

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization

International Bureau

(43) International Publication Date
28 June 2018 (28.06.2018)

(10) International Publication Number

WO 2018/118350 A1

(51) International Patent Classification:

C22C 21/10 (2006.01)

(21) International Application Number:

PCT/US2017/063481

(22) International Filing Date:

28 November 2017 (28.11.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/437,489 21 December 2016 (21.12.2016) US

(71) Applicant: ARCONIC INC. [US/US]; Arconic Corporate Center, 201 Isabella Street, Pittsburgh, PA 15212-5858 (US).

(72) Inventors: UNAL, Ali; 2208 Manordale Drive, Export, PA 15632 (US). NEWMAN, John; 1210 Stonecliffe Drive, Monroeville, PA 15146 (US). TOMES, David; 23711 Morning Light, San Antonio, TX 78261 (US). WYATT-MAIR, Gavin; 20 Folin Lane, Lafayette, CA 94549 (US).

(74) Agent: MALINO, Joshua C.; Greenberg Traurig, LLP, 500 Campus Drive, Suite 400, Florham Park, NJ 07932 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: HIGH ZINC ALUMINUM ALLOY PRODUCTS

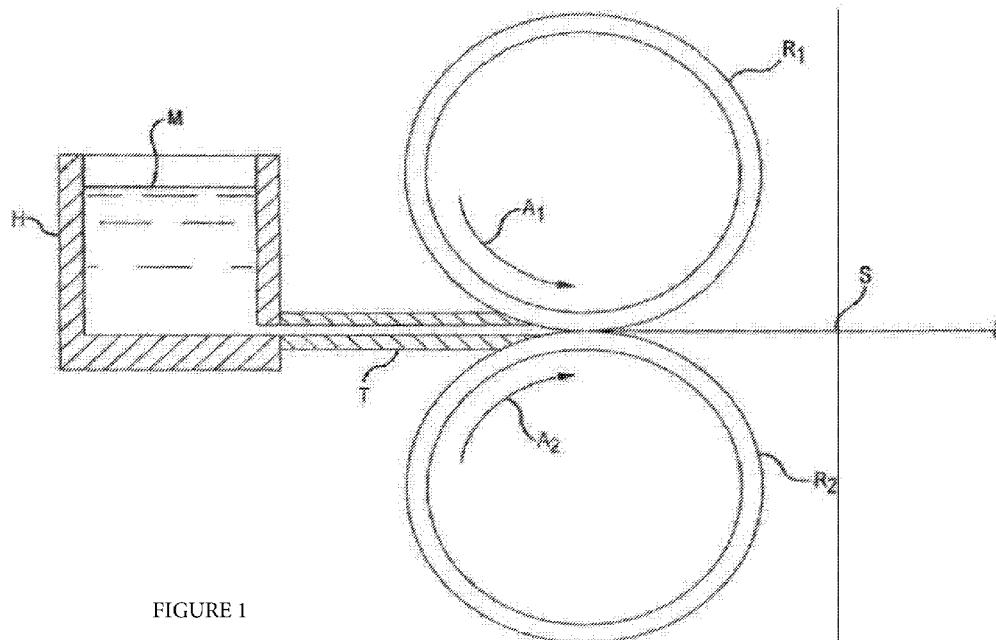


FIGURE 1

(57) Abstract: The present invention, in an embodiment, is cast product in the form of an aluminum alloy strip. The aluminum alloy strip includes 4 wt. % to 28 wt. % zinc and a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

HIGH ZINC ALUMINUM ALLOY PRODUCTS

RELATED APPLICATION

[0001] This application claims the priority of U.S. provisional application Ser. No. U.S.S.N. 62/437,489, entitled “High Zinc Aluminum Alloy Products” filed December 21, 2016, which is incorporated herein by reference in its entirety for all purposes.

BACKGROUND OF INVENTION

[0002] Casting aluminum alloys to form cast aluminum alloy products is known.

TECHNICAL FIELD

[0003] The present invention relates to cast aluminum alloy products, and products derived therefrom.

BRIEF SUMMARY OF INVENTION

[0004] In one or more embodiments detailed herein, the present invention is a cast product comprising an aluminum alloy strip; wherein the aluminum alloy strip comprises: 4 wt. % to 28 wt. % zinc; and wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

[0005] In one or more embodiments detailed herein, the aluminum alloy strip comprises 6 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 8 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 10 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 6 wt. % to 12 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 8 wt. % zinc.

[0006] In one or more embodiments detailed herein, the variation of the zinc weight percent is 12% or less between the surface and the thickness center of the aluminum alloy strip.

[0007] In one or more embodiments detailed herein, the present invention is a cast product comprising an aluminum alloy strip; wherein the aluminum alloy strip comprises: (i) 4 wt. % to 28 wt. % zinc; (ii) 1 wt. % to 3 wt. % copper; and (iii) 1 wt. % to 3 wt. % magnesium; and wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

[0008] In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 12 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc.

[0009] In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.0 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % copper.

[00010] In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.0 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % magnesium.

[00011] In one or more embodiments detailed herein, the cast product comprises an aluminum alloy strip; wherein the aluminum alloy strip comprises: 4 wt. % to 28 wt. % zinc and 1 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, a variation of a weight

percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

BRIEF DESCRIPTION OF THE DRAWINGS

[00012] FIG. 1 is a schematic of a non-limiting method of making the cast product;

[00013] FIG. 2 is an enlarged cross-sectional schematic of the molten metal delivery tip and rolls shown in FIG. 1;

[00014] FIG. 3 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00015] FIG. 4 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00016] FIG. 5 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00017] FIG. 6 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00018] FIG. 7 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00019] FIG. 8 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00020] FIG. 9 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00021] FIG. 10 shows the variation in zinc weight percentage from surface to a thickness depth of 3,000 micrometers in a cast product;

[00022] FIG. 11 shows the variation in zinc weight percentage through depth of a prior art ingot cast by direct chill casting;

[00023] FIG. 12 shows the variation in zinc weight percentage through depth of a prior art cast product;

[00024] FIG. 13 shows the weight percentages of zinc, magnesium and copper across grains from the surface to 200 micrometers thickness depth in a cast product according to an embodiment of the present invention.

[00025] FIG. 14 shows the weight percentages of the zinc, magnesium and copper across grains through thickness depth for a direct chill cast prior art product;

[00026] FIG. 15 shows the structure of a cast product according to an embodiment of the present invention;

[00027] FIG. 16 shows the structure of a cast product according to an embodiment of the present invention; and

[00028] FIG. 17 shows the structure of a cast product according to an embodiment of the present invention.

[00029] The figures constitute a part of this specification and include illustrative embodiments of the present invention and illustrate various objects and features thereof. Further, the figures are not necessarily to scale, some features may be exaggerated to show details of particular components. In addition, any measurements, specifications and the like shown in the figures are intended to be illustrative, and not restrictive. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

[00030] The present invention will be further explained with reference to the attached drawings, wherein like structures are referred to by like numerals throughout the several views. The drawings shown are not necessarily to scale, with emphasis instead generally being placed upon illustrating the principles of the present invention. Further, some features may be exaggerated to show details of particular components.

DETAILED DESCRIPTION OF THE INVENTION

[00031] Among those benefits and improvements that have been disclosed, other objects and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying figures. Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely illustrative of the invention that may be embodied in various forms. In addition, each of the examples given in connection with the various embodiments of the invention which are intended to be illustrative, and not restrictive.

[00032] Throughout the specification and claims, the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise. The phrases "in one embodiment" and "in some embodiments" as used herein do not necessarily refer to the same embodiment(s), though they may. Furthermore, the phrases "in another embodiment" and "in some other embodiments" as used herein do not necessarily refer to a different embodiment, although they may. Thus, as described below, various embodiments of the invention may be readily combined, without departing from the scope or spirit of the invention.

[00033] In addition, as used herein, the term "or" is an inclusive "or" operator, and is equivalent to the term "and/or," unless the context clearly dictates otherwise. The term "based on" is not exclusive and allows for being based on additional factors not described, unless the

context clearly dictates otherwise. In addition, throughout the specification, the meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[00034] As used herein, the term "at least one of A, B, or C" and the like, means "only A", "only B", "only C", or "any combination of A, B, and C."

[00035] In one or more embodiments detailed herein, the present invention is a cast product comprising an aluminum alloy strip; wherein the aluminum alloy strip comprises: 4 wt. % to 28 wt. % zinc; and wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

[00036] In one or more embodiments detailed herein, the aluminum alloy strip comprises 6 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 8 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 10 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 6 wt. % to 12 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 8 wt. % zinc.

[00037] In one or more embodiments detailed herein, the variation of the zinc weight percent is 12% or less between the surface and the thickness center of the aluminum alloy strip.

[00038] In one or more embodiments detailed herein, the present invention is a cast product comprising an aluminum alloy strip; wherein the aluminum alloy strip comprises: (i) 4 wt. % to 28 wt. % zinc; (ii) 1 wt. % to 3 wt. % copper; and (iii) 1 wt. % to 3 wt. % magnesium;

and wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

[00039] In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 12 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc.

[00040] In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.0 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % copper.

[00041] In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.0 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % magnesium.

[00042] In one or more embodiments detailed herein, the cast product comprises an aluminum alloy strip; wherein the aluminum alloy strip comprises: 4 wt. % to 28 wt. % zinc and 1 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

[00043] In one or more embodiments detailed herein, the present invention is a cast product comprising an aluminum alloy strip; wherein the aluminum alloy strip comprises: 4 wt. % to 25 wt. % zinc; and wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip.

[00044] In one or more embodiments detailed herein, the aluminum alloy strip comprises 6 wt. % to 25 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 8 wt. % to 25 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 10 wt. % to 25 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 12 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 8 wt. % zinc.

[00045] In one or more embodiments detailed herein, the variation of the zinc weight percent is 12% or less between the surface and the thickness depth of 3,000 micrometers in the aluminum alloy strip.

[00046] In one or more embodiments detailed herein, the present invention is a cast product comprising an aluminum alloy strip; wherein the aluminum alloy strip comprises: (i) 4 wt. % to 25 wt. % zinc; (ii) 1 wt. % to 3 wt. % copper; and (iii) 1 wt. % to 3 wt. % magnesium; and wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip.

[00047] In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 12 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc.

[00048] In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy

strip comprises 1 wt. % to 2.0 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % copper.

[00049] In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 2.0 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % magnesium.

[00050] As used herein, the term “aluminum alloy” means an aluminum metal with soluble elements either in the aluminum lattice or in a phase within aluminum. Elements may include aluminum, copper, iron, magnesium, nickel, silicon, zinc, chromium, manganese, titanium, vanadium, zirconium, tin, scandium, lithium. Elements are added to influence physical properties of the aluminum alloy and performance characteristics.

[00051] As used herein, the phrase “7xxx aluminum alloys” and the like means an aluminum alloy selected from 7xxx aluminum alloys registered with the Aluminum Association and unregistered variants of the same.

[00052] As used herein, the term “cast product” means a product that has been produced by a casting method such as continuous casting as detailed in U.S. Patent Nos. 6,672,368 and 7,125,612. In one or more embodiments detailed herein, the term “cast product” includes a product produced from the “cast product”. In one or more embodiments, the term “cast product” includes a rolled product produced from the “cast product”.

[00053] As used herein, the term “variation” of the weight percent of an alloying element in a specified thickness depth has units of “%” and is calculated according to the following equation:

[00054] (maximum weight percent of alloying element in the specified thickness depth – minimum weight percent of the alloying element in the specified thickness depth) / (average weight percent of the alloying element in the specified thickness depth)*100.

[00055] As used herein, the term “centerline segregation” means the enrichment or depletion of alloying elements in a central portion of an aluminum alloy strip. In embodiments, centerline segregation is determined based on a variation of the weight percent of an alloying element in a specified thickness depth of an aluminum alloy strip. In one or more embodiments detailed herein, centerline segregation is determined based on a variation of weight percent of an alloying element of greater than 15% between a surface and a thickness depth of 3,000 micrometers. In one or more embodiments detailed herein, centerline segregation is determined based on a variation of weight percent of an alloying element of greater than 15% between a surface and a thickness center of the aluminum alloy strip.

[00056] As used herein, the “weight percent of an alloying element” in a specified thickness depth is determined using the **“macro-segregation procedure”** detailed herein.

[00057] As used herein, the term “strip” may be of any suitable thickness, and is generally of sheet gauge (0.006 inch to 0.249 inch) or thin-plate gauge (0.250 inch to 0.400 inch), i.e., has a thickness in the range of from 0.006 inch to 0.400 inch. In one embodiment, the strip has a thickness of at least 0.040 inch. In one embodiment, the strip has a thickness of less than 0.320 inch. In one or more embodiments detailed herein, the strip has a thickness of from 0.0070 to 0.18 inches. In one or more embodiments detailed herein, the strip has a thickness of from 0.08 to 0.2 inches.

[00058] As used herein, “surface” means a top surface or a bottom surface of the cast product.

[00059] As used herein, “thickness center” means a depth of half the total thickness of the cast product or half thickness (t/2).

[00060] In one or more embodiments detailed herein, the aluminum alloy strip may include any aluminum alloy having 4 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip may include at least one of 1 wt. % to 3 wt. % copper and 1 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy may include 7xxx (zinc based) aluminum alloys.

[00061] In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 27 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 25 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 22 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 20 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 18 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 15 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 13 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 11 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 10 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 9 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 8 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 7 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 6 wt. %

zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 4 wt. % to 5 wt. % zinc.

[00062] In one or more embodiments detailed herein, the aluminum alloy strip has 5 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 6 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 7 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 8 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 9 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 10 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 11 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 13 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 15 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 18 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 20 wt. % to 28 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 22 wt. % to 28 wt. % zinc.

[00063] In one or more embodiments detailed herein, the aluminum alloy strip has 5 wt. % to 27 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 7 wt. % to 25 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 8 wt. % to 23 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 9 wt. % to 20 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 10 wt. % to 18 wt. % zinc. In one or more embodiments detailed herein, the aluminum alloy strip has 12 wt. % to 15 wt. % zinc.

[00064] In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.8 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.6 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.4 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.2 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.0 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.8 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.6 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.4 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.2 wt. % copper.

[00065] In one or more embodiments detailed herein, the aluminum alloy strip has 1.2 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1.4 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1.6 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1.8 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 2.0 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 2.2 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 2.4 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 2.6 wt. % to 3 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 2.8 wt. % to 3 wt. % copper.

[00066] In one or more embodiments detailed herein, the aluminum alloy strip has 1.2 wt. % to 2.8 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1.4 wt. % to 2.6 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1.6 wt. % to 2.4 wt. % copper. In one or more embodiments detailed herein, the aluminum alloy strip has 1.8 wt. % to 2.2 wt. % copper.

[00067] In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.8 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.6 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.4 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.2 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 2.0 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.8 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.6 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.4 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1 wt. % to 1.2 wt. % magnesium.

[00068] In one or more embodiments detailed herein, the aluminum alloy strip has 1.2 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1.4 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1.6 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1.8 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 2.0 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 2.2 wt. % to 3 wt. %

magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 2.4 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 2.6 wt. % to 3 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 2.8 wt. % to 3 wt. % magnesium.

[00069] In one or more embodiments detailed herein, the aluminum alloy strip has 1.2 wt. % to 2.8 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1.4 wt. % to 2.6 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1.6 wt. % to 2.4 wt. % magnesium. In one or more embodiments detailed herein, the aluminum alloy strip has 1.8 wt. % to 2.2 wt. % magnesium.

[00070] In one or more embodiments detailed herein, the aluminum alloy strip has 0.1 wt. % to 1.0 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.2 wt. % to 1.0 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.4 wt. % to 1.0 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.6 wt. % to 1.0 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.8 wt. % to 1.0 wt. % manganese.

[00071] In one or more embodiments detailed herein, the aluminum alloy strip has 0.1 wt. % to 0.8 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.1 wt. % to 0.9 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.1 wt. % to 0.7 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.1 wt. % to 0.5 wt. % manganese. In one or more embodiments detailed herein, the aluminum alloy strip has 0.1 wt. % to 0.3 wt. % manganese.

[00072] In one or more embodiments detailed herein, the aluminum alloy strip has 0.05 wt. % to 0.3 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy

strip has 0.1 wt. % to 0.3 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.15 wt. % to 0.3 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.2 wt. % to 0.3 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.25 wt. % to 0.3 wt. % chromium.

[00073] In one or more embodiments detailed herein, the aluminum alloy strip has 0.05 wt. % to 0.25 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.05 wt. % to 0.2 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.05 wt. % to 0.15 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.05 wt. % to 0.1 wt. % chromium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.15 wt. % to 0.25 wt. % chromium.

[00074] In one or more embodiments detailed herein, the aluminum alloy strip has 0.04 wt. % to 0.25 wt. % zirconium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.04 wt. % to 0.2 wt. % zirconium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.04 wt. % to 0.18 wt. % zirconium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.04 wt. % to 0.15 wt. % zirconium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.04 wt. % to 0.1 wt. % zirconium.

[00075] In one or more embodiments detailed herein, the aluminum alloy strip has 0.1 wt. % to 0.25 wt. % zirconium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.15 wt. % to 0.25 wt. % zirconium. In one or more embodiments detailed herein, the aluminum alloy strip has 0.2 wt. % to 0.25 wt. % zirconium.

[00076] In one or more embodiments detailed herein, the aluminum alloy strip has 0.07 wt. % to 0.14 wt. % zirconium.

[00077] In one or more embodiments detailed herein, the aluminum alloy strip includes at least one of zinc, copper, magnesium, manganese, chromium, or zirconium. In one or more embodiments detailed herein, the aluminum alloy strip is free of at least one of copper, magnesium, manganese, chromium, or zirconium.

[00078] In one or more embodiments detailed herein, the aluminum alloy strip may contain secondary elements and/or other elements. As used herein, "secondary elements" are Fe, Si, and/or Ti. As used herein, "other elements" includes any elements of the periodic table other than aluminum (Al), Zn, Cu, Mn, Cr, Zr, Mg, Fe, Si, and/or Ti.

[00079] In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 15% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 14% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 13% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 12% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 11% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 10% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 9% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 8% or less. In one or more embodiments detailed herein, a variation

of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 7% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 6% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 5% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 4% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 3% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 2% or less.

[00080] In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 14%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 13%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 12%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 11%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 10%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 9%. In one or

more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 8%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 7%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 6%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 0.1% to 5%. In one or more embodiments detailed herein, a variation of the zinc weight percent is 0.1% to 4% between a surface and a thickness center of the aluminum alloy strip.

[00081] In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 1% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 2% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 3% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 4% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 5% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 6% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 7% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of

the aluminum alloy strip is 8% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 9% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 10% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 11% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness center of the aluminum alloy strip is 12% to 15%.

[00082] In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 15% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 14% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 13% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 12% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 11% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 10% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 9% or less. In one or more embodiments detailed herein, a variation of the zinc weight

percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 8% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 7% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 6% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 5% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 4% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 3% or less. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 2% or less.

[00083] In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 14%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 13%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 12%. In one or more embodiments detailed herein, a variation of the zinc weight

percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 11%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 10%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 9%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 8%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 7%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 6%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 0.1% to 5%. In one or more embodiments detailed herein, a variation of the zinc weight percent is 0.1% to 4% between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip.

[00084] In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 1% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 2% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 3% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight

percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 4% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 5% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 6% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 7% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 8% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 9% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 10% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 11% to 15%. In one or more embodiments detailed herein, a variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the aluminum alloy strip is 12% to 15%.

[00085] In one or more embodiments detailed herein, the aluminum alloy has a zinc weight percent of 4% to 28% or any other weight percent range detailed herein and does not exhibit centerline segregation.

[00086] **Non-Limiting Method For Producing Aluminum Alloy Strip**

[00087] In embodiments, the casting of the aluminum alloy strip detailed herein may be accomplished via a continuous casting apparatus capable of producing continuously cast products that are solidified at high solidification rates. One example of a continuous casting apparatus capable of achieving the above-described solidification rates is the apparatus described in U.S. Patent Nos. 6,672,368 and 7,125,612, incorporated by reference in their entirety. In one or more embodiments detailed herein, the aluminum alloy strip is continuously cast using the MicromillTM process described in U.S. Patent Nos. 6,672,368 and 7,125,612.

[00088] In embodiments, as illustrated in Figures 1-2, a molten aluminum alloy metal M may be stored in a hopper H (or tundish) and delivered through a feed tip T, in a direction B, to a pair of rolls R₁ and R₂, having respective roll surfaces D₁ and D₂, which are each rotated in respective directions A₁ and A₂, to produce a solid cast product S. In one or more embodiments detailed herein, gaps G₁ and G₂ may be maintained between the feed tip T and respective rolls R₁ and R₂ as small as possible to prevent molten metal from leaking out, and to minimize the exposure of the molten metal to the atmosphere, while maintaining a separation between the feed tip T and rolls R₁ and R₂. A plane L through the centerline of the rolls R₁ and R₂ passes through a region of minimum clearance between the rolls R₁ and R₂ referred to as the roll nip N.

[00089] In one or more embodiments detailed herein, during casting, the molten metal M directly contacts the cooled rolls R₁ and R₂ at regions 2 and 4, respectively. Upon contact with the rolls R₁ and R₂, the metal M begins to cool and solidify. The cooling metal produces an upper shell 6 of solidified metal adjacent the roll R₁ and a lower shell 8 of solidified metal adjacent to the roll R₂. The thickness of the shells 6 and 8 increases as the metal M advances towards the nip N. Large dendrites 10 of solidified metal (not shown to scale) may be produced at the interfaces between each of the upper and lower shells 6 and 8 and the molten metal M. The large dendrites

10 may be broken and dragged into a center portion 12 of the slower moving flow of the molten metal M and may be carried in the direction of arrows C₁ and C₂. The dragging action of the flow can cause the large dendrites 10 to be broken further into smaller dendrites 14 (not shown to scale). In the central portion 12 upstream of the nip N referred to as a region 16, the metal M is semi-solid and may include a solid component (the solidified small dendrites 14) and a molten metal component. The metal M in the region 16 may have a mushy consistency due in part to the dispersion of the small dendrites 14 therein. At the location of the nip N, some of the molten metal may be squeezed backwards in a direction opposite to the arrows C₁ and C₂. The forward rotation of the rolls R₁ and R₂ at the nip N advances substantially only the solid portion of the metal (the upper and lower shells 6 and 8 and the small dendrites 14 in the central portion 12) while forcing molten metal in the central portion 12 upstream from the nip N such that the metal may be completely solid as it leaves the point of the nip N. In this manner and in one or more embodiments detailed herein, a freeze front of metal may be formed at the nip N. Downstream of the nip N, the central portion 12 may be a solid central portion, 18 containing the small dendrites 14 sandwiched between the upper shell 6 and the lower shell 8. In the central portion, 18, the small dendrites 14 may be 20 microns to 50 microns in size and have a generally globular shape. The three portions, of the upper and lower shells 6 and 8 and the solidified central portion 18, constitute a single, solid cast product (S in Figure 1 and element 20 in Figure 2). Thus, the aluminum alloy cast product 20 may include a first portion of an aluminum alloy and a second portion of the aluminum alloy (corresponding to the shells 6 and 8) with an intermediate portion (the solidified central portion 18) therebetween. The solid central portion 18 may constitute 20 percent to 30 percent of the total thickness of the cast product 20.

[00090] The rolls R_1 and R_2 may serve as heat sinks for the heat of the molten metal M. In one embodiment, heat may be transferred from the molten metal M to the rolls R_1 and R_2 in a uniform manner to ensure uniformity in the surface of the cast product 20. Surfaces D_1 and D_2 of the respective rolls R_1 and R_2 may be made from steel, copper, nickel, or other suitable material and may be textured and may include surface irregularities (not shown) which may contact the molten metal M.

[00091] The control, maintenance and selection of the appropriate speed of the rolls R_1 and R_2 may impact the ability to continuously cast products. The roll speed determines the speed that the molten metal M advances towards the nip N. If the speed is too slow, the large dendrites 10 will not experience sufficient forces to become entrained in the central portion 12 and break into the small dendrites 14. In one or more embodiments detailed herein, the roll speed may be selected such that a freeze front, or point of complete solidification, of the molten metal M may form at the nip N. Accordingly, the present casting apparatus and methods may be suited for operation at high speeds such as those ranging from 25 to 500 feet per minute; alternatively from 40 to 500 feet per minute; alternatively from 40 to 400 feet per minute; alternatively from 100 to 400 feet per minute; and alternatively from 150 to 300 feet per minute. The linear rate per unit area that molten aluminum is delivered to the rolls R_1 and R_2 may be less than the speed of the rolls R_1 and R_2 or about one quarter of the roll speed.

[00092] Continuous casting of aluminum alloys according to the present disclosure may be achieved by initially selecting the desired dimension of the nip N corresponding to the desired gauge of the cast product S. The speed of the rolls R_1 and R_2 may be increased to a desired production rate or to a speed which is less than the speed which causes the roll separating force increases to a level which indicates that rolling is occurring between the rolls R_1 and R_2 . Casting

at the rates contemplated by an embodiment of the present invention (i.e. 25 to 400 feet per minute) solidifies the aluminum alloy cast product about 1000 times faster than aluminum alloy cast as an ingot cast and improves the properties of the cast product over aluminum alloys cast as an ingot. The rate at which the molten metal is cooled may be selected to achieve rapid solidification of the outer regions of the metal. Indeed, the cooling of the outer regions of metal may occur at a rate of at least 1000 degrees Celsius per second.

[00093] The continuous cast strip may be of any suitable thickness, and is generally of sheet gauge (0.006 inch to 0.249 inch) or thin-plate gauge (0.250 inch to 0.400 inch), i.e., has a thickness in the range of from 0.006 inch to 0.400 inch. In one embodiment, the strip has a thickness of at least 0.040 inch. In one embodiment, the strip has a thickness of less than 0.320 inch.

[00094] **Macro-Segregation Procedure**

[00095] Samples are first mounted and polished in Lucite using standard metallographic preparation techniques for aluminum. An Electron Probe Micro Analyzer (“EPMA”) is used to profile the distribution of the alloying elements across a thickness to show the macro-segregation of the alloying elements.

[00096] EPMA line scans are set with an initial spot of 100 micrometers diameter about 50 micrometers from the sample surface moving in the thickness direction until the other surface is reached. The defocused beam spots are calculated to maintain a 50 micrometer separation to provide 50% overlap between points.

[00097] A JEOL JXA 8530F Field Emission Electron Probe Microanalyzer Hyperprobe with 4 Wave dispersive spectrometers and JEOL SDD-EDS are used to gather the data. The operating conditions are:

[00098] Accelerating Voltage: 15kV

[00099] Beam Intensity: 100nA

[000100] Defocus electron beam: 100µm

[000101] Line scan profile step 50 µm

[000102] Analyzed elements may include: Ti, Zr, Mg, Si, Mn, Fe, Cu, Zn and Al

[000103] The wave dispersive spectrometer (WDS) crystal and spectrometers are used as detailed in the Table 1.

Table 1

Spectrometer	Diffracting Crystal	Counter	Element
1	PETJ	Gas Flow (P-10)	Ti, Zr
2	TAP	Gas Flow (P-10)	Mg, Si
3	LIFH	Sealed Xe gas	Mn, Fe
4	LIFL	Sealed Xe gas	Cu, Zn
5		SDD-EDS	Al

The counting time is 10 seconds for all elements

[000104] A background measurement is collected every 50 spots for 5 seconds on positive and negative background locations. Elements measured are quantitatively analyzed using the JEOL quant ZAF analysis package for metals with atomic number correction by Philibert-Tixier method and fluorescence excitation correction by Reed method.

[000105] Alternately, the concentration of alloying elements through depth of a sample was determined using a quantometer consistent with the method used to analyze the samples from U.S. Patent No. 6,672,368.

[000106] **Micro-Segregation Procedure**

[000107] Samples are first mounted and polished in Lucite using standard metallographic preparation techniques for aluminum. An EPMA is used to profile the distribution of the alloying elements across a thickness to show the micro-segregation of the alloying elements.

[000108] EPMA line scans are set with a focused spot moving with a 1 micrometer step across several grains to provide overlapping points through multiple grains.

[000109] A JEOL JXA 8530F Field Emission Electron Probe Microanalyzer Hyperprobe with 4 Wave dispersive spectrometers and JEOL SDD-EDS are used to gather the data. The operating conditions are:

[000110] Accelerating Voltage: 15kV

[000111] Beam Intensity: 100nA

[000112] Focused electron beam

[000113] Line scan profile step 1 μ m

[000114] Analyzed elements may include: Ti, Zr, Mg, Si, Mn, Fe, Cu, Zn and Al

[000115] The WDS crystal and spectrometers are used as detailed in Table 1.

[000116] A background measurement is collected every 50 spots for 5 seconds on positive and negative background locations. Elements measured are quantitatively analyzed using the JEOL quant ZAF analysis package for metals with atomic number correction by Philibert-Tixier method and fluorescence excitation correction by Reed method.

[000117] NON-LIMITING EXAMPLES

[000118] Aluminum alloy samples were cast using the apparatus detailed in U.S. Patent No. 6,672,368 at a speed of 55 feet per minute to 85 feet per minute and had a final thickness detailed in the tables below. The average weight percentages of the zinc, magnesium and copper from the surface to 3,000 micrometers thickness depth in each sample was determined using either the

“macro-segregation” procedure detailed herein or via quantometer. Table 2 below shows the average weight percentages of zinc, copper and magnesium from surface to a thickness depth of 3,000 micrometers in each of the cast samples and the method used to determine the weight percentages in each sample:

Table 2

Sample	Thickness (mm)	Avg. Zn wt.%	Avg. Mg wt.%	Avg. Cu wt.%	Method
1	3.5	4.26	1.50	1.59	macro-segregation procedure
2	3.3	5.60	1.85	2.28	quantometer
3	3.9	6.38	1.47	1.53	macro-segregation procedure
4	3.4	7.34	2.13	1.90	quantometer
5	3.4	7.56	1.94	2.42	quantometer
6	4.1	8.71	1.68	1.43	macro-segregation procedure
7	3.9	15.98	1.21	1.53	macro-segregation procedure
8	3.6	27.46	0.97	1.64	macro-segregation procedure

[000119] Table 3 below shows the variation of zinc weight percentages in each of the samples from surface to a thickness depth of 3,000 micrometers:

Table 3

Sample	Min. Zn wt.%	Max. Zn wt.%	Avg. Zn wt.%	Variation (%)
1	3.91	4.52	4.26	14.40
2	5.40	5.75	5.60	6.25
3	6.17	6.66	6.38	7.68
4	7.11	7.54	7.34	5.86
5	6.95	7.71	7.56	10.05
6	8.34	8.96	8.71	7.12
7	15.10	17.09	15.98	12.45
8	25.53	29.70	27.46	15.19

[000120] The average weight percentages of the zinc, magnesium and copper from the surface to the thickness center in each sample were determined using either the “**macro-segregation**” procedure detailed herein or via quantometer. Table 4 below shows the average weight percentages of zinc, copper and magnesium from surface to a thickness center in each of the cast samples and the method used to determine the weight percentages in each sample:

Table 4

Sample	Thickness (mm)	Avg. Zn wt.%	Avg. Mg wt.%	Avg. Cu wt.%	Method
1	3.5	4.27	1.50	1.61	macro-segregation procedure
2	3.3	5.64	1.86	2.28	quantometer
3	3.9	6.36	1.47	1.52	macro-segregation procedure
4	3.4	7.33	2.12	1.88	quantometer
5	3.4	7.54	1.93	2.42	quantometer
6	4.1	8.71	1.70	1.42	macro-segregation procedure
7	3.9	15.97	1.21	1.52	macro-segregation procedure
8	3.6	27.54	0.99	1.70	macro-segregation procedure

[000121] Table 5 below shows the variation of zinc weight percentages in each of the samples from surface to a thickness center in each sample:

Table 5

Sample	Min. Zn wt.%	Max. Zn wt.%	Avg. Zn wt.%	Variation (%)
1	3.91	4.52	4.27	14.29
2	5.48	5.75	5.64	4.79
3	6.17	6.57	6.36	6.29
4	7.11	7.54	7.33	5.87
5	6.95	7.71	7.54	10.08
6	8.44	8.96	8.71	5.97
7	15.10	17.09	15.97	12.46
8	25.96	29.70	27.54	13.58

[000122] The data generated for each sample is plotted in Figures 3-10. A comparison the weight percentages of the zinc, magnesium and copper through thickness of a direct chill cast prior art product and a continuously cast prior art product of U.S. Patent No. 6,672,368 are also included as Figures 11-12 for comparison.

[000123] As shown in Figures 3-10 and the tables above, the inventors surprisingly found that the variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in samples 1-7 according to the present invention is less than 15%. Moreover, the variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers of sample 8 is greater than 15%. Similarly, based on visual inspection of Figures 11-12, the variation of the zinc weight percent between a surface and a thickness depth of 3,000 micrometers in the direct chill cast prior art product and the continuously cast prior art product is greater than 15%.

[000124] As shown in Figures 3-10 and the tables above, the inventors surprisingly found that the variation of the zinc weight percent between a surface and a thickness center in samples 1-8 according to the present invention is less than 15%. Moreover, based on visual inspection of Figures 11-12, the variation of the zinc weight percent between a surface and a thickness center of the direct chill cast prior art product and the continuously cast prior art product is greater than 15%.

[000125] The weight percentages of the zinc, magnesium and copper across grains from the surface to 200 micrometers thickness depth in sample 6 was determined using the “micro-segregation” procedure detailed herein. The data is presented in Figure 13. For comparison, the weight percentages of the zinc, magnesium and copper across grains through thickness for a

direct chill cast prior art product are shown in Figure 14. As shown in Figure 13, the inventors surprisingly found that the weight percent of the primary alloying elements Zn, Cu and Mg were substantially uniform across the grains within the matrix with an increase in the weight percent of the alloying elements at the positions of second phase particles at grain boundaries and within the grains.

[000126] Figure 15 shows the structure of sample 6. The structure of samples of aluminum alloys having average zinc contents of 16% and 25% cast using the apparatus detailed in U.S. Patent No. 6,672,368 at a speed of 55 feet per minute are shown in Figures 16 and 17, respectively. Figures 15-17 show products of the present invention have a globular grain structure and are substantially free of micro-segregation. Moreover, as illustrated in Figures 15-17, the products of the present invention may be substantially free of dendrites and consist primarily of globular non-dendritic grains – i.e., a globular grain structure. Also, as shown by the absence of shading within the grains of Figures 15-17 when the samples are observed in polarized light, the products are substantially free of micro-segregation effects.

[000127] While a number of embodiments of the present invention have been described, it is understood that these embodiments are illustrative only, and not restrictive, and that many modifications may become apparent to those of ordinary skill in the art. Further still, the various steps may be carried out in any desired order (and any desired steps may be added and/or any desired steps may be eliminated).

CLAIMS

We claim:

1. A cast product comprising:

an aluminum alloy strip;

wherein the aluminum alloy strip comprises:

4 wt. % to 28 wt. % zinc; and

wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

2. The cast product of claim 1, wherein the aluminum alloy strip comprises 6 wt. % to 28 wt. % zinc.

3. The cast product of claim 1, wherein the aluminum alloy strip comprises 8 wt. % to 28 wt. % zinc.

4. The cast product of claim 1, wherein the aluminum alloy strip comprises 10 wt. % to 28 wt. % zinc.

5. The cast product of claim 1, wherein the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc

6. The cast product of claim 1, wherein the aluminum alloy strip comprises 6 wt. % to 12 wt. % zinc.

7. The cast product of claim 1, wherein the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc.

8. The cast product of claim 1, wherein the aluminum alloy strip comprises 4 wt. % to 8 wt. % zinc.

9. The cast product of claim 6, wherein the variation of the zinc weight percent is 12% or less between the surface and the thickness center of the aluminum alloy strip.

10. A cast product comprising:

an aluminum alloy strip;

wherein the aluminum alloy strip comprises:

(i) 4 wt. % to 28 wt. % zinc;

(ii) 1 wt. % to 3 wt. % copper; and

(iii) 1 wt. % to 3 wt. % magnesium;

wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

11. The cast product of claim 10, wherein the aluminum alloy strip comprises 4 wt. % to 15 wt. % zinc

12. The cast product of claim 10, wherein the aluminum alloy strip comprises 4 wt. % to 12 wt. % zinc.

13. The cast product of claim 10, wherein the aluminum alloy strip comprises 4 wt. % to 10 wt. % zinc.

14. The cast product of claim 10, wherein the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % copper.

15. The cast product of claim 10, wherein the aluminum alloy strip comprises 1 wt. % to 2.0 wt. % copper.

16. The cast product of claim 10, wherein the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % copper.

17. The cast product of claim 10, wherein the aluminum alloy strip comprises 1 wt. % to 2.5 wt. % magnesium.

18. The cast product of claim 10, wherein the aluminum alloy strip comprises 1 wt. % to 2.0 wt. % magnesium.

19. The cast product of claim 10, wherein the aluminum alloy strip comprises 1 wt. % to 1.5 wt. % magnesium.

20. A cast product comprising:

an aluminum alloy strip;

wherein the aluminum alloy strip comprises:

(i) 4 wt. % to 28 wt. % zinc; and

(ii) 1 wt. % to 3 wt. % copper;

wherein a variation of a weight percent of the zinc is 15% or less between a surface and a thickness center of the aluminum alloy strip.

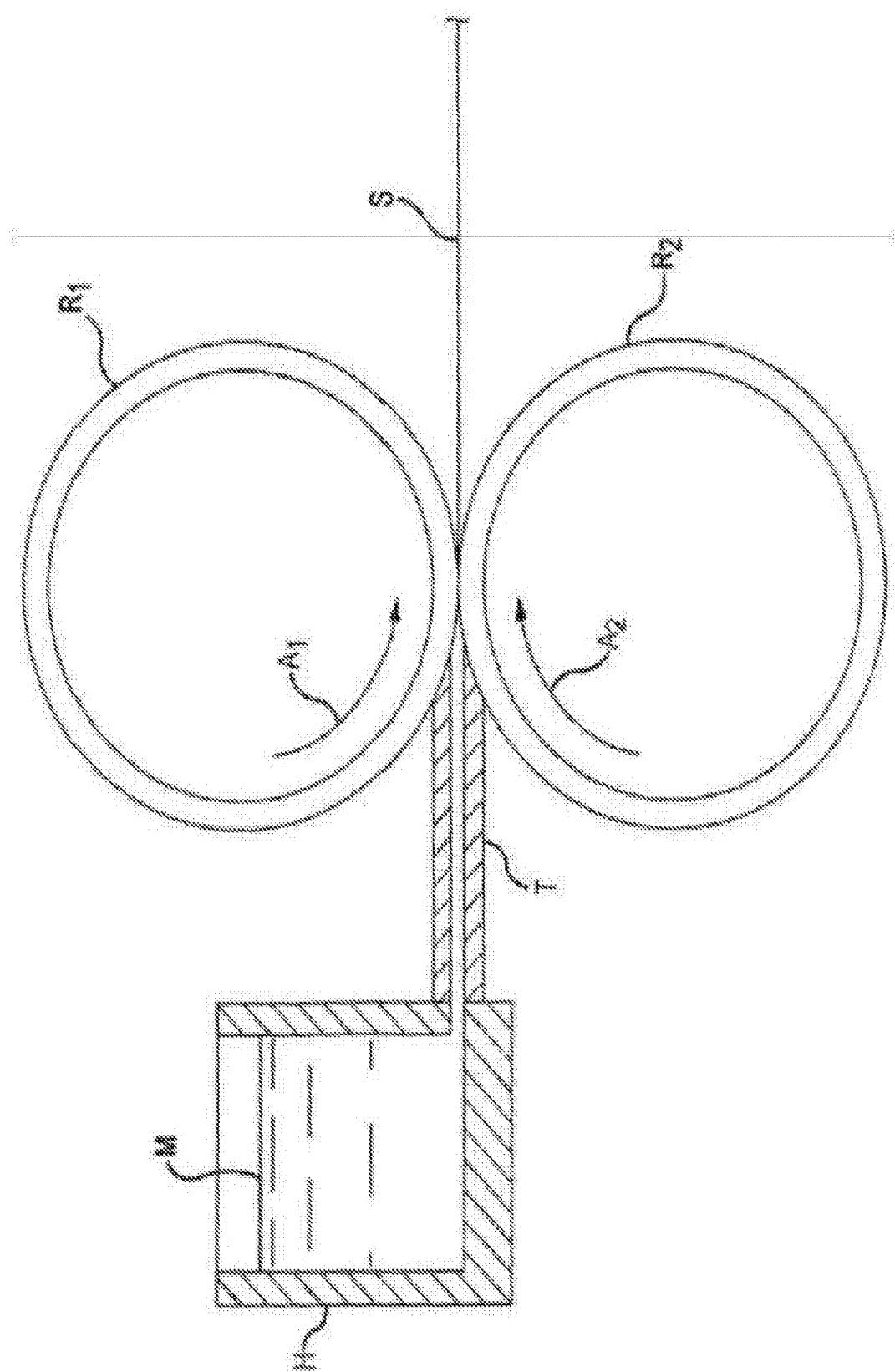


FIGURE 1

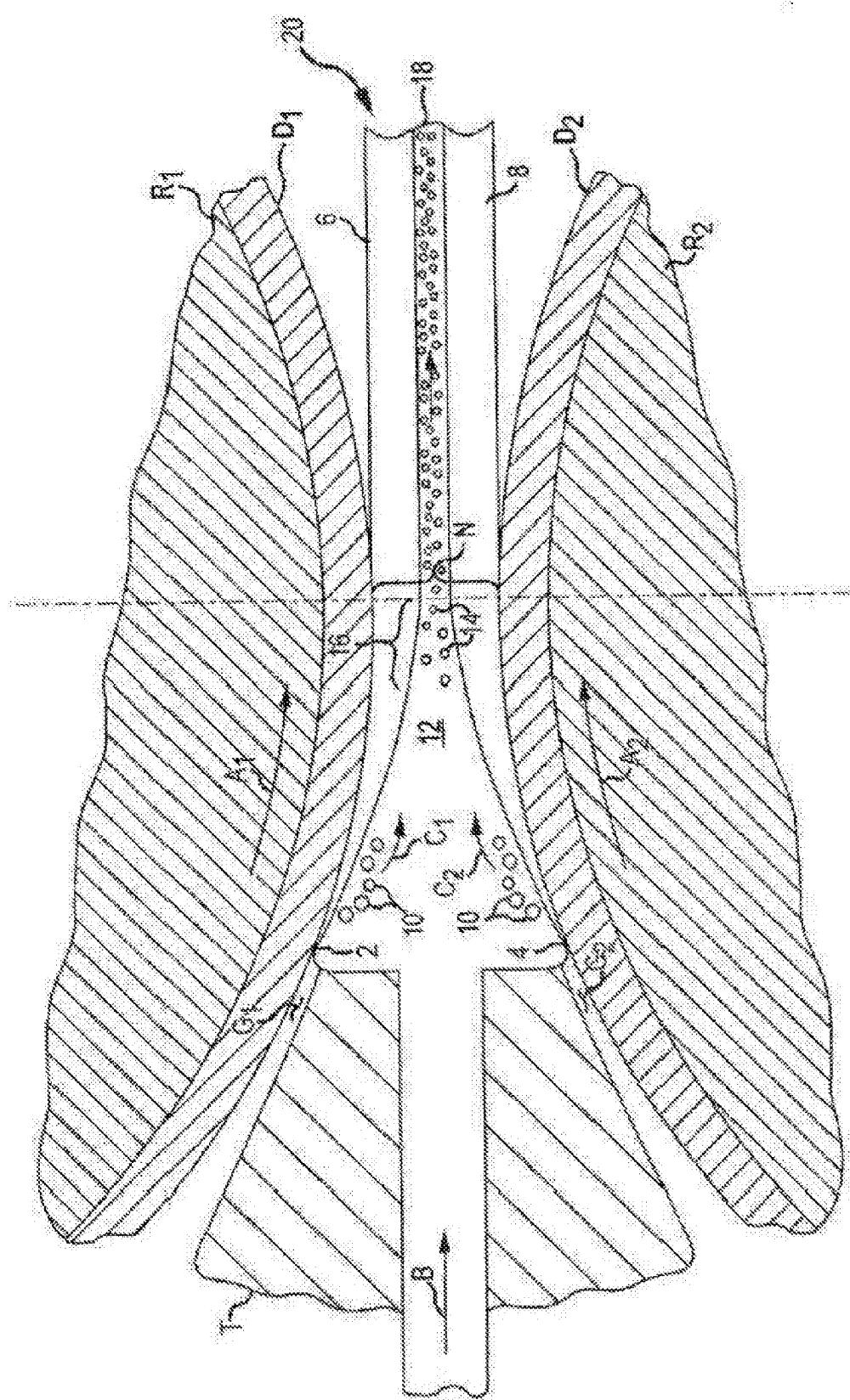


FIGURE 2

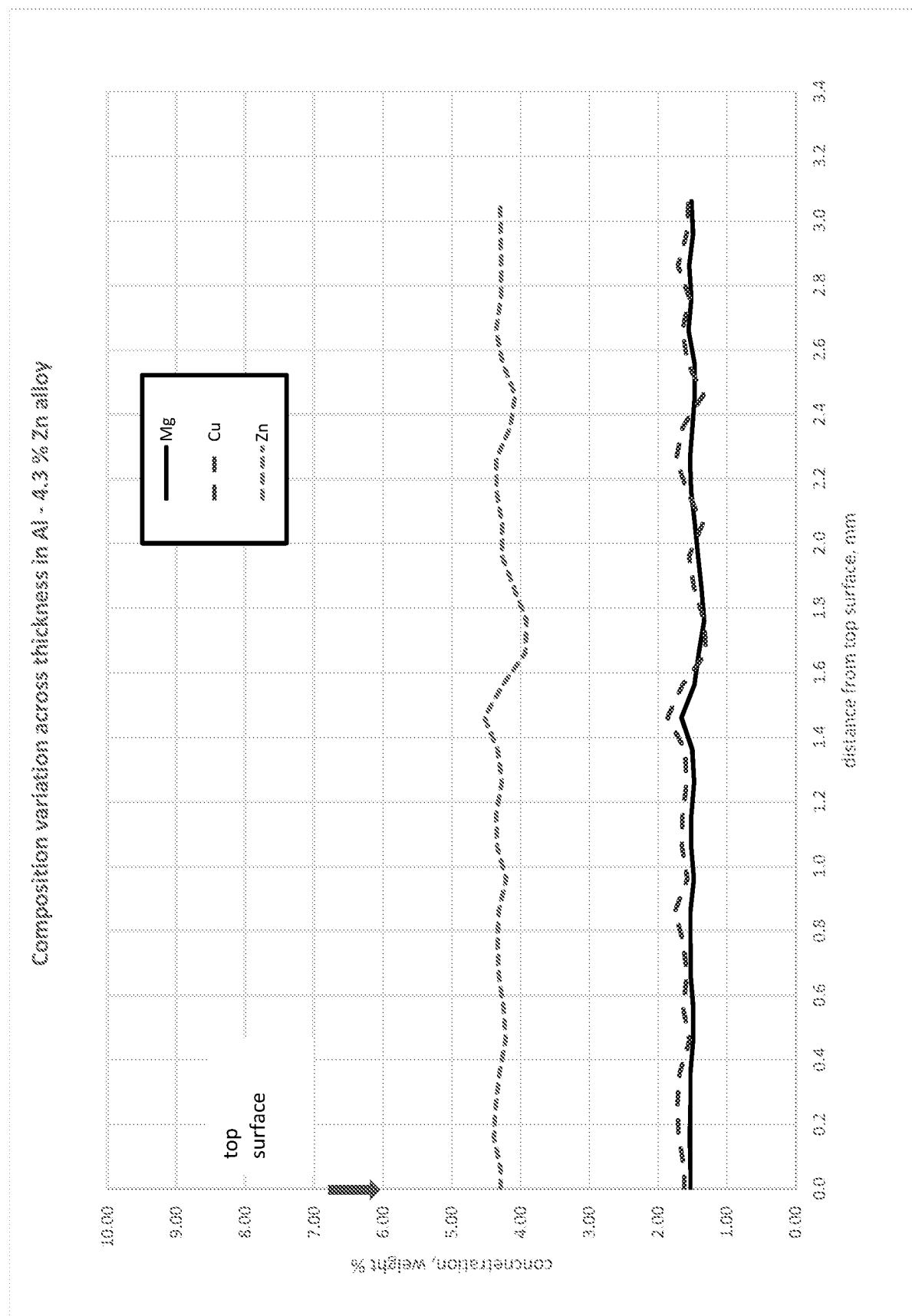


FIGURE 3

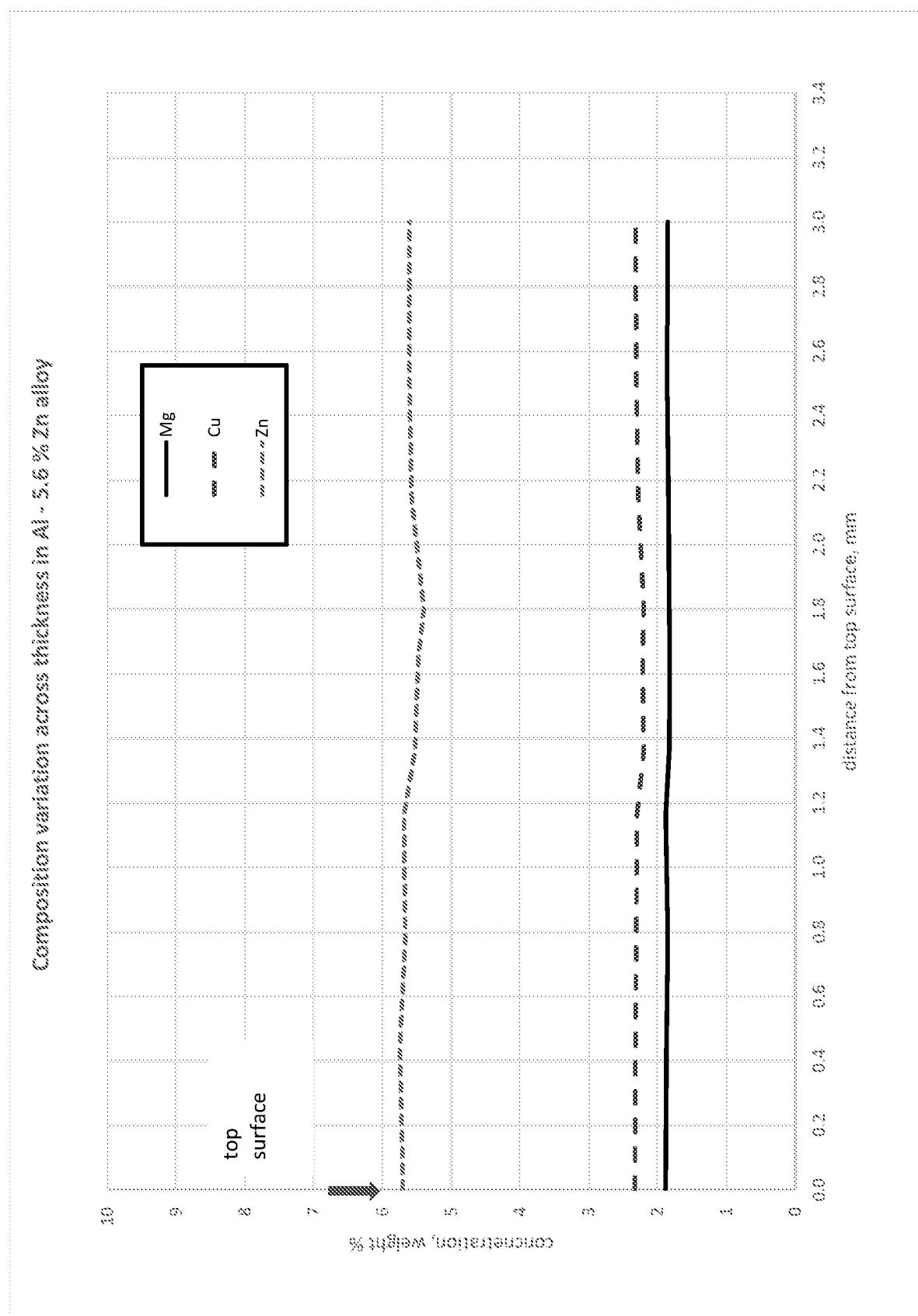


FIGURE 4

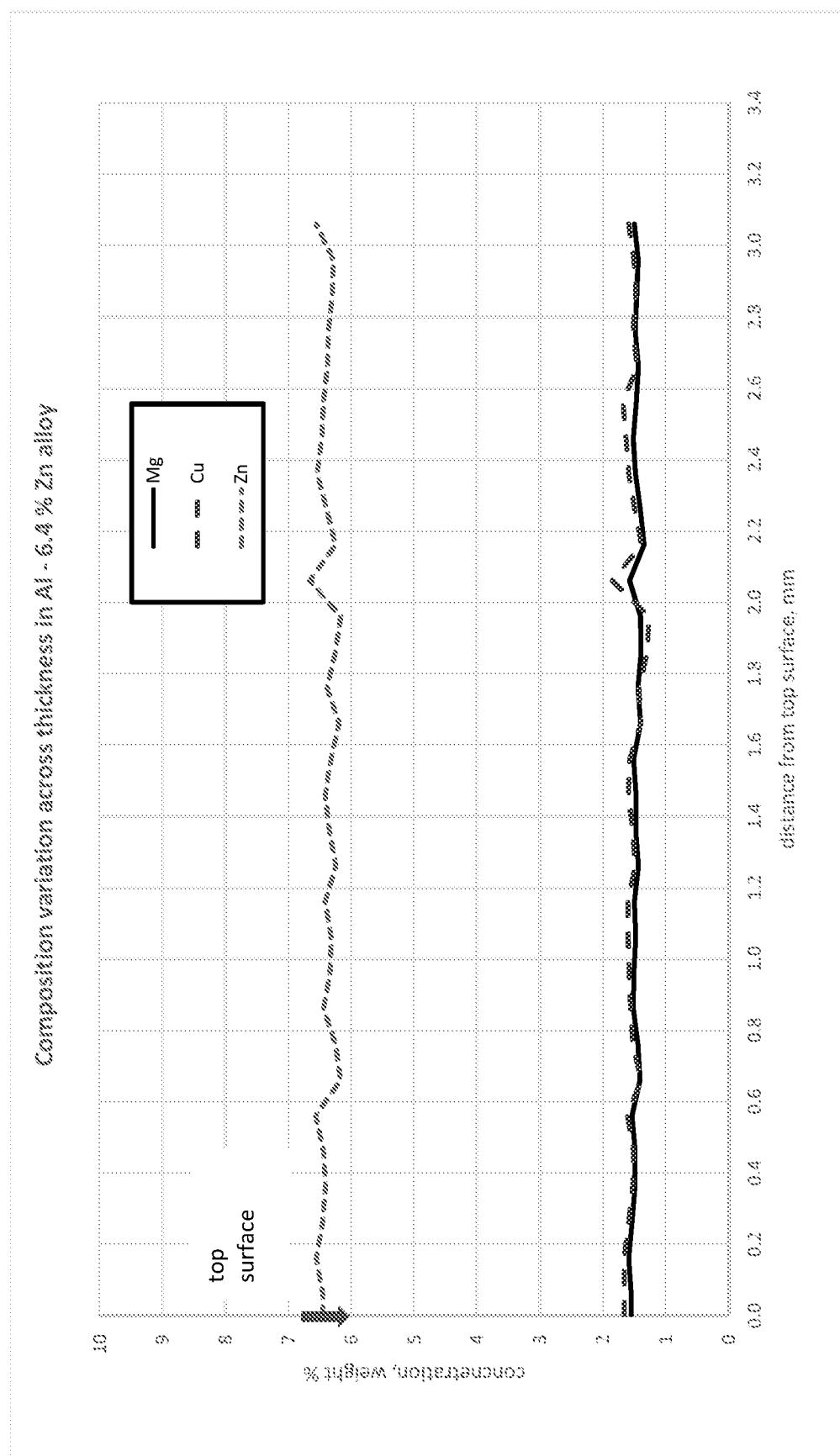


FIGURE 5

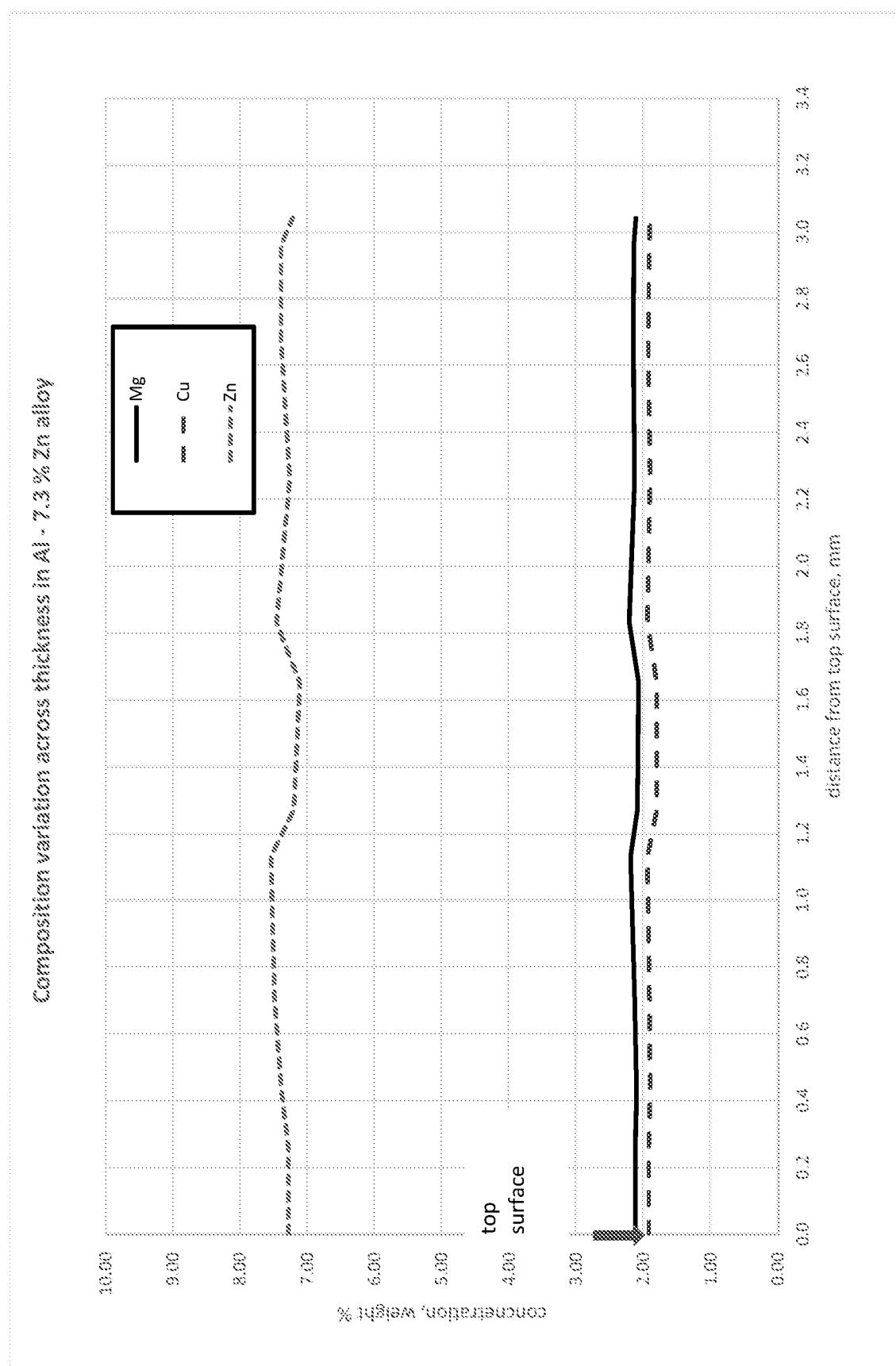


FIGURE 6

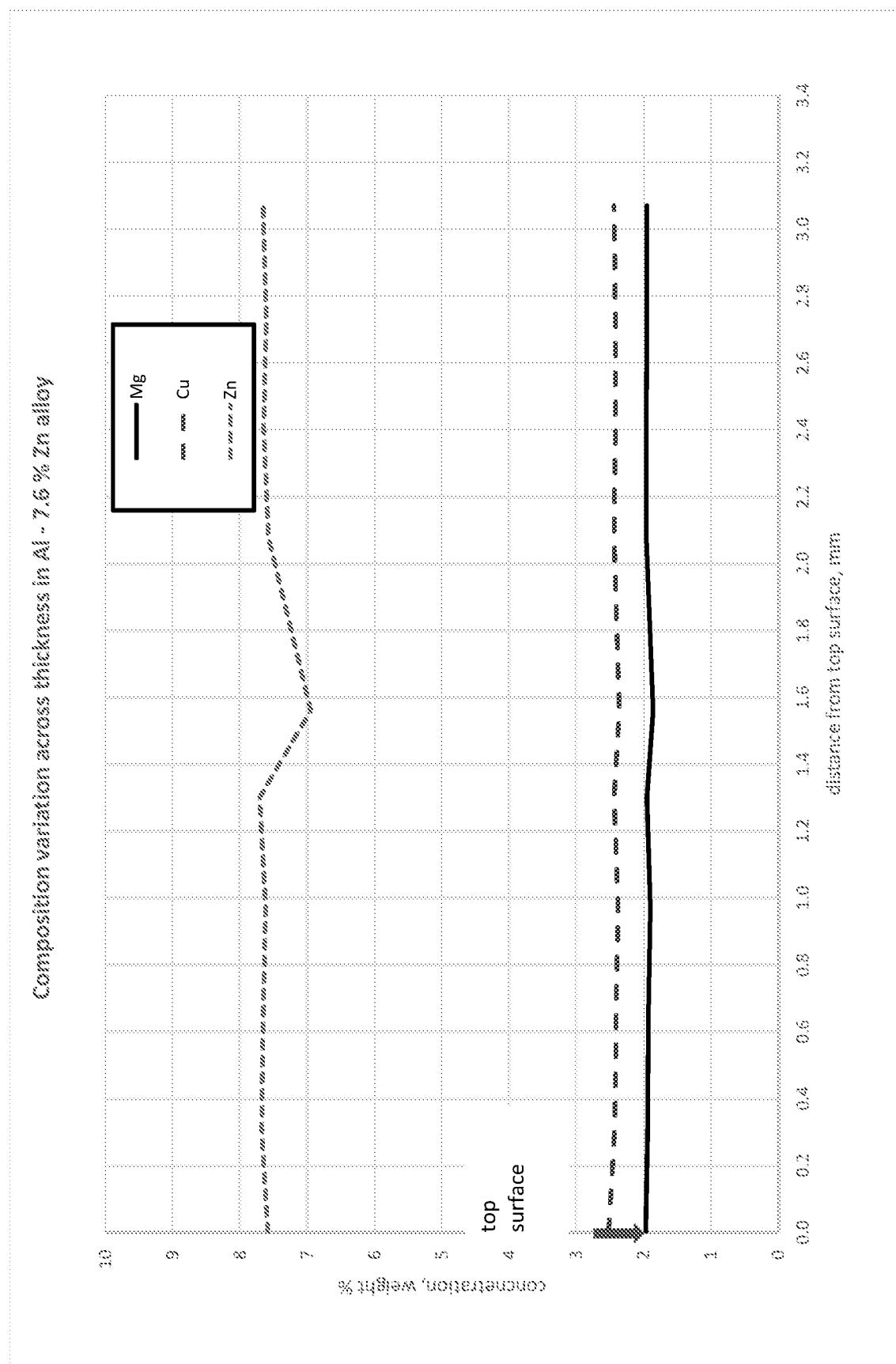


FIGURE 7

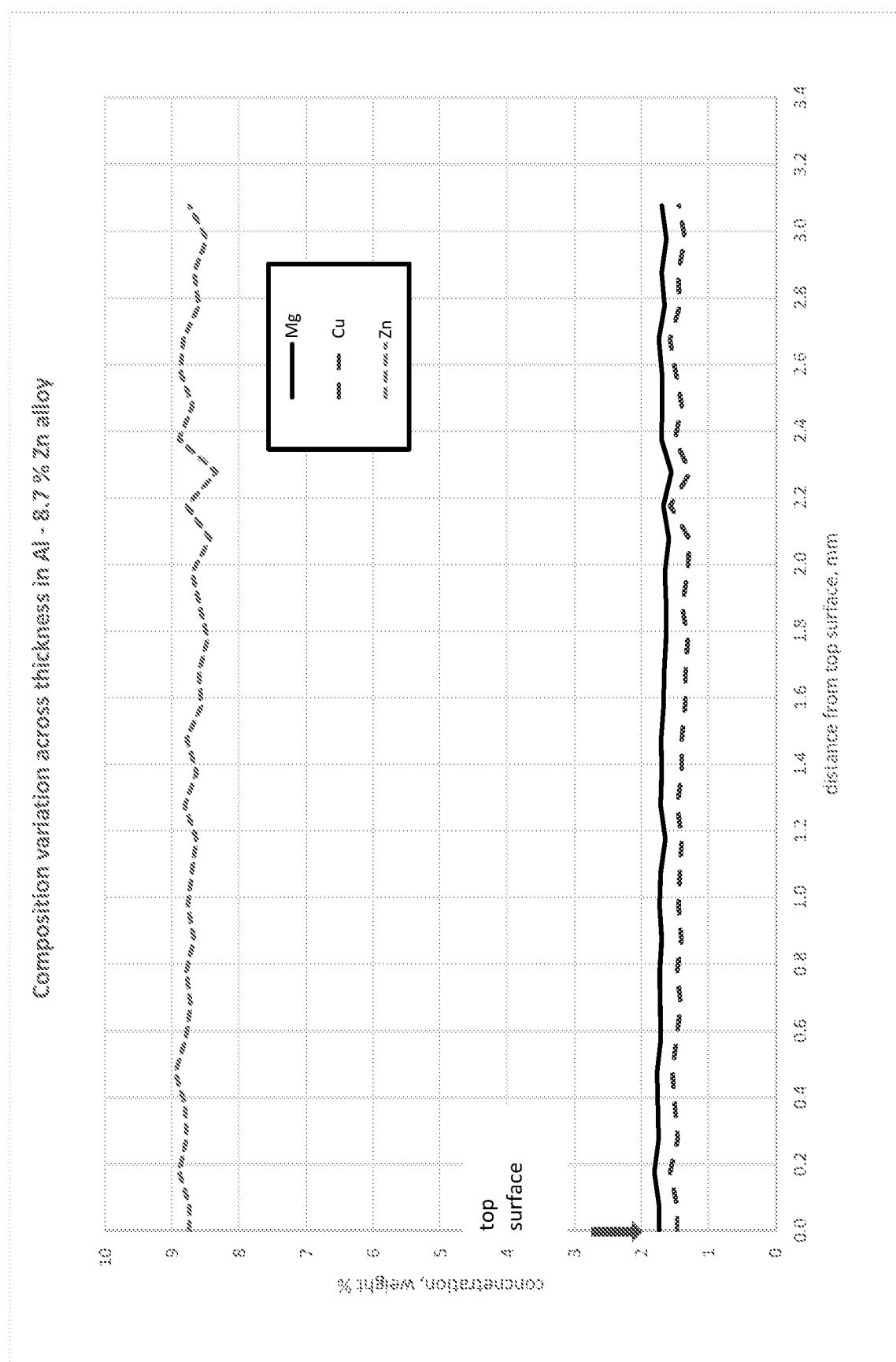


FIGURE 8

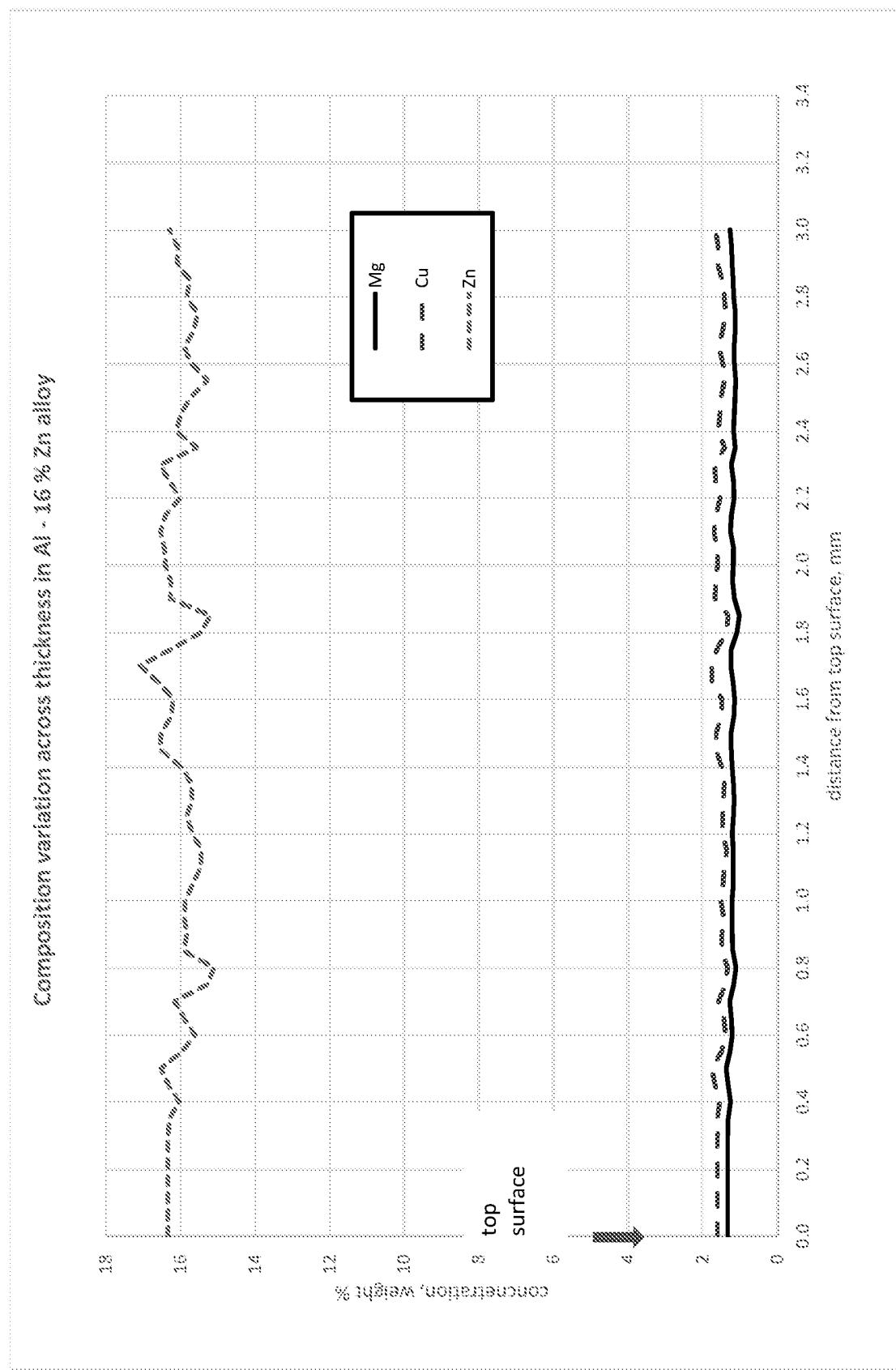


FIGURE 9

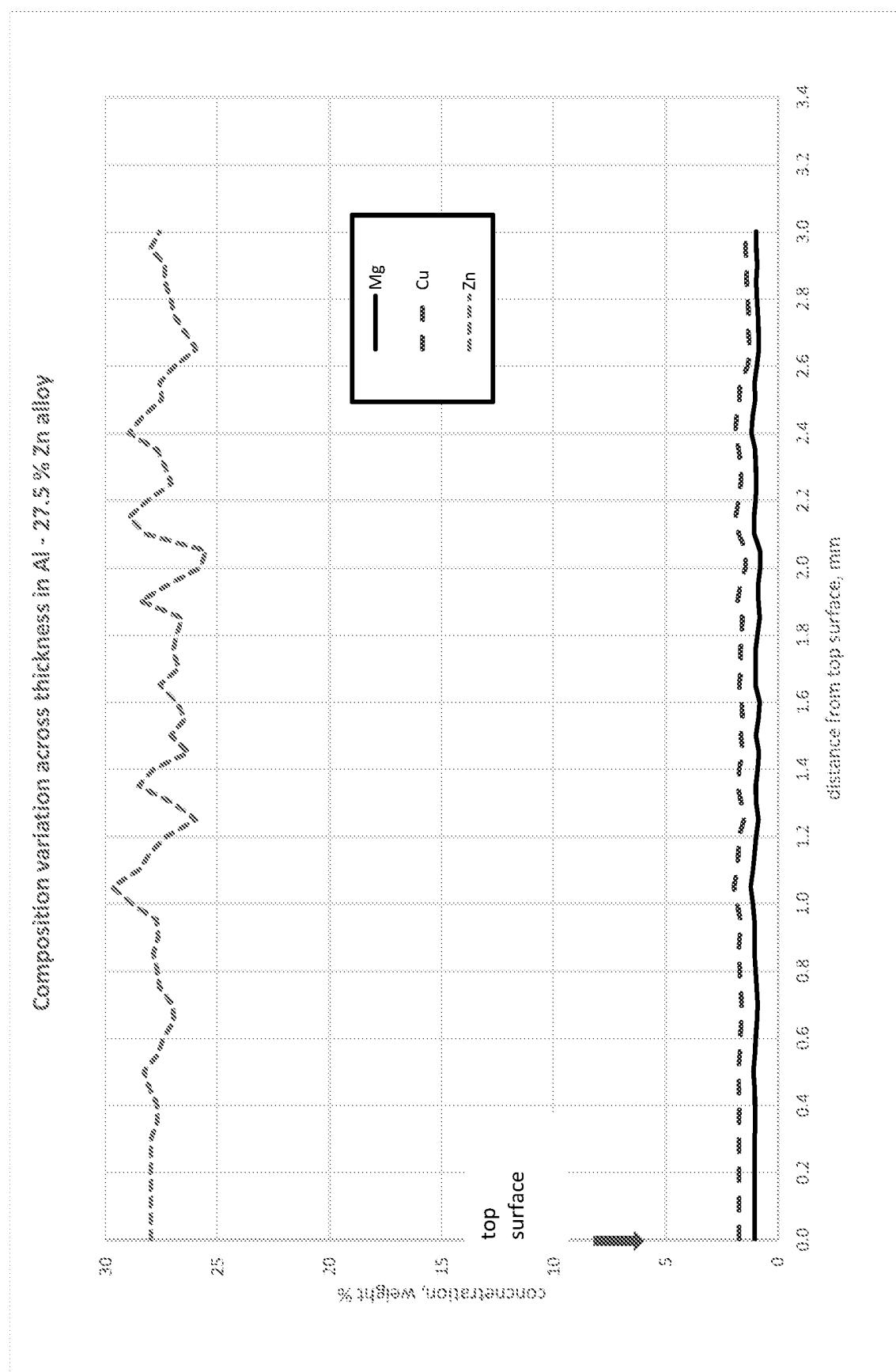
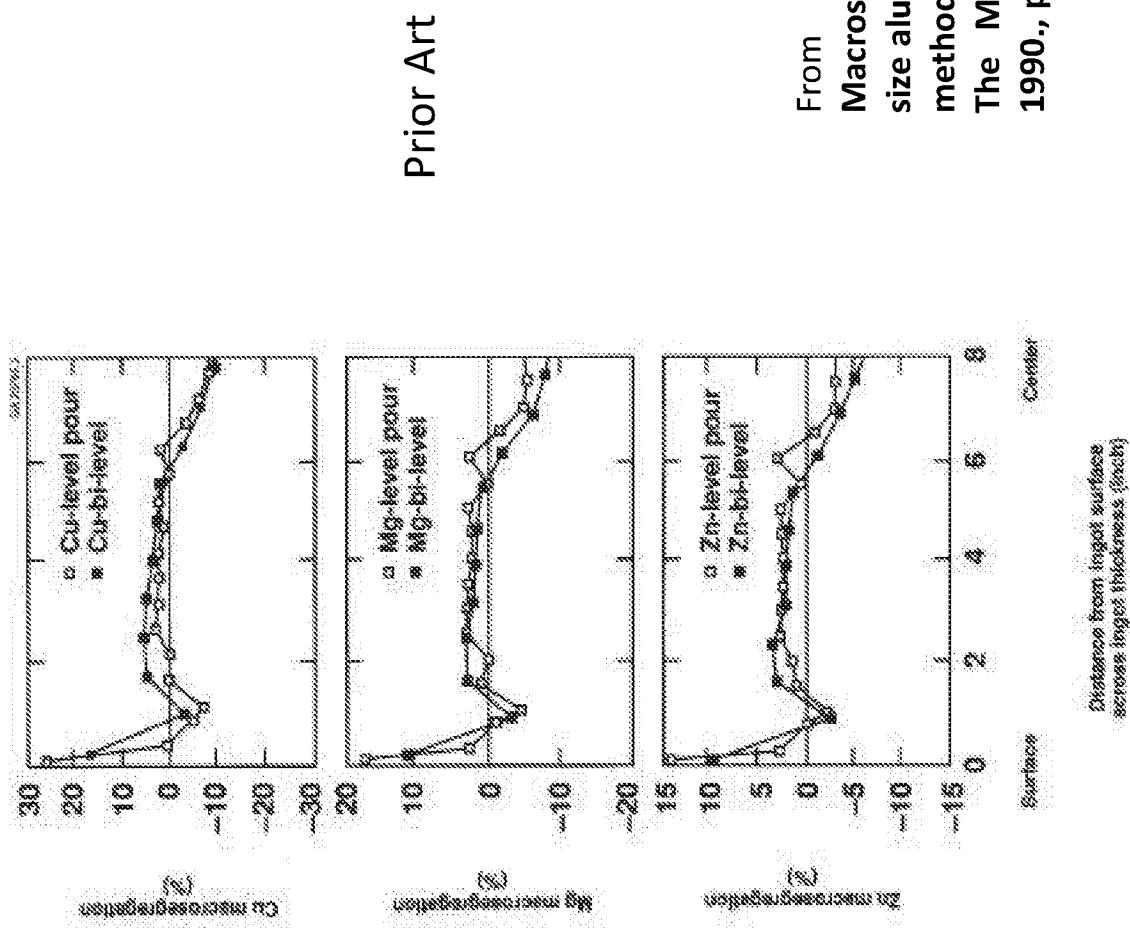


FIGURE 10



From M. G. Chu and J. E. Jacoby:
Macrosegregation characteristics of commercial
size aluminum alloy ingot cast by the direct chill
method, Light Metals 1990, ed. C. M. Bickert,
The Minerals, Metals and Materials Society,
1990., pp. 925-930.

Macrosegregation profiles of 16" x 30" Al-Zn-Mg-Cu ingot
 Cast by the bi-level and level pour methods.
 The Y Axis Represents the Deviation of Each Major Alloy
 Elements from the Mean Chemistry
 Figure 3

FIGURE 11

Segregation of eutectic forming elements Si, Fe, Ni and Zn

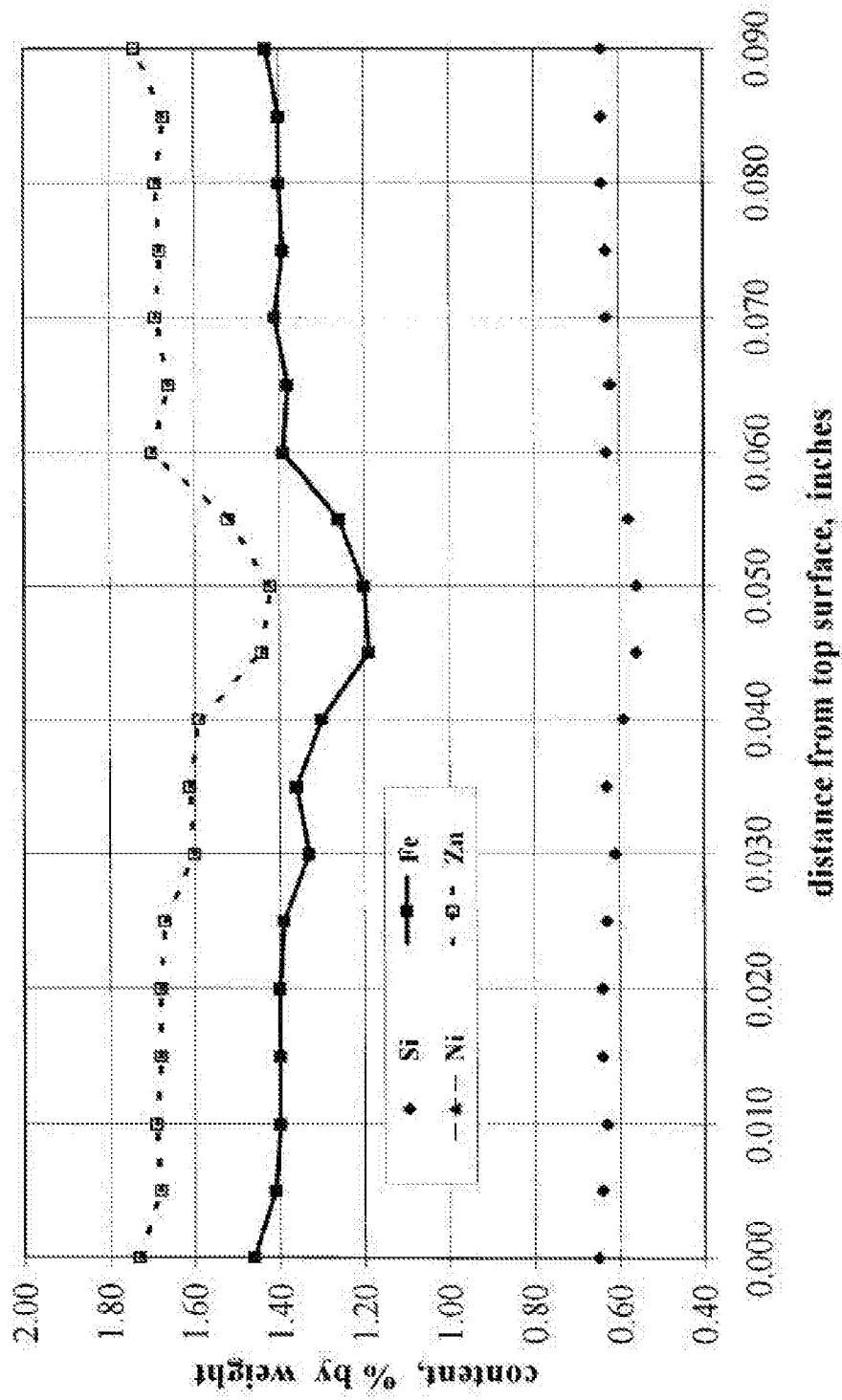


FIGURE 12

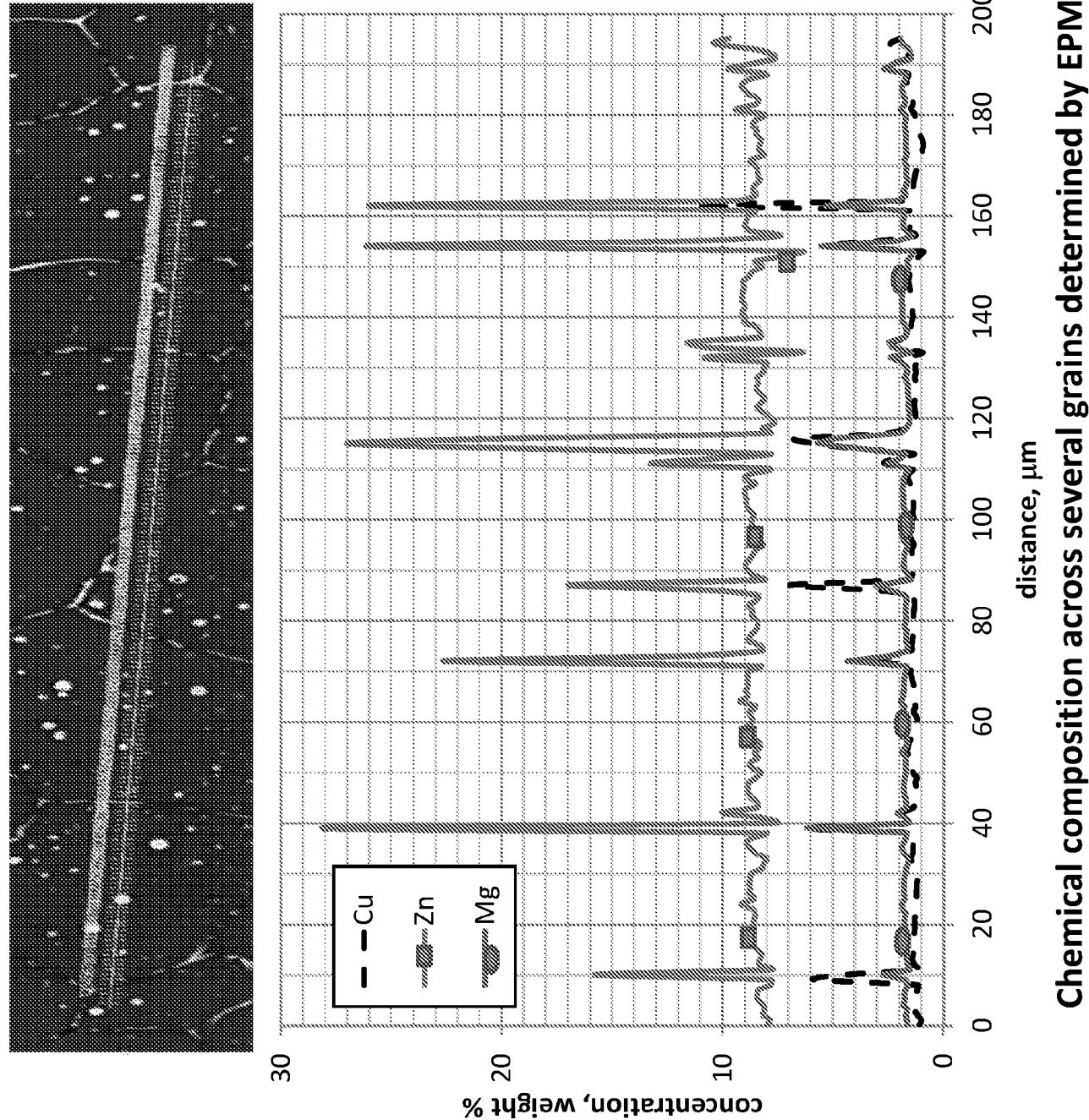


FIGURE 13

Prior Art

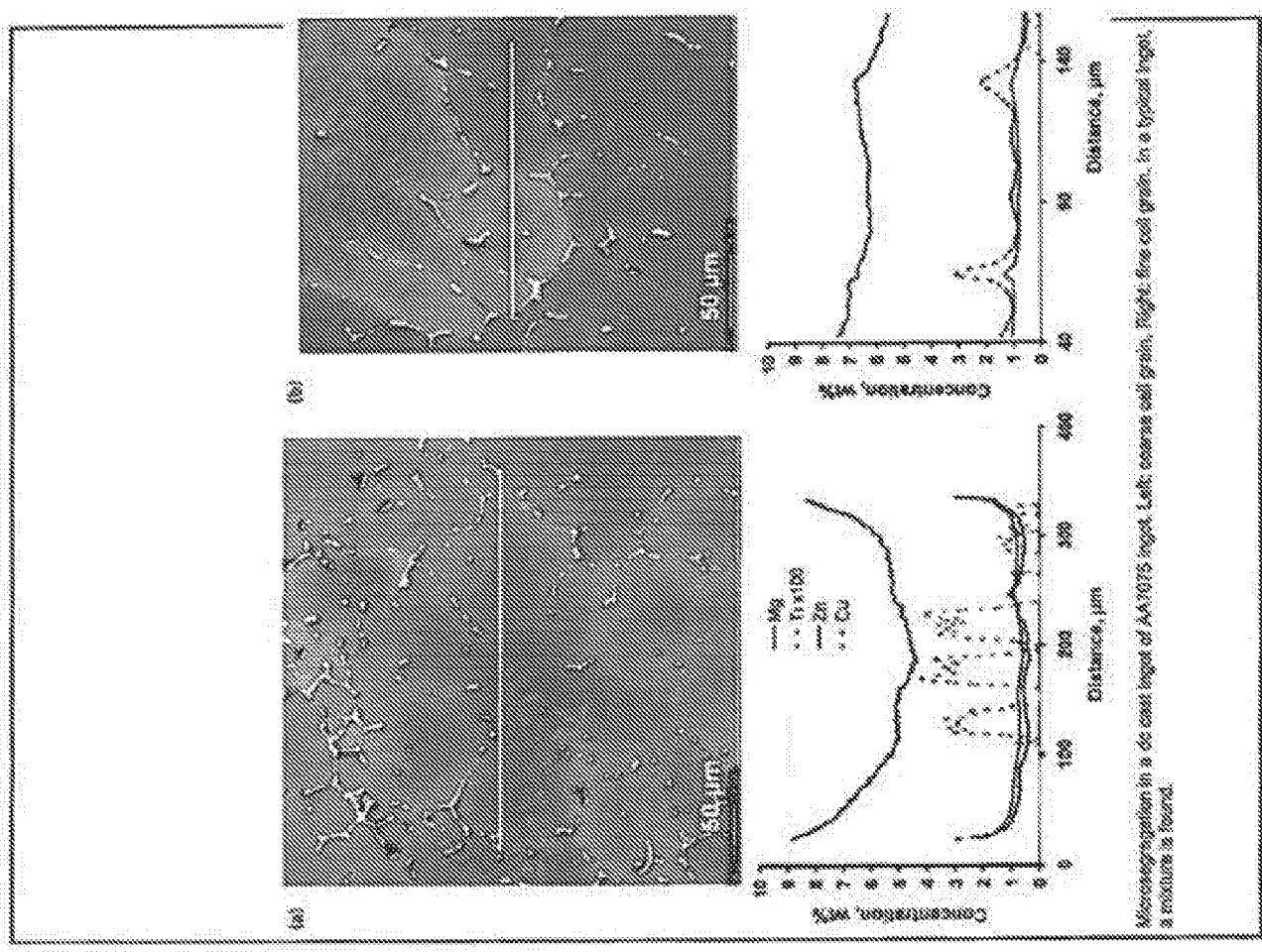


FIGURE 14

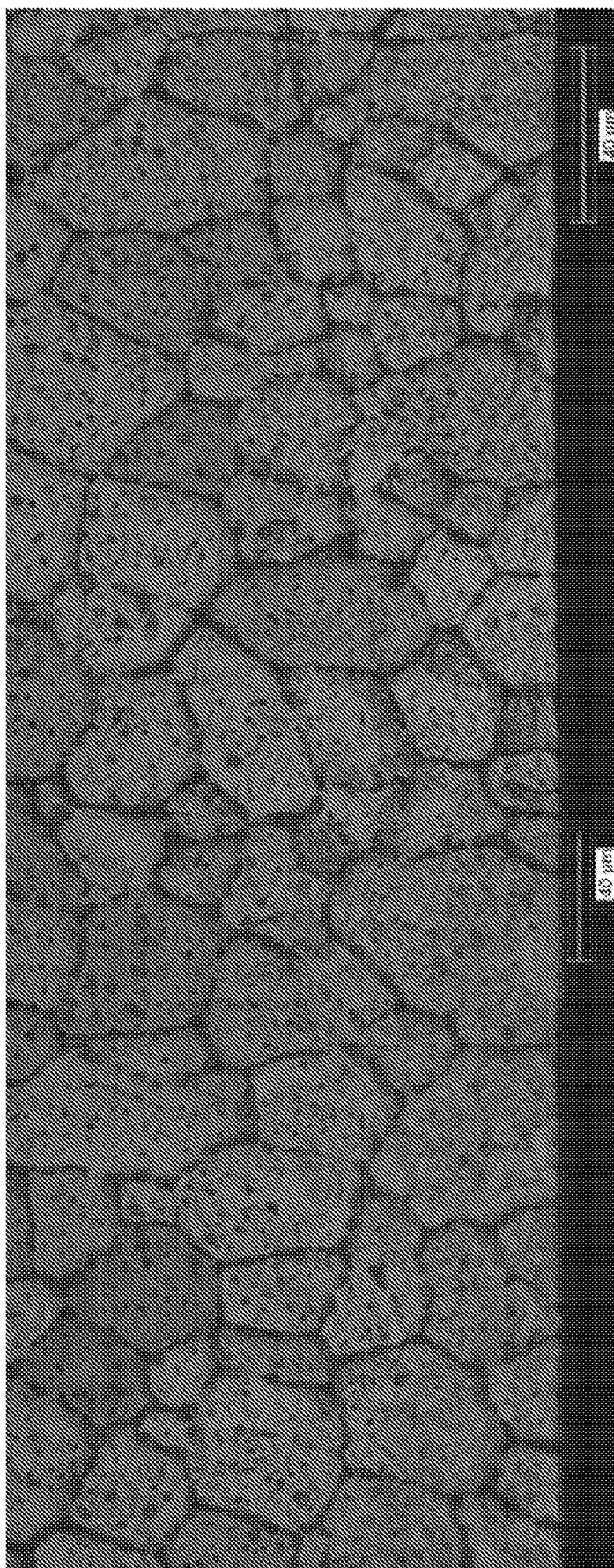


FIGURE 15

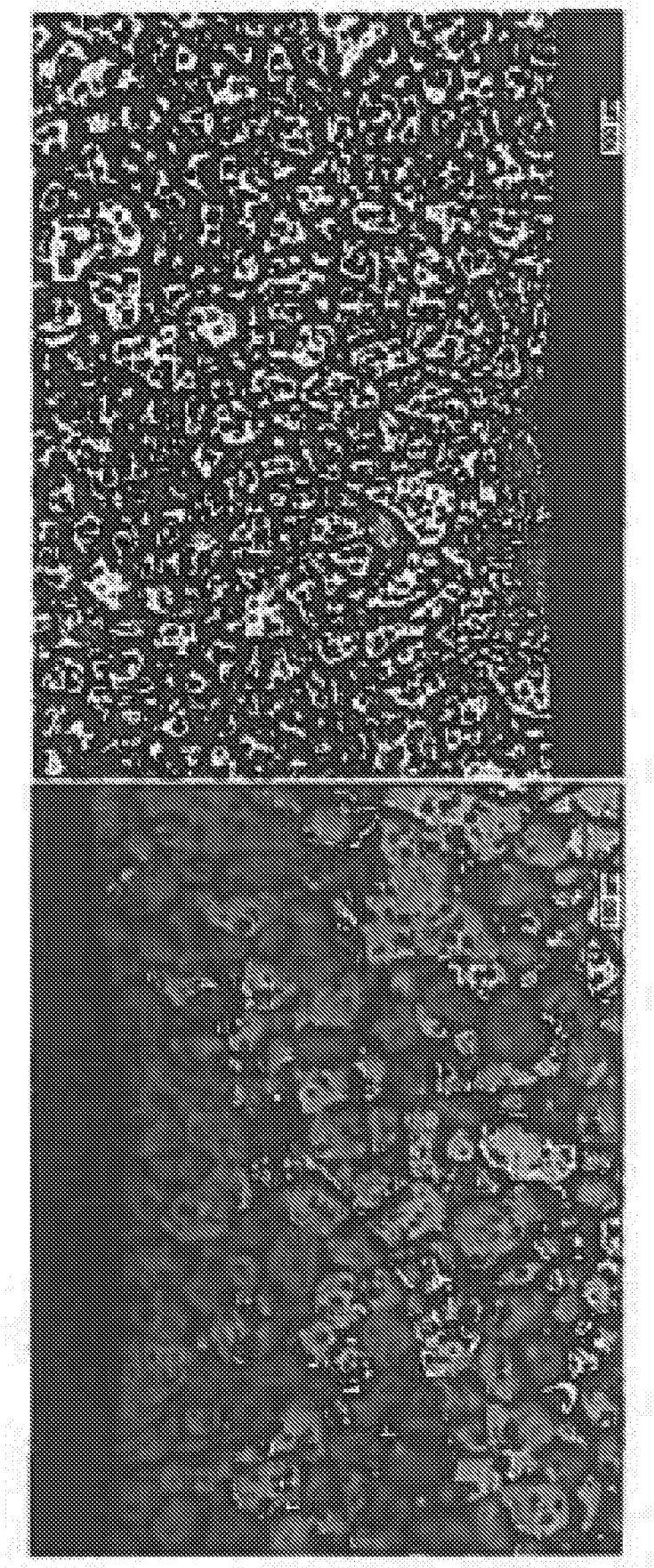


FIGURE 16

FIGURE 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/063481

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C 21/10; C22F 1/04; C22C 21/06; B22D 11/06; B22D 21/04Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: cast product, aluminum alloy strip, zinc, copper, magnesium

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0064058 A1 (KOREA INSTITUTE OF MACHINERY AND MATERIALS) 05 March 2015 See paragraphs [0003], [0023]-[0115]; claims 1-13; and figure 2.	1-20
A	US 5135713 A (RIOJA et al.) 04 August 1992 See column 3, line 4 - column 8, line 2; and figure 4.	1-20
A	US 2005-0269000 A1 (DENZER et al.) 08 December 2005 See paragraphs [0021]-[0045]; and figure 4.	1-20
A	US 2002-0121319 A1 (CHAKRABARTI et al.) 05 September 2002 See paragraphs [0049]-[0084]; and figure 12.	1-20
A	WO 2012-033939 A2 (ALCOA INC. et al.) 15 March 2012 See paragraphs [0004]-[0051]; and figure 15.	1-20

 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
 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
 "O" document referring to an oral disclosure, use, exhibition or other means
 "P" document published prior to the international filing date but later than the priority date claimed

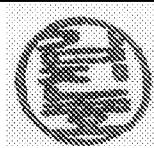
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
 "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered 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
15 March 2018 (15.03.2018)Date of mailing of the international search report
16 March 2018 (16.03.2018)Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer

KIM, Jin Ho

Telephone No. +82-42-481-8699



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/063481

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015-0064058 A1	05/03/2015	KR 10-1511632 B1 KR 10-2015-0027961 A	13/04/2015 13/03/2015
US 5135713 A	04/08/1992	CA 1228490 A CA 1256354 A CA 1283565 C CA 1321126 C EP 0157600 A2 EP 0157600 B1 EP 0188762 A1 EP 0247181 A1 EP 0247181 B1 EP 0266741 A1 EP 0266741 B1 EP 0325937 A1 EP 0325937 B1 JP 01-242750 A JP 3101280 B2 JP 60-221543 A JP 61-210147 A JP 7013281 B2 US 4648913 A US 4795502 A US 4797165 A US 4806174 A US 4816087 A US 4844750 A US 4897126 A US 4915747 A US 4921548 A US 4961792 A US 5066342 A US 5108519 A US 5137686 A WO 87-03011 A1 WO 88-03575 A1	27/10/1987 27/06/1989 30/04/1991 10/08/1993 09/10/1985 01/07/1992 30/07/1986 02/12/1987 02/10/1991 11/05/1988 27/12/1991 02/08/1989 09/03/1994 27/09/1989 23/10/2000 06/11/1985 18/09/1986 15/02/1995 10/03/1987 03/01/1989 10/01/1989 21/02/1989 28/03/1989 04/07/1989 30/01/1990 10/04/1990 01/05/1990 09/10/1990 19/11/1991 28/04/1992 11/08/1992 21/05/1987 19/05/1988
US 2005-0269000 A1	08/12/2005	AU 2002-245705 A1 BR 0208271 A CA 2441168 A1 CN 1531603 A EP 1373591 A2 US 2003-0051784 A1 WO 02-075010 A2 WO 02-075010 A3	03/10/2002 09/03/2004 26/09/2002 22/09/2004 02/01/2004 20/03/2003 26/09/2002 13/03/2003
US 2002-0121319 A1	05/09/2002	AT 555223 T BR 0116422 A BR 0116422 B1	15/05/2012 30/12/2003 13/07/2010

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/063481

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		CA 2432089 A1	04/07/2002
		CA 2432089 C	30/04/2013
		CN 102134670 A	27/07/2011
		CN 102134671 A	27/07/2011
		CN 102134671 B	11/12/2013
		CN 103088241 A	08/05/2013
		CN 103088241 B	22/04/2015
		CN 1489637 A	14/04/2004
		EP 1346073 A1	24/09/2003
		EP 1346073 B1	25/04/2012
		EP 2322677 A1	18/05/2011
		EP 2322677 B1	16/12/2015
		EP 2322677 B9	20/04/2016
		IL 156386 A	31/10/2007
		IL 184854 A	03/12/2007
		JP 2004-517210 A	10/06/2004
		JP 4209676 B2	14/01/2009
		KR 10-0892242 B1	09/04/2009
		KR 10-2003-0061013 A	16/07/2003
		RU 2003-122354 A	27/02/2005
		RU 2008-108622 A	10/09/2009
		RU 2009-143523 A	27/05/2011
		RU 2329330 C2	20/07/2008
		RU 2384638 C2	20/03/2010
		RU 2531214 C2	20/10/2014
		US 2002-0150498 A1	17/10/2002
		US 2005-0150579 A1	14/07/2005
		US 2005-0257865 A1	24/11/2005
		US 2006-0083654 A1	20/04/2006
		US 2011-0268603 A1	03/11/2011
		US 2013-0312877 A1	28/11/2013
		US 6972110 B2	06/12/2005
		US 7678205 B2	16/03/2010
		US 8083870 B2	27/12/2011
		US 8524014 B2	03/09/2013
		WO 2002-052053 A1	04/07/2002
		WO 2002-052053 A8	26/02/2004
WO 2012-033939 A2	15/03/2012	AU 2011-226794 A1	22/03/2012
		AU 2011-226794 B2	05/04/2012
		AU 2011-226795 A1	22/03/2012
		AU 2011-226795 B2	01/11/2012
		AU 2011-226797 A1	22/03/2012
		AU 2011-226797 B2	19/04/2012
		AU 2011-226799 A1	22/03/2012
		AU 2011-226799 B2	12/04/2012
		AU 2012-202427 A1	17/05/2012
		AU 2012-202429 A1	17/05/2012
		AU 2012-202430 A1	17/05/2012
		AU 2012-244173 A1	15/11/2012

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/063481

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		BR 112013005453 A2	03/05/2016
		BR 112013005557 A2	03/05/2016
		BR 112013005659 A2	03/05/2016
		CA 2810245 A1	15/03/2012
		CA 2810246 A1	05/04/2012
		CA 2810250 A1	15/03/2012
		CA 2810251 A1	15/03/2012
		CN 103119184 A	22/05/2013
		CN 103119184 B	05/08/2015
		CN 103119185 A	22/05/2013
		CN 103119185 B	12/08/2015
		CN 103168110 A	19/06/2013
		CN 103168111 A	19/06/2013
		CN 103168111 B	29/07/2015
		CN 105063522 A	18/11/2015
		EP 2614168 A2	17/07/2013
		EP 2614168 A4	14/10/2015
		EP 2614169 A2	17/07/2013
		EP 2614169 A4	07/10/2015
		EP 2614170 A2	17/07/2013
		EP 2614170 A4	14/10/2015
		EP 2625302 A2	14/08/2013
		EP 2625302 A4	07/10/2015
		JP 2013-537936 A	07/10/2013
		JP 2013-542319 A	21/11/2013
		JP 2013-542320 A	21/11/2013
		KR 10-2013-0108338 A	02/10/2013
		KR 10-2013-0108339 A	02/10/2013
		KR 10-2014-0001860 A	07/01/2014
		MX 2013002635 A	24/04/2013
		MX 2013002636 A	09/05/2013
		MX 2013002637 A	09/05/2013
		MX 344421 B	15/12/2016
		RU 2013-115413 A	20/10/2014
		RU 2013-115426 A	20/11/2014
		RU 2013-115430 A	20/10/2014
		RU 2013-115468 A	20/10/2014
		RU 2581543 C2	20/04/2016
		RU 2581544 C2	20/04/2016
		RU 2603521 C2	27/11/2016
		US 2012-0055588 A1	08/03/2012
		US 2012-0055589 A1	08/03/2012
		US 2012-0055590 A1	08/03/2012
		US 2012-0055591 A1	08/03/2012
		US 2014-0248177 A1	04/09/2014
		US 2016-0115577 A1	28/04/2016
		US 2016-0122852 A1	05/05/2016
		US 8999079 B2	07/04/2015
		US 9194028 B2	24/11/2015
		US 9249484 B2	02/02/2016

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/063481

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 9359660 B2	07/06/2016
		WO 2012-033939 A3	09/08/2012
		WO 2012-033949 A2	15/03/2012
		WO 2012-033949 A3	31/05/2012
		WO 2012-033954 A2	15/03/2012
		WO 2012-033954 A3	07/06/2012
		WO 2012-044450 A2	05/04/2012
		WO 2012-044450 A3	05/07/2012
		WO 2012-044450 A9	18/05/2012