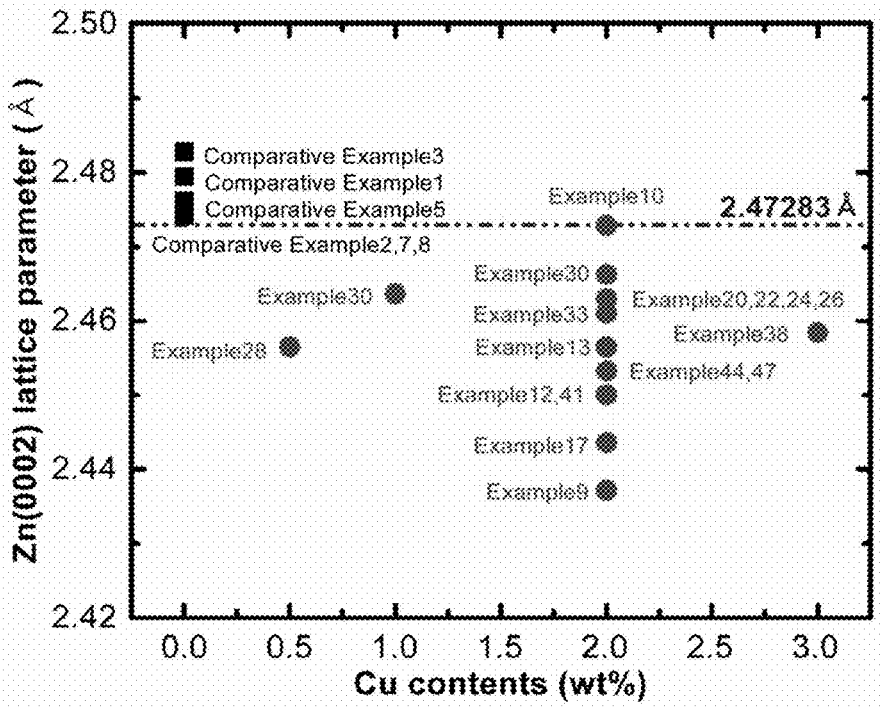

Zn(0002) lattice parameter (Å)
2.50
2.48
2.46
2.44
2.42
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Cu contents (wt%)
Comparative Example3
Comparative Example1
Comparative Example5
Example10
2.47283 Å
Comparative Example2,7,8
Example30
Example30
Example20,22,24,26
Example33
Example38
Example28
Example13
Example44,47
Example12,41
Example17
Example9

FIG. 10A

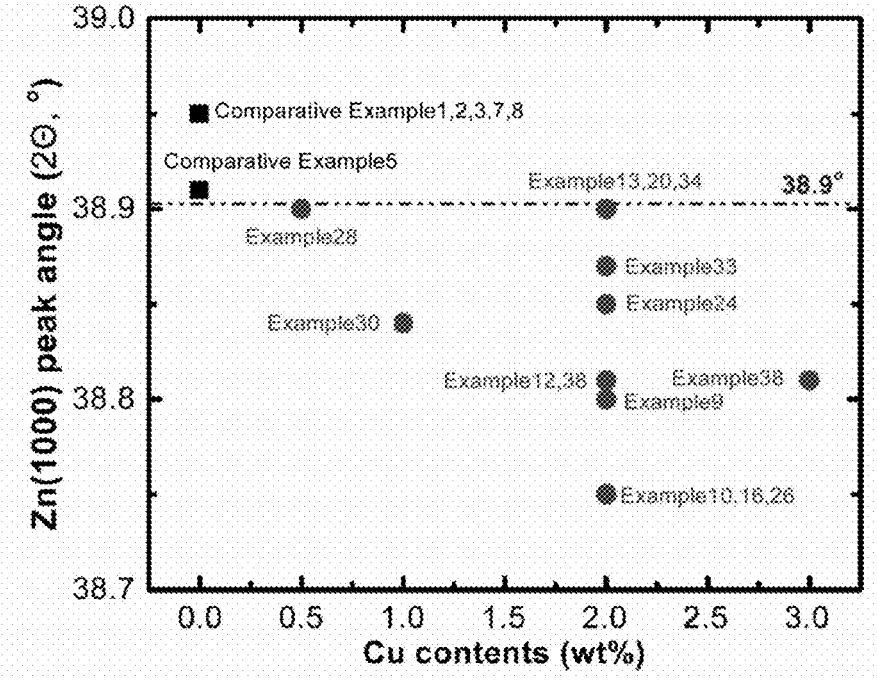


FIG. 10B

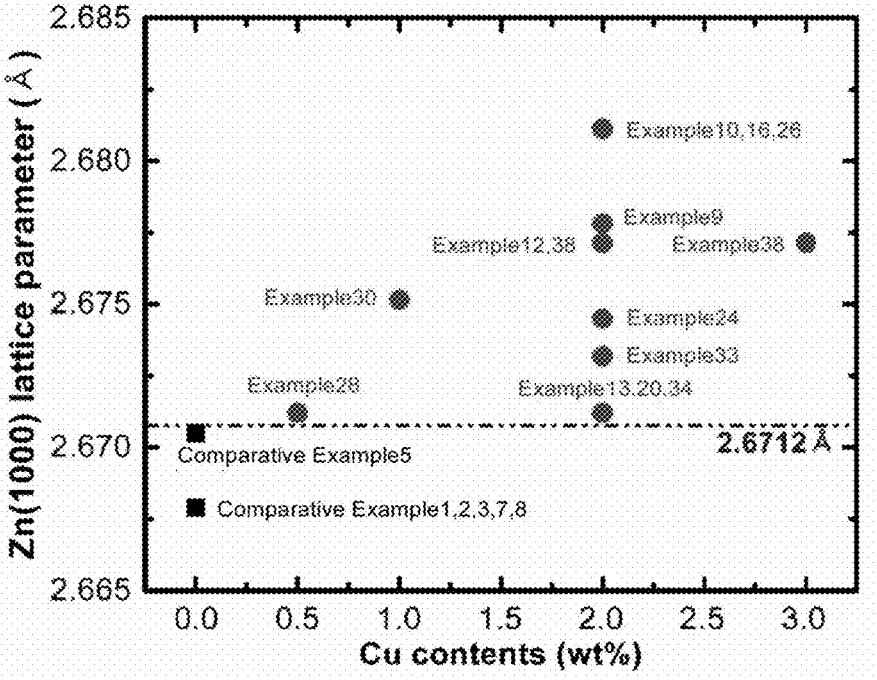


FIG. 11A

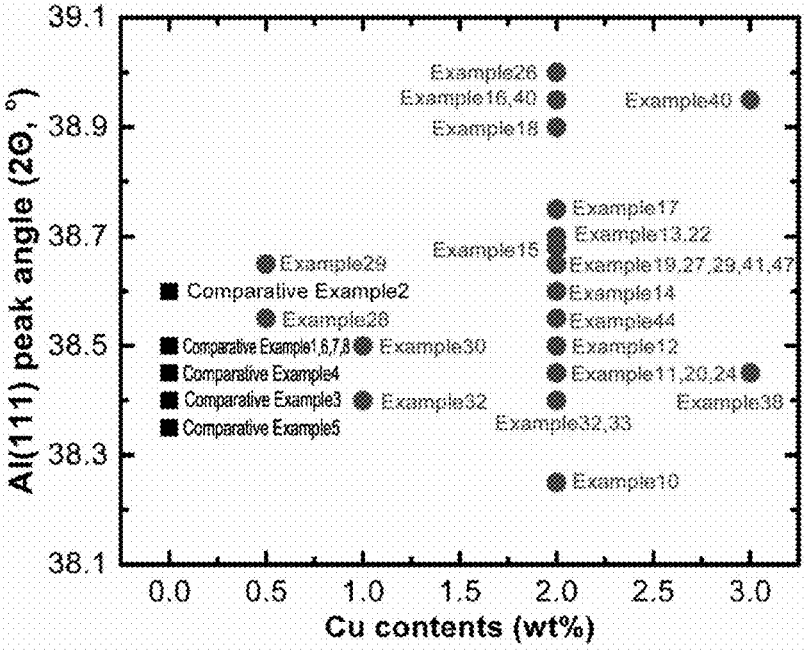


FIG. 11B

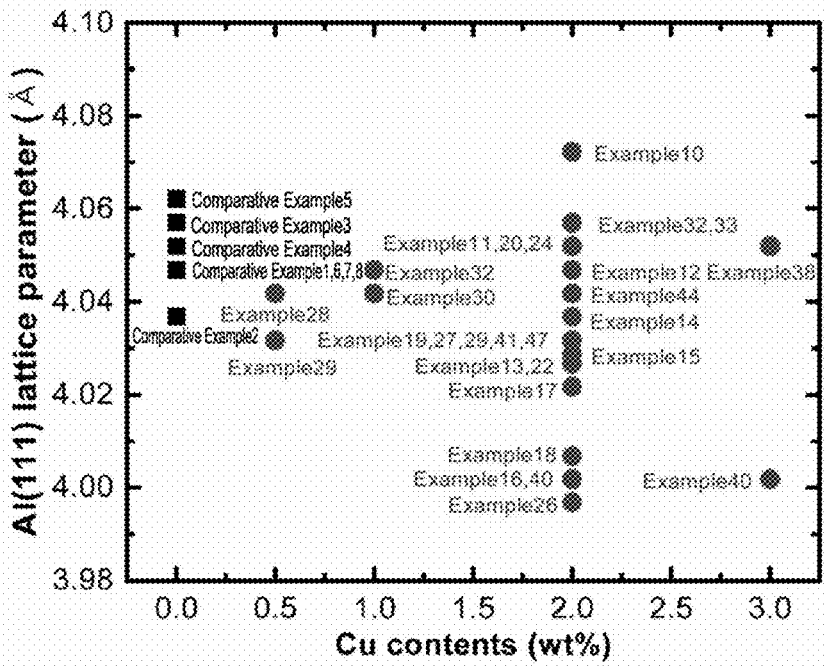


FIG. 12A

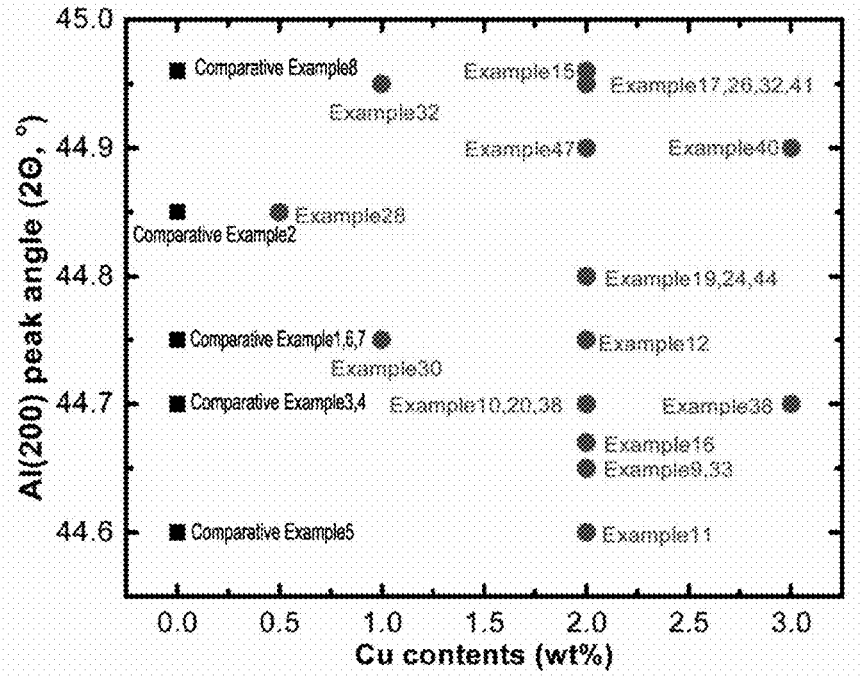


FIG. 12B

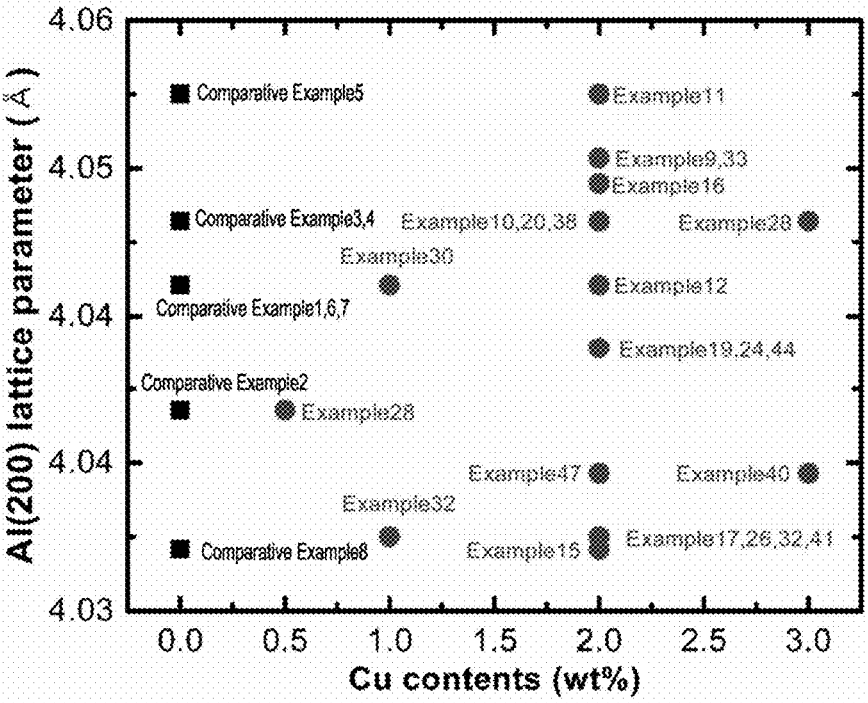


FIG. 13A

Comparative Example2: Cooling after heat treatment at 400°C of Al-45Zn

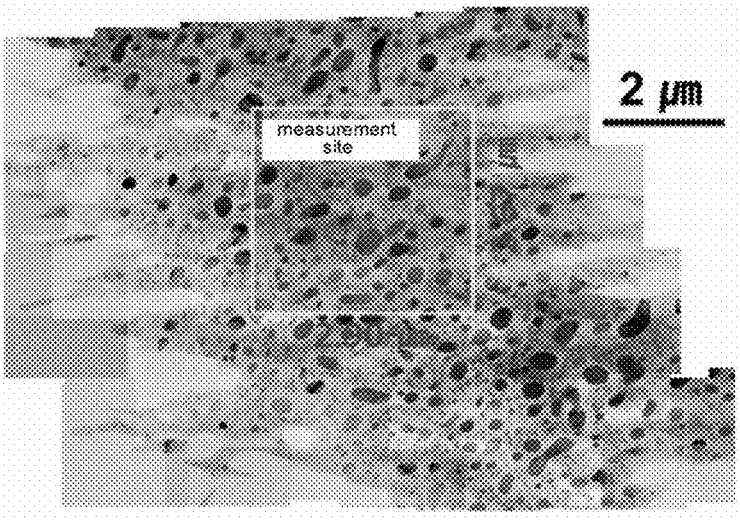


FIG. 13B

Example37: Cooling after heat treatment at 400°C of Al-43Zn-2Cu

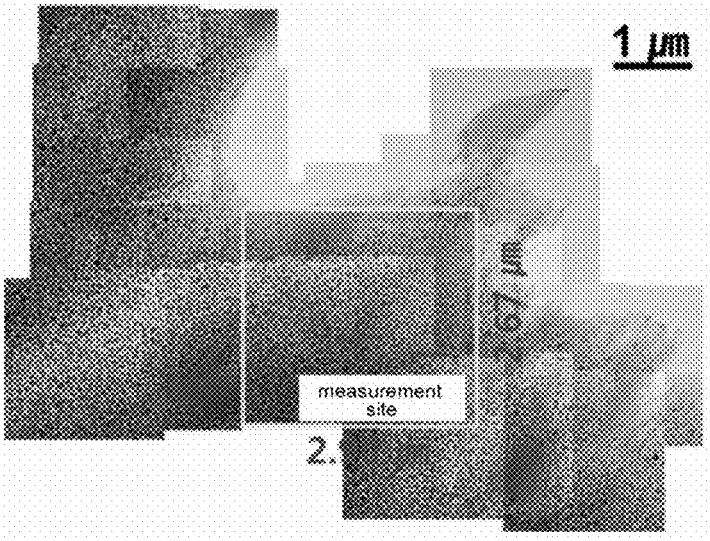


FIG. 13C

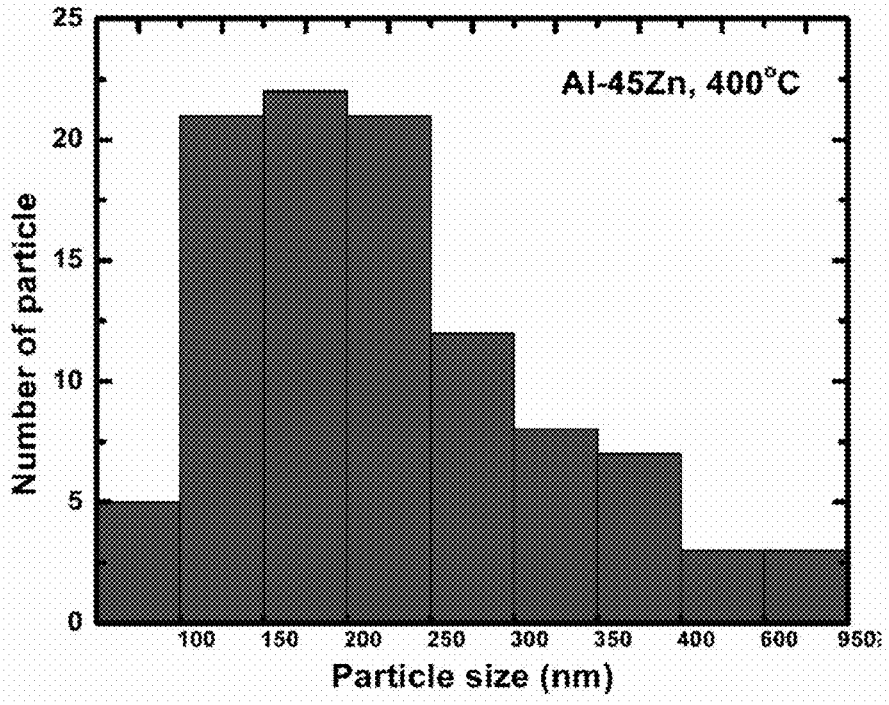


FIG. 13D

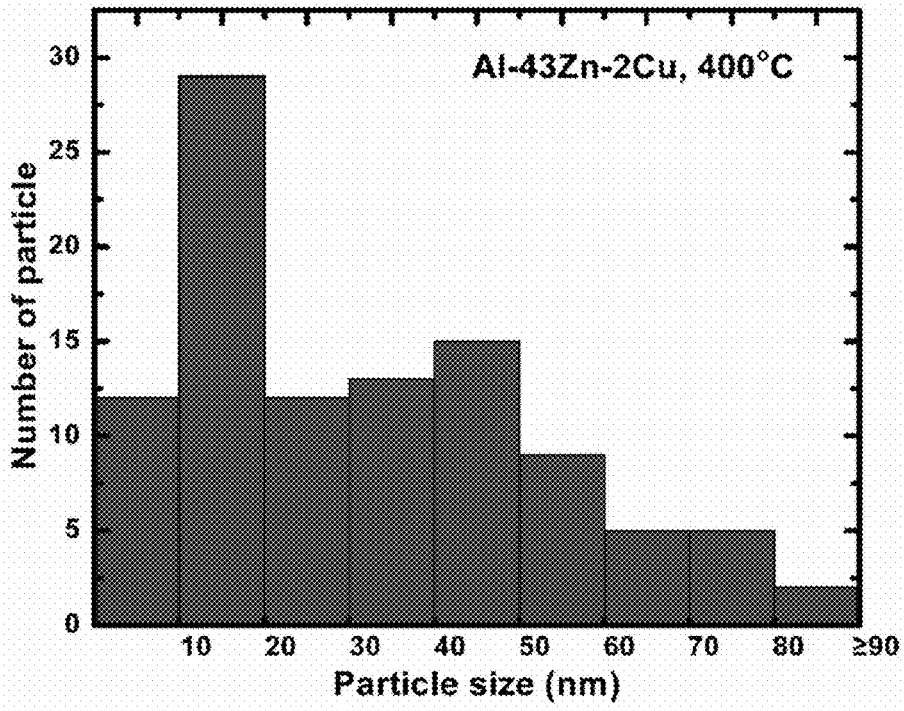


FIG. 14

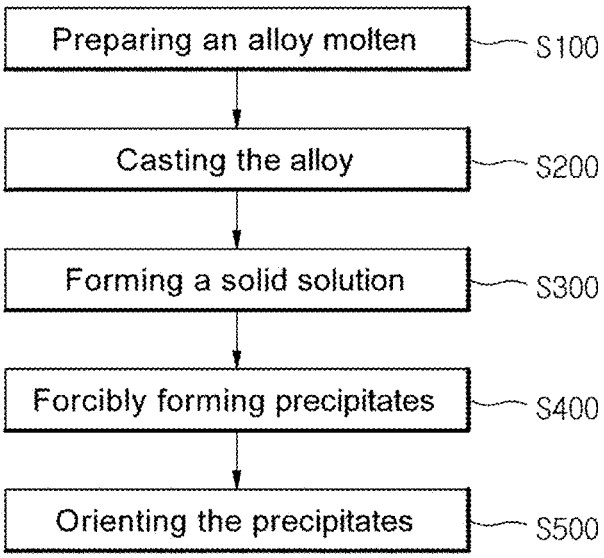

Preparing an alloy molten
S100
Casting the alloy
S200
Forming a solid solution
S300
Forcibly forming precipitates
S400
Orienting the precipitates
S500

FIG. 15

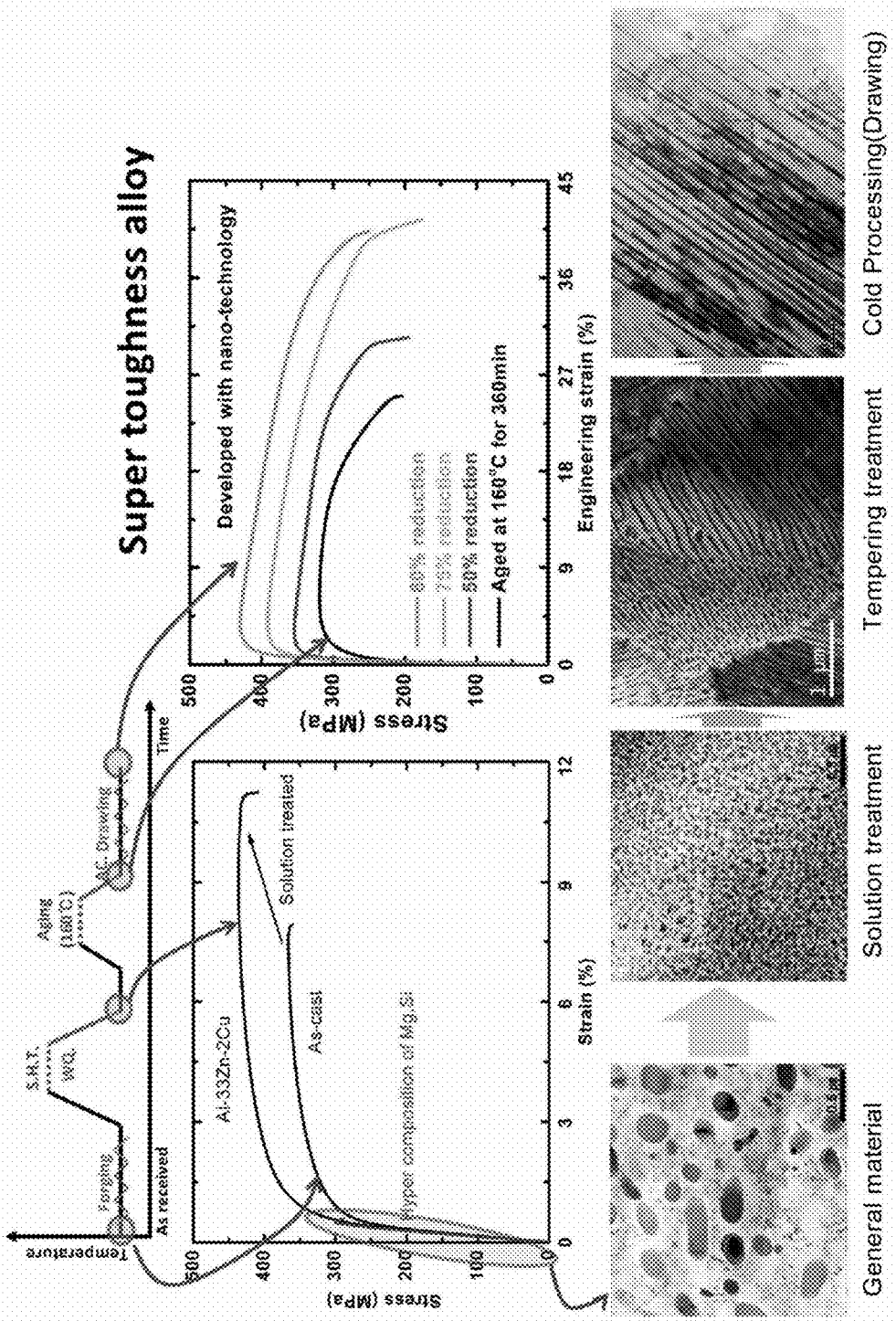
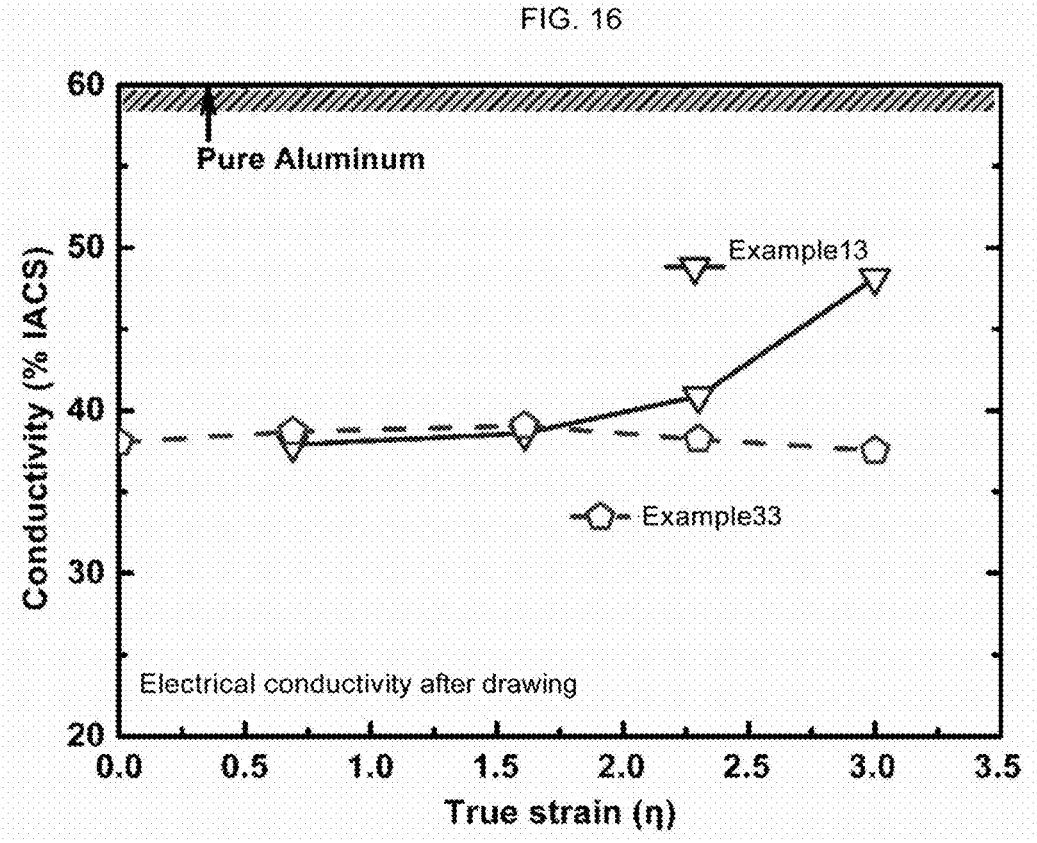

Super toughness alloy
Temperature
Time
Forging
As received
S.H.T.
W.Q.
Aging
(160°C)
W.C. Drawing
Al-33Zn-2Cu
As-cast
Solution treated
Hyper composition of Mg,Si
Stress (MPa)
Strain (%)
Developed with nano-technology
60% reduction
75% reduction
50% reduction
Aged at 160°C for 360min
Engineering strain (%)
General material
Solution treatment
Tempering treatment
Cold Processing(Drawing)

FIG. 16


Pure Aluminum
Example13
Example33
Electrical conductivity after drawing
Conductivity (% IACS)
True strain (η)
60
50
40
30
20
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

AL-ZN-CU ALLOY AND MANUFACTURING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit under 35 USC § 119(a) of Korean Patent Application No. 10-2017-0048119 filed on Apr. 13, 2017 in the Korean Intellectual Property Office, the entire disclosure of which is incorporated herein by reference for all purposes.

BACKGROUND

1. Field

[0002] The following description relates to an Al—Zn—Cu alloy and a manufacturing method thereof and more particularly, to an Al—Zn—Cu casting alloy, a heat-treated alloy and a wrought alloy having improved castability, tensile strength and elongation at the same time, and a manufacturing method thereof.

2. Description of Related Art

[0003] A casting process is widely used in various fields such as in the production of electric parts, optical instruments, vehicles, spinning machines, constructions, measuring instruments and the like, particularly automobile parts.

[0004] Aluminum alloys such as Al—Si alloys and Al—Mg alloys, which have excellent casting properties, have been generally used as cast aluminum alloys, but their tensile strengths are low. Therefore, aluminum alloys having a relatively high tensile strength are used for plastic processing such as extrusion, rolling, and forging. Such an aluminum alloy for plastic processing is excellent in plastic workability, but has a problem of poor castability in which cracking occurs during casting.

[0005] On the other hand, an aluminum alloy has been used as a structural material since it is a lightweight alloy and has excellent corrosion resistance and thermal conductivity. Since aluminum has a low mechanical property, an aluminum alloy including one or more of metals such as zinc, copper, silicon, magnesium, nickel, cobalt, zirconium, cerium and the like is widely used as a structural material such as an interior/exterior material in various industrial fields such as automobiles, ships, aircrafts. An aluminum-zinc alloy is used to improve aluminum hardness, usually containing 10 to 14 wt % of zinc relative to the total weight of the alloy.

[0006] In order to be used as a structural material for automobiles, ships, aircrafts, etc., tensile strength, elongation, and impact absorption energy are considered to be important mechanical characteristics. Generally, there is a problem that it is difficult to simultaneously improve the tensile strength and the elongation because there is a trade-off relationship in which one of the characteristics of the tensile strength and the elongation is attenuated when the other is improved (FIG. **1**).

[0007] Korean Patent No. 10-1387647 discloses an ultra-high tensile strength aluminum casting alloy and manufacturing method thereof.

SUMMARY

[0008] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0009] An object of the present invention is to provide an Al—Zn—Cu alloy having an improved casting property by minimizing cracking and the like.

[0010] Another object of the present invention is to provide an Al—Zn—Cu cast alloy and a heat-treated alloy having improved tensile strength and elongation at the same time.

[0011] Still another object of the present invention is to provide a manufacturing method capable of efficiently producing an Al—Zn—Cu cast alloy, a heat-treated alloy and a processing alloy having improved casting property, tensile strength and elongation at the same time.

[0012] According to an aspect of the present invention, there is provided an Al—Zn—Cu alloy comprising: 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy, wherein a tensile strength is 230 to 450 MPa and an elongation is 2.75 to 10% in the cast state.

[0013] According to an embodiment of the present invention, the tensile strength in the cast state may be 310 to 450 Mpa.

[0014] According to an embodiment of the present invention, the elongation in the cast state may be 4 to 10%.

[0015] According to another aspect of the present invention, there is provided an Al—Zn—Cu alloy comprising: 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy, wherein 2θ of a Zn(0002) plane of a lattice constant in the X-ray diffraction is 36.3 to 36.9.

[0016] According to further another aspect of the present invention, there is provided an Al—Zn—Cu alloy comprising: 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy, wherein 2θ of a Zn(0002) plane of a lattice constant in the X-ray diffraction is 38.7 to 38.9.

[0017] According to further another aspect of the present invention, there is provided an Al—Zn—Cu alloy comprising: 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy, wherein a conductivity is 37% IACS (International Annealed Copper Standard) or more.

[0018] According to further another aspect of the present invention, there is provided an Al—Zn—Cu alloy comprising: 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy, wherein at least one of the diameter and the length of a Zn phase in an Al matrix is 10 to 100 nm.

[0019] According to an embodiment of the present invention, the Al—Zn—Cu alloy may further comprise at least one of more than 0 to less than 1 part by weight of magnesium and more than 0 to less than 0.5 parts by weight of silicon, based on the total weight of the alloy.

[0020] According to further another aspect of the present invention, the Al—Zn—Cu alloy may be heat-treated to have a tensile strength of 330 to 600 Mpa.

[0021] According to an embodiment of the present invention, the Al—Zn—Cu alloy may have an elongation of 4 to 12%.

[0022] According to an embodiment of the present invention, the heat-treatment may be performed at a temperature of 150 to 500° C.

[0023] According to further another aspect of the present invention, there is provided a method for manufacturing an Al—Zn—Cu alloy comprising: preparing an alloy molten comprising: 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy; and casting by filling the alloy molten into a metallic mold or a sand mold.

[0024] According to an embodiment of the present invention, the step for preparing an alloy molten may be performed at 650 to 750° C. and comprises degassing after the alloy is completely melted.

[0025] According to an embodiment of the present invention, tensile strength of the Al—Zn—Cu alloy may be 230 to 450 MPa and elongation may be 2.75 to 10% in the cast state.

[0026] According to an embodiment of the present invention, the Al—Zn—Cu alloy may have 2θ of a Zn(0002) plane of the lattice constant in the X-ray diffraction of 36.3 to 36.9.

[0027] According to an embodiment of the present invention, the Al—Zn—Cu alloy may have 2θ of a Zn(1000) plane of the lattice constant in the X-ray diffraction of 38.7 to 38.9.

[0028] According to an embodiment of the present invention, the Al—Zn—Cu alloy may have at least one of the diameter and the length of the Zn phase in the Al matrix of 10 to 100 nm.

[0029] According to an embodiment of the present invention, the method may further comprise forming a solid solution by heat-treating the Al—Zn—Cu alloy at a temperature of 150 to 500° C.

[0030] According to an embodiment of the present invention, the heat-treatment may be performed for 30 minutes or more.

[0031] According to further another aspect of the present invention, there is provided a cast product manufactured from the alloy.

[0032] According to further another aspect of the present invention, there is provided an aluminum alloy product manufactured from the alloy.

[0033] According to the present invention, it is possible to provide an Al—Zn—Cu alloy having improved casting properties by minimizing cracking and the like.

[0034] According to the present invention, it is possible to provide an Al—Zn—Cu alloy and a heat-treated alloy having improved strength and elongation at the same time.

[0035] According to the present invention, it is possible to efficiently produce an Al—Zn—Cu cast alloy, a heat-treated alloy and a processing alloy with improved casting properties, tensile strength and elongation at the same time.

[0036] According to the present invention, it is possible to efficiently produce an Al—Zn—Cu alloy having improved moldability, tensile strength, elongation and conductivity at the same time.

[0037] Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] FIG. **1** is graphs illustrating a trade-off relationship between tensile strength and ductility of conventional aluminum alloy for processing and aluminum alloy for casting.

[0039] FIG. **2** is an image illustrating that moldability of a cast alloy according to an embodiment of the present invention is excellent.

[0040] FIG. **3** is a graph illustrating that an Al—Zn—Cu alloy according to an embodiment of the present invention is simultaneously improved in tensile strength and elongation as compared with a conventional alloy.

[0041] FIG. **4** is images illustrating improvement in mechanical properties of a cast alloy according to an embodiment of the present invention due to reduction in size of a zinc phase and reduction in distance between particles.

[0042] FIG. **5** is images illustrating that copper is incorporated into zinc particles when copper is added.

[0043] FIG. **6** is a diagram illustrating an interface of an Al/Zn—Cu alloy according to an embodiment of the present invention for calculating a change in interface energy between a zinc phase and an aluminum phase by copper addition.

[0044] FIG. **7**A is a graph illustrating a change in interface energy of a zinc phase by copper addition.

[0045] FIG. **7**B is a graph illustrating a change in lattice constant of zinc by copper addition.

[0046] FIGS. **8**A and **8**B are graphs illustrating a change in lattice constant of a zinc (0002) plane by copper addition.

[0047] FIGS. **9**A and **9**B are graphs illustrating changes in peak angle (2θ) and lattice constant of a Zn(0002) plane depending on Cu content of an alloy according to an embodiment of the present invention.

[0048] FIGS. **10**A and **10**B are graphs illustrating changes in peak angle (2θ) and lattice constant of a Zn(1000) plane depending on Cu content of the alloy according to an embodiment of the present invention.

[0049] FIGS. **11**A and **11**B are graphs illustrating changes in peak angle (2θ) and lattice constant of an Al(111) plane depending on Cu content of an alloy according to an embodiment of the present invention.

[0050] FIGS. **12**A and **12**B are graphs illustrating changes in peak angle (2θ) and lattice constant of an Al(200) depending on Cu content of an alloy according to an embodiment of the present invention.

[0051] FIGS. **13**A and **13**B are images illustrating a change in the size of a zinc phase upon cooling after heat treatment of an alloy according to an embodiment of the present invention by Cu addition.

[0052] FIGS. **13**C and **13**D are graphs illustrating the zinc phase size of the measurement site indicated in FIGS. **13**A and **13**B.

[0053] FIG. **14** is a flowchart illustrating a method for manufacturing an Al—Zn—Cu alloy according to an embodiment of the present invention.

[0054] FIG. **15** is diagrams illustrating a method for manufacturing an Al—Zn—Cu alloy according to an embodiment of the present invention and characteristics of the alloy by process.

[0055] FIG. **16** is a graph illustrating a change in conductivity according to true strains of an Al—Zn—Cu alloy according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0056] The terms used in the description are intended to describe certain embodiments only, and shall by no means restrict the present disclosure. Unless clearly used otherwise, expressions in the singular number include a plural meaning.

[0057] In the present description, an expression such as "comprising" or "consisting of" is intended to designate a characteristic, a number, a step, an operation, an element, a part or combinations thereof, and shall not be construed to preclude any presence or possibility of one or more other characteristics, numbers, steps, operations, elements, parts or combinations thereof.

[0058] In the present description, when a component is referred to "comprising", it means that it can include other components as well, without excluding other components unless particularly stated otherwise. Also, throughout the specification, the term "on" means to be located above or below a target portion, and does not necessarily mean that it is located on the upper side with respect to the gravitational direction.

[0059] While the present disclosure has been described with reference to particular embodiments, it is to be appreciated that various changes and modifications may be made by those skilled in the art without departing from the spirit and scope of the present disclosure, as defined by the appended claims and their equivalents. Throughout the description of the present disclosure, when describing a certain technology is determined to evade the point of the present disclosure, the pertinent detailed description will be omitted.

[0060] While such terms as "first" and "second," etc., may be used to describe various components, such components must not be limited to the above terms. The above terms are used only to distinguish one component from another.

[0061] The disclosure will be described below in more detail with reference to the accompanying drawings, in which those components are rendered the same reference number that are the same or are in correspondence, regardless of the figure number, and redundant explanations are omitted.

[0062] An Al—Zn—Cu alloy of the present invention comprises 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the balance of aluminum, wherein a tensile strength is 230 to 450 MPa and an elongation is 2.75 to 10% in the cast state.

[0063] The Al—Zn—Cu alloy of the present invention has a remarkable improved moldability as compared with a conventional cast alloy at the above compositional amounts. That is, the cast alloy according to the present invention does not cause cracks even when a cross-sectional area is reduced by 75% in the cold working (FIG. **2**).

[0064] In addition, the Al—Zn—Cu alloy of the present invention can simultaneously improve tensile strength and elongation in the cast state (FIG. **3**).

[0065] In the present invention, zinc (Zn) is added to aluminum as an alloy element to effectively increase tensile strength and hardness. In the Al—Zn—Cu alloy for casting according to the present invention, zinc is added in an amount of 18 to 50 parts by weight based on the total weight of the alloy, but it is not limited thereto. When the content of zinc is less than 18 parts by weight, the effect of increasing the tensile strength is insignificant. When the content of zinc is more than 50 parts by weight, the casting property is lowered and may cause hot shortness.

[0066] The zinc content may be 20 to 50 parts by weight, 20 to 45 parts by weight, 20 to 40 parts by weight, 30 to 50 parts by weight, 30 to 45 parts by weight, or 30 to 40 parts by weight, but it is not limited thereto. The zinc content may be in the range of 30 to 45 parts by weight based on the total weight of the alloy, but it is not limited thereto. In this case, the Al—Zn—Cu alloy may have a tensile strength of 350 to 450 MPa and an elongation of 4 to 10% in the cast state (FIG. **3**).

[0067] In the present invention, copper (Cu) is added to aluminum as an alloy element to make the largest contribution to the increase in tensile strength. The addition of copper to the aluminum-zinc alloy reduces the size of the zinc particle during cooling after the heat treatment, thereby significantly reducing the distance between the particles (FIG. **4** and FIG. **5**).

[0068] Copper added in the present invention is incorporated in zinc to lower the interface energy on a Zn precipitate phase/an Al matrix phase (FIG. **6**). As the interface energy on the precipitation phase and the matrix phase decreases, the average size of precipitates decreases. Thus, the addition of copper reduces the average size of the precipitate zinc. As a result, the spacing between the zinc particles is greatly reduced and the tensile strength of the cast alloy is increased.

[0069] Referring to FIG. **6**, the closest surfaces of the Al phase and the Zn phase, which are the surfaces with low energy, are bonded to each other. The Zn(0002) and Al(100) planes are bonded, and have the most Al—Zn bonds. When the content of copper is increased to 6 wt %, the interface energy (E_{inter}) between Al(111) and Zn(0001) can be defined by the following Equation 1.

Equation 1

$$E_{inter} = \frac{E_{Al/Zn(Cu)} - (E_{Al} + E_{Zn(Cu)})}{A} \quad (1)$$

[0070] $E_{AlZn(Cu)}$, E_{Al} and $E_{Zn(Cu)}$ are the total energies of interface structure of Al/Zn(Cu), bulk Al and bulk Zn(Cu), respectively, and A is the total area of the Al/Zn(Cu) interface.

[0071] (References: Equation: Perdew-Burke-Emzerhof approximation (PBE) [1] for the exchange-correlation potential as implanted in the Vienna Ab-initio Simulation Package code (VASP).[2,3] [1] J. P. Perdew, K. Burke, and M. Ernzerhof, Phys. Rev. Lett. 77, 3865 (1996) [2] G. Kresse and J. Hafner, Phys. Rev. B 47, 558 (1993) [3] G. Kresse and J. Furthmuller, Phys. Rev. B 54, 11169 (1996))

[0072] In the Al—Zn—Cu alloy for casting according to the present invention, copper is added in an amount of 0.05 to 5 parts by weight based on the total weight of the alloy, but it is not limited thereto. When the content of copper is less than 0.05 parts by weight, the effect of increasing the tensile strength is insignificant. When the content of copper is more than 5 parts by weight, the castability may be lowered and may cause hot shortness.

[0073] The content of copper may be 0.05 to 5 parts by weight, 0.05 to 4 parts by weight, 0.05 to 3 parts by weight, 0.05 to 2 parts by weight, 0.1 to 5 parts by weight, 0.1 to 4 parts by weight, 0.1 to 3 parts by weight, 0.1 to 2 parts by weight, 0.5 to 5 parts by weight, 0.5 to 4 parts by weight, 0.5 to 3 parts by weight, 0.5 to 2 parts by weight, 1 to 5 parts by weight, 1 to 4 parts by weight, 1 to 3 parts by weight, 1

to 2 parts by weight, 2 to 5 parts by weight, 2 to 4 parts by weight, 2 to 3 parts by weight, 3 to 5 parts by weight, or 3 to 4 parts by weight, but it is not limited thereto.

[0074] The content of copper may be in the range of 1 to 4 parts by weight based on the total weight of the alloy, though it is not limited thereto. In this case, the Al—Zn—Cu alloy may have a tensile strength of 310 to 450 MPa and an elongation of 4 to 10% in the cast state.

[0075] The Al—Zn—Cu alloy of the present invention has 2θ of a Zn(0002) plane of a lattice constant of 36.3 to 36.9 in X-ray diffraction.

[0076] As described above, Cu in the Al—Zn—Cu alloy of the present invention remarkably reduces the interface energy on the Zn precipitation phase/the Al matrix phase. Therefore, the addition of copper to the aluminum-zinc alloy sharply reduces the interface energy of the Zn(0002)/Al (100) plane within a certain range (FIG. **7**A). In addition, the addition of copper to the aluminum-zinc alloy significantly reduces the lattice constant of the Zn(0002) plane, while the lattice constant of the Zn(1000) plane increases gently with increasing copper solubility (FIG. **7**B). Therefore, according to the present invention, a sharp reduction in the interface energy of the Zn(0002)/Al(100) plane due to the addition of copper to the aluminum-zinc alloy is a direct cause of a significant reduction in the lattice constant of the Zn(0002) plane.

[0077] The lattice constant as described above corresponds to the maximum peak angle on X-ray diffraction. Thus, the addition of copper to the aluminum-zinc alloy significantly reduces the lattice constant of the Zn(0002) plane and increases 2θ of the Zn(0002) plane during X-ray measurement (FIGS. **8**A and **8**B).

[0078] Accordingly, the Al—Zn—Cu alloy of the present invention exhibits an increase in 2θ of a Zn(0002) plane of a lattice constant in the X-ray diffraction to the range of 36.3 to 36.9 (FIGS. **9**A and **9**B).

[0079] As described above, the lattice constant corresponds to the maximum peak angle on X-ray diffraction. In addition, the addition of copper to the aluminum-zinc alloy increases a lattice constant of the Zn(1000) plane and decreases the 2θ of the Zn(1000) plane during X-ray measurement.

[0080] Accordingly, the Al—Zn—Cu alloy of the present invention exhibits a reduction in 2θ of a Zn(1000) plane of a lattice constant in the X-ray diffraction to the range of 38.7 to 38.9 (FIGS. **10**A and **10**B).

[0081] On the other hand, the position of the Al peak is not directly affected by the addition of Cu, since copper is not incorporated in the aluminum matrix (FIG. **11**A-FIG. **12**B).

[0082] The Al—Zn—Cu alloy of the present invention may have at least one of a diameter and a length of a Zn phase in an Al matrix of 10 to 100 nm. As described above, when copper is added to the aluminum-zinc alloy, the average size of zinc, which is a precipitation phase, decreases (FIG. **13**A-FIG. **13**D). As a result, the distance between the zinc particles is greatly reduced and the tensile strength of the cast alloy is increased. When at least one of the diameter and the length of the Zn phase in the Al matrix is less than 10 nm or exceeds 100 nm, the increase in the tensile strength of the alloy due to the addition of copper may be insignificant.

[0083] The Al—Zn—Cu alloy of the present invention comprises 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum based on the total weight of the alloy, and the conductivity may be higher than 37% International Annealed Copper Standard (IACS). The Al—Zn—Cu alloy according to the present invention improves the tensile strength and elongation as well as the conductivity (FIG. **16**).

[0084] According to one embodiment of the present invention, the Al—Zn—Cu alloy may further comprise at least one of more than 0 to less than 1 part by weight of magnesium and more than 0 to less than 0.5 parts by weight of silicon based on the total weight of the alloy.

[0085] In the present invention, magnesium (Mg) is added to aluminum as an alloy element to effectively increase tensile strength and hardness. In the Al—Zn—Cu alloy according to the present invention, magnesium is added in an amount of more than 0 parts by weight to less than 1 part by weight based on the total weight of the alloy, but it is not limited thereto. When the magnesium content is 1 part by weight or more, grain boundary corrosion and stress corrosion occur, thereby causing deterioration of corrosion resistance and rapid decrease of elongation.

[0086] The content of magnesium may be 0.1 to 0.9 parts by weight, 0.1 to 0.7 parts by weight, 0.1 to 0.5 parts by weight, 0.1 to 0.3 parts by weight, 0.2 to 0.9 parts by weight, 0.2 to 0.7 parts by weight, 0.2 to 0.5 parts by weight, or 0.2 to 0.3 parts by weight, but it is not limited thereto. The magnesium content may be 0.1 to 0.3 parts by weight based on the total weight of the alloy. In this case, the Al—Zn—Cu alloy may have a tensile strength of 380 to 450 MPa and an elongation of 4 to 10% in the cast state.

[0087] In the present invention, silicon (Si) is an added to aluminum as an alloy element to contribute to improvement in casting and mechanical properties. In the Al—Zn—Cu alloy for casting according to the present invention, silicon is added in an amount of more than 0 parts by weight to less than 0.5 parts by weight based on the total weight of the alloy. When the content of silicon exceeds 0.5 parts by weight, it may cause the elongation to drop sharply without increasing the tensile strength.

[0088] The content of silicon may be 0.05 to 0.4 parts by weight, 0.05 to 0.3 parts by weight, 0.05 to 0.2 parts by weight, 0.05 to 0.1 part by weight, 0.1 to 0.4 parts by weight, 0.1 to 0.3 parts by weight, or 0.1 to 0.2 parts by weight, but it is not limited thereto. The content of silicon is preferably 0.05 to 0.2 part by weight based on the total weight of the alloy. In this case, the Al—Zn—Cu alloy may have a tensile strength of 380 to 450 MPa and an elongation of 4 to 10% in the cast state.

[0089] A heat-treated Al—Zn—Cu alloy of the present invention has a tensile strength of 330 to 600 MPa. The tensile strength of the alloy can be remarkably increased by heat treatment.

[0090] In addition, the heat-treated Al—Zn—Cu alloy of the present invention may have an elongation of 4 to 12%. The tensile strength and the elongation of the alloy can be remarkably increased simultaneously by the heat treatment.

[0091] In the present invention, the heat treatment temperature may be 150 to 500° C., but it is not limited thereto. If the heat treatment temperature is lower than 150° C., the elongation can be improved but the tensile strength may be lowered. If the heat treatment temperature is higher than 500° C., the tensile strength can be improved but the elongation can be lowered.

[0092] FIG. **14** is a flowchart illustrating a method for manufacturing an Al—Zn—Cu alloy according to an

embodiment of the present invention. FIG. **15** is diagrams illustrating a method for manufacturing an Al—Zn—Cu alloy according to an embodiment of the present invention and characteristics of the alloy by process.

[0093] Referring to FIG. **14** and FIG. **15**, an alloy material for casting is prepared to provide a molten alloy (S**100**).

[0094] More particularly, the alloy molten including 18 to 50 parts by weight of zinc; 0.05 to 5 parts by weight of copper; and the rest being aluminum, based on the total weight of the alloy is prepared.

[0095] The step for preparing an alloy molten of S**100** is performed at 650 to 750° C., and a degassing operation may be performed after the alloy is completely melted.

[0096] In S**200**, the produced molten alloy is cast by filling it to a metallic mold or a sand mold. The cast alloy has the following properties which are as described above.

[0097] A tensile strength may be 230 to 450 MPa in the cast state, and an elongation may be 2.75 to 10%. Further, 2θ of a Zn(0002) plane of a lattice constant in the X-ray diffraction may be 36.3 to 36.9. 2θ Of a Zn(1000) plane of a lattice constant in the X-ray diffraction may be 38.7 to 38.9. At least one of the diameter and the length of the Zn phase in the Al matrix may be 10 to 100 nm.

[0098] Thus, according to the present invention, there is provided a cast article produced from the alloy. Also provided is an aluminum alloy product manufactured from the alloy.

[0099] The method may further include forming a solid solution by heat-treating the Al—Zn—Cu alloy at a temperature of 150 to 500° C. of S**300**.

[0100] The solid solution may be formed by heat-treating the Al—Zn—Cu. The heat treatment may be a homogenization treatment and/or a solubilization treatment. Due to the generation of the solid solution, the Al—Zn—Cu alloy becomes a state containing the solid solution.

[0101] The temperature range of forming a solid solution may be 150 to 500° C. The temperature range can be determined in consideration of the maximum employment limit temperature at which the liquid phase of the Al—Zn—Cu alloy is not formed and the solid solution can be formed. In the case of an Al—Zn—Cu alloy, discontinuous precipitates are not produced because a poly-phase is formed without forming a single phase at a temperature exceeding 500° C. The step of forming a solid solution may be performed by heating for 30 minutes or more. Although it is not limited thereto, the heat treatment is preferably carried out at 450° C. for 120 minutes to form a solid solution.

[0102] The method may further include forcibly forming discontinuous precipitates using the Al—Zn—Cu alloy including the solid solution (S**400**).

[0103] The step of forcibly forming discontinuous precipitates is a step of forming discontinuous precipitates or lamellar precipitates in the alloy. The aluminum alloy containing the solid solution is tempered to forcibly form discontinuous precipitates or lamellar precipitates of 5% or more per unit area. The tempering treatment may be performed at 120 to 200° C. which is lower than that of forming the solid solution. For example, the tempering treatment may be performed at 160° C. The tempering treatment may be performed for 5 minutes to 400 minutes.

[0104] For example, when the alloy material includes a precipitation-accelerating metal, water quenching or air quenching may be performed after the solid solution is formed. By tempering for more than 2 hours, discontinuous precipitates may be forcibly produced.

[0105] As described above, water quenching or air quenching before the tempering treatment can form oriented type precipitates by rapidly quenching the temperature lowering speed very quickly. When the temperature is lowered slowly, these precipitates may not be oriented even if the discontinuous precipitates or lamellar precipitates are forcibly formed.

[0106] After the discontinuous precipitates or the lamellar precipitates are forcibly formed as described above, the aluminum-zinc alloy containing the precipitates is calcined to form oriented precipitates (S**500**).

[0107] The step for forming oriented precipitates is a step of artificially orienting the forcibly formed discontinuous precipitates, and may be carried out through rolling, drawing and/or extrusion.

[0108] A drawing ratio, which is a reduction rate of the cross-sectional area, may be at least 50%. As the drawing ratio increases, the thickness of the oriented precipitates itself and the distance between the oriented precipitates may decrease, and the tensile strength may be improved.

[0109] The step for orientation may be performed in a liquid nitrogen atmosphere. When oriented in a liquid nitrogen atmosphere, the heat generated in the step for orientation may be minimized to facilitate orientation of the discontinuous precipitates, resulting in increased tensile strength.

[0110] The Al—Zn—Cu alloy may have one or more of the following characteristics (1) to (5):

[0111] 1) The Al—Zn—Cu alloy includes discontinuous precipitates or lamellar precipitates forcibly produced at 5% or more per unit area of the Al—Zn—Cu alloy;

[0112] 2) The average aspect ratio of the discontinuous precipitates or the lamellar precipitates is 20 or more;

[0113] 3) The average length of the discontinuous precipitates or the lamellar precipitates is 1.4 μm or more:

[0114] 4) The average interval of the discontinuous precipitates or the lamellar precipitates is 105 nm or less; and

[0115] 5) The average thickness of the discontinuous precipitates or the lamellar precipitates is 55 nm or less.

[0116] As described above, the Al—Zn—Cu alloy of the present invention forcibly forms discontinuous precipitates or lamellar precipitates during the manufacturing process, and includes oriented precipitates formed by using the same, so that the tensile strength, the elongation and the conductivity can be improved at the same time to be provided as an excellent metal material.

[0117] Therefore, the Al—Zn—Cu alloy of the present invention can improve both tensile strength and elongation at the same time only by casting, and can further improve strength and elongation at the time of processing, so that it can be usefully used in the production of casting and processing materials.

EXAMPLES

[0118] Hereinafter, the present invention will be described in more detail with reference to specific production examples and comparative examples of the present invention.

Examples 1-46 and Comparative Examples 1-10

[0119] Table 1 shows contents of elements of an aluminum-zinc alloy of Examples and Comparative Examples.

[0120] The Al—Zn—Cu alloy having the content of each element in Table 1 was melted by electric furnace melting and high-frequency induction melting. All alloys were cast using a 99.9% pure raw material. Using an electric furnace, 5 kg of each specimen was melted and temperature was maintained at 700° C. After complete melting, A degassing operation was performed with Ar gas for 10 minutes. After molten state was maintained for 10 minutes, it was filled into a metallic mold or a sand mold. Five minutes after filling, the ingot was taken out of the mold.

[0121] Homogenization treatment was carried out at 450° C. for 120 minutes in order to remove impurities generated during casting. Subsequently, annealing was performed at a reduction rate of 20% at 400° C. every 15 minutes to perform swaging to a total cold processing area reduction rate of 75%. After 1 hour, the resulting solution was subjected to solution treatment at 450° C. for 2 hours, followed by water-quenching treatment. Then, precipitation treatment for producing discontinuous precipitates was carried out at 160° C. for 360 minutes.

TABLE 1

(wt %)	Al	Zn	Cu	Mg	Si	Mold	Heat-treatment Temp. (° C.)	Tensile Strength (MPa)	Elongation (%)	Interface energy(J/m^2) Zn(0002)/Al(100)
Comparative Example 1	Bal.	45	—			Metallic Mold	As cast	286	4	0.139
Comparative Example 2	Bal.	45	—			Metallic Mold	400	312	1.36	
Comparative Example 3	Bal.	20	—			Metallic Mold	As cast	290	3.8	
Comparative Example 4	Bal.	20	—			Metallic Mold	400	199	16.3	
Comparative Example 5	Bal.	25	—			Metallic Mold	As cast	227	10.3	
Comparative Example 6	Bal.	25	—			Metallic Mold	400	350	0.8	
Comparative Example 7	Bal.	35	—			Metallic Mold	As cast	290	2.3	
Comparative Example 8	Bal.	35	—			Metallic Mold	400	310	0.32	
Example 1	Bal.	44.31	0.69							0.084
Example 2	Bal.	43.63	1.37							0.085
Example 3	Bal.	42.94	2.06							0.084
Example 4	Bal.	42.26	2.74							0.082
Example 5	Bal.	41.57	3.43							0.087
Example 6	Bal.	40.89	4.11							0.095
Example 7	Bal.	40.2	4.80							0.109
Example 8	Bal.	39.52	5.48							0.126
Example 9	Bal.	18	2			Metallic Mold	As cast	337	4.1	
Example 10	Bal.	23	2			Metallic Mold	As cast	310	6.1	
Example 11	Bal.	23	2			Metallic Mold	400	330	4.5	
Example 12	Bal.	33	2			Metallic Mold	As cast	359	4.6	
Example 13	Bal.	33	2			Metallic Mold	160	325	22	
Example 14	Bal.	33	2			Metallic Mold	330	366	7.9	
Example 15	Bal.	33	2			Metallic Mold	490	436	11.1	
Example 16	Bal.	33	2			Sand Mold	As cast	365	8.0	
Example 17	Bal.	33	2			Sand Mold	160	307	13.4	
Example 18	Bal.	33	2			Sand Mold	330	410	8.8	
Example 19	Bal.	33	2			Sand Mold	490	430	9.7	
Example 20	Bal.	39	2			Metallic Mold	As cast	373	6.4	
Example 21	Bal.	39	2			Metallic Mold	160	319	9.0	
Example 22	Bal.	39	2			Metallic Mold	350	414	6.3	
Example 23	Bal.	39	2			Metallic Mold	430	441	8.2	
Example 24	Bal.	39	2			Sand Mold	As cast	350	6.6	
Example 25	Bal.	39	2			Sand Mold	160	309	10.2	
Example 26	Bal.	39	2			Sand Mold	350	416	6.7	
Example 27	Bal.	39	2			Sand Mold	430	436	6.5	
Example 28	Bal.	44.5	0.5			Metallic Mold	As cast	322	7.8	
Example 29	Bal.	44.5	0.5			Metallic Mold	400	451	3.2	
Example 30	Bal.	44	1			Metallic Mold	As cast	315	3.1	
Example 31	Bal.	44	1			Metallic Mold	160	320	20.5	
Example 32	Bal.	44	1			Metallic Mold	400	437	6.2	
Example 33	Bal.	43	2			Metallic Mold	As cast	338	3.9	
Example 34	Bal.	43	2			Metallic Mold	160	315	24	
Example 35	Bal.	43	2			Metallic Mold	160	320	25	
Example 36	Bal.	43	2			Metallic Mold	370	508	4.8	
Example 37	Bal.	43	2			Metallic Mold	400	600	4.5	
Example 38	Bal.	42	3			Metallic Mold	As cast	401	6.7	
Example 39	Bal.	42	3			Metallic Mold	160	300	6.5	
Example 40	Bal.	42	3			Metallic Mold	400	554	4.8	
Example 41	Bal.	33	2	0.2	0.1	Metallic Mold	As cast	391	6.74	
Example 42	Bal.	33	2	0.2	0.1	Metallic Mold	160	300	10	
Example 43	Bal.	33	2	0.2	0.1	Metallic Mold	400	469	1.27	
Example 44	Bal.	33	2	0.5	0.3	Metallic Mold	As cast	341	2.59	
Example 45	Bal.	33	2	0.5	0.3	Metallic Mold	160	285	4	
Example 46	Bal.	33	2	0.5	0.3	Metallic Mold	400	437	1.33	
Comparative Example 9	Bal.	33	2	1	0.5	Metallic Mold	As cast	300	0.8	
Comparative Example 10	Bal.	33	2	1	0.5	Metallic Mold	400	245	0.4	

[0122] Evaluation of Cold Workability after Casting

[0123] FIG. **2** is an image illustrating that moldability of a cast alloy according to an embodiment of the present invention is excellent. As shown in FIG. **2**, in the case of an aluminum-zinc alloy containing no copper, cracks occurred from a reduction rate of the sectional area of 17% in cold working after casting. However, in the case of the Al—Zn—Cu alloy of the present invention, cracks did not occur even at a reduction rate of the sectional area of 75% and the moldability was excellent.

[0124] Evaluation of Mechanical Properties of Cast

[0125] FIG. **3** is a graph illustrating that an Al—Zn—Cu alloy according to an embodiment of the present invention is simultaneously improved in tensile strength and elongation as compared with a conventional alloy.

[0126] FIG. **4** is images illustrating improvement in mechanical properties of a cast alloy according to an embodiment of the present invention due to reduction in size of a zinc phase and reduction in distance between particles. The addition of Cu to the Al—Zn alloy shows that the particle-to-particle spacing is greatly reduced due to the decrease in the size of the zinc particles during cooling after the heat treatment, thereby improving the tensile strength of the particles in the alloy.

[0127] FIG. **5** is images illustrating that copper is incorporated into zinc particles when copper is added. Copper is incorporated within the zinc particles to reduce the interface energy on the zinc precipitation phase/aluminum phase matrix.

[0128] Evaluation of Interfacial Enemies and Lattice Constants of Zn Phase by Cu Addition

[0129] Table 2 and FIG. **7**A show the change in the interface energy of the zinc phase by the addition of copper. When the lattice constant of Zn by DFT (Density Functional Theory) is calculated (0° K), the addition of Cu to the Al—Zn alloy significantly reduces the interface energy of Zn and Al phases. The interface energy of the Zn(0002)/Al (100) plane is significantly decreased by Cu addition.

TABLE 2

(wt %)	Al	Zn	Cu	Interface energy(J/m^2) Zn(0002)/Al(100)
Comparative Example 1	Bal.	45	—	0.139
Example 1	Bal.	44.31	0.69	0.084
Example 2	Bal.	43.63	1.37	0.085
Example 3	Bal	42.94	2.06	0.084
Example 4	Bal.	42.26	2.74	0.082
Example 5	Bal.	41.57	3.43	0.087
Example 6	Bal.	40.89	4.11	0.095
Example 7	Bal.	40.2	4.80	0.109
Example 8	Bal.	39.52	5.48	0.126

[0130] FIG. **7**B is a graph illustrating a change in lattice constant of zinc by copper addition. The addition of Cu to the Al—Zn alloy reduces the lattice constant of the Zn(0002) plane, and the increase in the Cu concentration in the Zn phase reduces the lattice constant of the Zn(0002) plane within a certain range. The lattice constant of the Zn(1000) plane increases as the Cu content increases. The reduction of the interface energy of the Zn(0002) plane/Al(111) plane is a direct cause of the reduction of the lattice constant of the Z (0002) plane.

[0131] FIGS. **8**A and **8**B are graphs illustrating a change in lattice constant of a zinc (0002) plane by copper addition. The addition of Cu to the Al—Zn alloy shows a decrease in the lattice constant of the Zn(0002) plane, that is, an increase in 2θ of Zn(0002) in X-ray measurement.

[0132] X-Ray Analysis of Alloy

[0133] FIGS. **9**A and **9**B are graphs illustrating changes in peak angle (2θ) and lattice constant of a Zn(0002) plane depending on Cu content of an alloy according to an embodiment of the present invention. FIGS. **10**A and **10**B are graphs illustrating changes in peak angle (2θ) and lattice constant of a Zn(1000) plane depending on Cu content of the alloy according to an embodiment of the present invention.

[0134] When the alloy according to the present invention was analyzed by X-ray, 2θ of a Zn(0002) plane is decreased to 36.30 to 36.90 and the 2θ of a Zn(1000) plane is increased to 38.70 to 38.90.

[0135] **11**A and **11**B are graphs illustrating changes in peak angle (2θ) and lattice constant of an Al(111) plane depending on Cu content of an alloy according to an embodiment of the present invention. FIGS. **12**A and **12**B are graphs illustrating changes in peak angle (2θ) and lattice constant of an Al(200) depending on Cu content of an alloy according to an embodiment of the present invention. It is noted that the position of the Al peak is not directly affected by Cu addition because Cu is not incorporated in the Al matrix.

[0136] Microstructure Analysis of Alloy

[0137] FIGS. **13**A and **13**B is TEM images illustrating a change in the size of a zinc phase upon cooling after heat treatment of an alloy according to an embodiment of the present invention by Cu addition. FIGS. **13**C and **13**D is graphs illustrating the zinc phase size of the measurement site indicated in FIGS. **13**A and **13**B.

[0138] The size of the Zn phase in the Al matrix ranges from 10 nm to 100 nm, and the size of the Zn phase is remarkably reduced by the addition of copper.

[0139] Evaluation of Electrical Conductivity after Drawing

[0140] FIG. **16** is a graph illustrating a change in conductivity according to true strains of an Al—Zn—Cu alloy according to an embodiment of the present invention.

[0141] The conductivity of the alloy according to Example 13 and Example 33 of the present invention after heat treatment was measured to be 37% IACS (International Annealed Copper Standard) or higher. In particular, the conductivity of the alloy according to Example 13 increases to 53% IACS.

[0142] While this disclosure includes specific examples, it will be apparent to one of ordinary skill in the art that various changes in form and details may be made in these examples without departing from the spirit and scope of the claims and their equivalents. The examples described herein are to be considered in a descriptive sense only, and not for purposes of limitation. Descriptions of features or aspects in each example are to be considered as being applicable to similar features or aspects in other examples. Suitable results may be achieved if the described techniques are performed in a different order, and/or if components in a described system, architecture, device, or circuit are combined in a different manner, and/or replaced or supplemented by other components or their equivalents. Therefore, the scope of the disclosure is defined not by the detailed description, but by the claims and their equivalents, and all variations within the scope of the claims and their equivalents are to be construed as being included in the disclosure

What is claimed is:

1. An Al—Zn—Cu alloy comprising:

18 to 50 parts by weight of zinc;

0.05 to 5 parts by weight of copper; and

the rest being aluminum, based on the total weight of the alloy,

wherein the Al—Zn—Cu alloy has at least one of the following features:

1) a tensile strength of 230 to 450 MPa and an elongation of 2.75 to 10% in the cast state;

2) 2θ of a Zn(0002) plane of a lattice constant in the X-ray diffraction of 36.3 to 36.9; and

3) 2θ of a Zn(1000) plane of the lattice constant in the X-ray diffraction of 38.7 to 38.9.

2. The Al—Zn—Cu alloy of claim **1**, wherein the tensile strength in the cast state is 310 to 450 Mpa.

3. The Al—Zn—Cu alloy of claim **1**, wherein the elongation in the cast state is 4 to 10%.

4. The Al—Zn—Cu alloy of claim **1**, wherein a conductivity is 37% IACS (International Annealed Copper Standard) or more.

5. The Al—Zn—Cu alloy of claim **1**, wherein at least one of the diameter and the length of a Zn phase in an Al matrix is 10 to 100 nm.

6. The Al—Zn—Cu alloy of claim **1**, further comprising at least one of more than 0 to less than 1 part by weight of magnesium and more than 0 to less than 0.5 parts by weight of silicon, based on the total weight of the alloy.

7. An Al—Zn—Cu alloy heat-treated with the Al—Zn—Cu alloy of claim **1** to have a tensile strength of 330 to 600 Mpa.

8. The Al—Zn—Cu alloy of claim **7**, wherein the Al—Zn—Cu alloy has elongation of 4 to 12%.

9. The Al—Zn—Cu alloy of claim **7**, wherein the heat-treatment is performed at a temperature of 150 to 500° C.

10. A method for manufacturing an Al—Zn—Cu alloy of claim **1** comprising:

preparing an alloy molten comprising:

18 to 50 parts by weight of zinc;

0.05 to 5 parts by weight of copper; and

the rest being aluminum, based on the total weight of the alloy; and

casting by filling the alloy molten into a metallic mold or a sand mold.

11. The method of claim **10**, wherein the step for preparing an alloy molten is performed at 650 to 750° C. and comprises degassing after the alloy is completely melted.

12. The method of claim **10**, wherein tensile strength of the Al—Zn—Cu alloy is 230 to 450 MPa and elongation is 2.75 to 10% in the cast state.

13. The method of claim **10**, wherein the Al—Zn—Cu alloy has 2θ of a Zn(0002) plane of the lattice constant in the X-ray diffraction of 36.3 to 36.9.

14. The method of claim **10**, wherein the Al—Zn—Cu alloy has 2θ of a Zn(1000) plane of the lattice constant in the X-ray diffraction of 38.7 to 38.9.

15. The method of claim **10**, wherein the Al—Zn—Cu alloy has at least one of the diameter and the length of the Zn phase in the Al matrix of 10 to 100 nm.

16. The method of claim **10**, further comprising forming a solid solution by heat-treating the Al—Zn—Cu alloy at a temperature of 150 to 500 IC.

17. The method of claim **16**, wherein the heat-treatment is performed for 30 minutes or more.

18. A cast product manufactured from the alloy of claim **1**.

19. A machined aluminum alloy product manufactured from the alloy of claim **1**.

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