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(54) **NEW SCRAP-BASED ALUMINUM ALLOY PRODUCTS**

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(57) **ABSTRACT**

New aluminum alloys are disclosed. The new aluminum alloys may include from 1.05 to 1.55 wt. % Si, from 0.85 to 2.10 wt. % Mg, from 0.15 to 0.75 wt. % Cu, from 0.20 to 0.90 wt. % Fe, from 0.5 to 1.5 wt. % Mn, from 0.01 to 0.15 wt. % Ti, up to 0.4 wt. % Zn, up to 0.25 wt. % of any of Cr, Zr and V, and up to 0.05 wt. % Ni, the balance being aluminum, incidental elements and impurities. The new aluminum alloys may be at least partially derived from scrap materials, such as UBC or brazing scrap. The new aluminum alloy may be processed into an H-temper sheet product. The new aluminum alloys may realize and improved combination of at least two of strength, elongation and corrosion resistance.

NEW SCRAP-BASED ALUMINUM ALLOY PRODUCTS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of International Patent Application No. PCT/US2023/023056, entitled "New Scrap-Based Aluminum Alloy Products," filed May 22, 2023, which claims the benefit of U.S. Provisional Application No. 63/344,968 entitled "New Scrap-Based Aluminum Alloy Products," filed May 23, 2022. Each of the above-identified patent applications are hereby incorporated by reference in their entirety.

BACKGROUND

[0002] As noted in U.S. Patent Application Publication No. 2021/0087664, aluminum can contribute to a part of carbon footprint. An effective method of reducing the carbon footprint and aluminum mining is by increasing the use of recycled aluminum, especially post-consumer recycled (PCR) aluminum. One of the major sources of PCR aluminum is used beverage can (UBC) scrap. Increased recycling can have a large impact on reducing the carbon footprint and primary aluminum consumption.

SUMMARY OF THE DISCLOSURE

[0003] Broadly, the present patent application relates to new aluminum alloys. The new aluminum alloys may be scrap derived, thereby reducing their cost of manufacture. Despite being scrap derived, the new aluminum alloys may realize exceptional mechanical properties and corrosion resistance. In one embodiment, a new aluminum alloy includes from 1.05 to 1.55 wt. % Si, from 0.85 to 2.10 wt. % Mg, from 0.15 to 0.75 wt. % Cu, from 0.20 to 0.90 wt. % Fe, from 0.5 to 1.5 wt. % Mn, from 0.01 to 0.15 wt. % Ti, up to 0.4 wt. % Zn, up to 0.25 wt. % of any of Cr, Zr and V, and up to 0.05 wt. % Ni, the balance being aluminum, incidental elements and impurities. In one approach, a new aluminum alloy is in the form of a sheet product having a thickness of from 0.4 to 4 mm. In one embodiment, the aluminum alloy sheet product realizes at least one of the following microstructural characteristics: (i) not greater than 50 vol. % recrystallized grains, (ii) an Mg_2Si area percent of at least 0.5%, (iii) an average Mg_2Si particle area of at least 0.5 particles per square micrometer, (iv) a constituent area percent of at least 0.5%, and (v) an average constituent particle area of at least 0.5 particles per square micrometer. Methods of determining these microstructural characteristics are described in the Microstructure Assessment Procedure, described below.

i. Compositions

[0004] As noted above, the new aluminum alloys generally include from 1.05 to 1.55 wt. % Si. Such silicon levels may facilitate, for instance, improved scrap utilization rates and/or improved mechanical properties. In one embodiment, a new aluminum alloy includes at least 1.10 wt. % Si. In another embodiment, a new aluminum alloy includes at least 1.15 wt. % Si. In one embodiment, a new aluminum alloy includes not greater than 1.45 wt. % Si. In another embodiment, a new aluminum alloy includes not greater than 1.40 wt. % Si.

[0005] As noted above, the new aluminum alloys generally include from 0.85 to 2.10 wt. % Mg. Such magnesium levels may facilitate, for instance, improved mechanical properties (e.g., strain hardening). In one embodiment, a new aluminum alloy includes at least 0.90 wt. %. Mg. In another embodiment, a new aluminum alloy includes at least 0.95 wt. % Mg. In one embodiment, a new aluminum alloy includes not greater than 2.05 wt. % Mg. In another embodiment, a new aluminum alloy includes not greater than 2.00 wt. % Mg. In yet another embodiment, a new aluminum alloy includes not greater than 1.95 wt. % Mg. In another embodiment, a new aluminum alloy includes not greater than 1.90 wt. % Mg.

[0006] As noted above, the new aluminum alloys generally include from 0.15 to 0.75 wt. % Cu. Such levels of copper may, for instance, facilitate improved mechanical properties without unnecessarily degrading corrosion resistance. In one embodiment, a new aluminum alloy includes at least 0.20 wt. %. Cu. In another embodiment, a new aluminum alloy includes at least 0.25 wt. % Cu. In yet another embodiment, a new aluminum alloy includes at least 0.30 wt. % Cu. In one embodiment, a new aluminum alloy includes not greater than 0.70 wt. % Cu. In another embodiment, a new aluminum alloy includes not greater than 0.65 wt. % Cu. In yet another embodiment, a new aluminum alloy includes not greater than 0.60 wt. % Cu.

[0007] As noted above, the new aluminum alloys generally include from 0.20 to 0.90 wt. % Fe. Such levels of iron may, for instance, facilitate high scrap tolerance and/or dispersoid formation. In one embodiment, a new aluminum alloy includes at least 0.25 wt. %. Fe. In another embodiment, a new aluminum alloy includes at least 0.30 wt. % Fe. In one embodiment, a new aluminum alloy includes not greater than 0.85 wt. % Fe. In another embodiment, a new aluminum alloy includes not greater than 0.80 wt. % Fe. In yet another embodiment, a new aluminum alloy includes not greater than 0.75 wt. % Fe.

[0008] As noted above, the new aluminum alloys generally include from 0.5 to 1.5 wt. % Mn. Such levels of manganese may, for instance, facilitate high scrap tolerance and/or dispersoid formation. In one embodiment, a new aluminum alloy includes at least 0.55 wt. %. Mn. In another embodiment, a new aluminum alloy includes at least 0.60 wt. % Mn. In yet another embodiment, a new aluminum alloy includes at least 0.65 wt. % Mn. In another embodiment, a new aluminum alloy includes at least 0.70 wt. % Mn. In yet another embodiment, a new aluminum alloy includes at least 0.75 wt. % Mn. In another embodiment, a new aluminum alloy includes at least 0.80 wt. % Mn. In yet another embodiment, a new aluminum alloy includes at least 0.85 wt. % Mn. In another embodiment, a new aluminum alloy includes at least 0.90 wt. % Mn. In yet another embodiment, a new aluminum alloy includes at least 0.95 wt. % Mn. In another embodiment, a new aluminum alloy includes at least 1.0 wt. % Mn. In one embodiment, a new aluminum alloy includes not greater than 1.45 wt. % Mn. In another embodiment, a new aluminum alloy includes not greater than 1.40 wt. % Mn. In yet another embodiment, a new aluminum alloy includes not greater than 1.35 wt. % Mn. In another embodiment, a new aluminum alloy includes not greater than 1.30 wt. % Mn. In yet another embodiment, a new aluminum alloy includes not greater than 1.25 wt. % Mn. In another embodiment, a new aluminum alloy includes not greater than 1.20 wt. % Mn.

[0009] As noted above, the new aluminum alloys generally include from 0.01 to 0.15 wt. % Ti. Titanium may

facilitate, for instance, grain refining. In one embodiment, a new aluminum alloy includes at least 0.02 wt. % Ti. In another embodiment, a new aluminum alloy includes at least 0.03 wt. % Ti. In yet another embodiment, a new aluminum alloy includes at least 0.04 wt. % Ti. In yet another embodiment, a new aluminum alloy includes at least 0.05 wt. % Ti. In one embodiment, a new aluminum alloy includes not greater than 0.12 wt. % Ti. In another embodiment, a new aluminum alloy includes not greater than 0.10 wt. % Ti. In yet another embodiment, a new aluminum alloy includes not greater than 0.08 wt. % Ti. In yet another embodiment, a new aluminum alloy includes not greater than 0.05 wt. % Ti.

[0010] As noted, above, the new aluminum alloys may include up to 0.40 wt. % Zn, which may facilitate high scrap tolerance. In one embodiment, a new aluminum alloy includes not greater than 0.35 wt. % Zn. In another embodiment, a new aluminum alloy includes not greater than 0.30 wt. % Zn. In yet another embodiment, a new aluminum alloy includes not greater than 0.25 wt. % Zn. In another embodiment, a new aluminum alloy includes not greater than 0.20 wt. % Zn. In one embodiment, a new aluminum alloy includes at least 0.01 wt. % Zn. In another embodiment, a new aluminum alloy includes at least 0.05 wt. % Zn.

[0011] As noted above, the new aluminum alloys may include up to 0.25 wt. % of any of Cr, Zr and V, which may be useful to control recrystallization. In one approach, a new aluminum alloy includes from not greater than 0.20 wt. % Zr. In another approach, a new aluminum alloy includes not greater than 0.15 wt. % Zr. In one embodiment, a new aluminum alloy includes not greater than 0.10 wt. % Zr. In another embodiment, a new aluminum alloy includes not greater than 0.08 wt. % Zr. In yet another embodiment, a new aluminum alloy includes not greater than 0.05 wt. % Zr. In another embodiment, a new aluminum alloy includes not greater than 0.04 wt. % Zr. In yet another embodiment, a new aluminum alloy includes not greater than 0.03 wt. % Zr. In one embodiment, a new aluminum alloy includes at least 0.01 wt. % Zr.

[0012] In one approach, a new aluminum alloy includes from not greater than 0.20 wt. % Cr. In one embodiment, a new aluminum alloy includes not greater than 0.15 wt. % Cr. In another embodiment, a new aluminum alloy includes not greater than 0.10 wt. % Cr. In another embodiment, a new aluminum alloy includes not greater than 0.08 wt. % Cr. In yet another embodiment, a new aluminum alloy includes not greater than 0.05 wt. % Cr. In another embodiment, a new aluminum alloy includes not greater than 0.04 wt. % Cr. In yet another embodiment, a new aluminum alloy includes not greater than 0.03 wt. % Cr. In one embodiment, a new aluminum alloy includes at least 0.01 wt. % Cr.

[0013] In one approach, a new aluminum alloy includes not greater than 0.20 wt. % V. In one embodiment, a new aluminum alloy includes not greater than 0.15 wt. % V. In another embodiment, a new aluminum alloy includes not greater than 0.10 wt. % V. In another embodiment, a new aluminum alloy includes not greater than 0.08 wt. % V. In yet another embodiment, a new aluminum alloy includes not greater than 0.05 wt. % V. In another embodiment, a new aluminum alloy includes not greater than 0.04 wt. % V. In yet another embodiment, a new aluminum alloy includes not greater than 0.03 wt. % V. In one embodiment, a new aluminum alloy includes at least 0.01 wt. % V.

[0014] The new aluminum alloys generally include the stated alloying ingredients, the balance being aluminum, optional incidental elements, and impurities. As used herein, "incidental elements" means those elements or materials, other than the above listed elements, that may optionally be added to the alloy to assist in the production of the alloy. Examples of incidental elements include casting aids, such as deoxidizers. Optional incidental elements may be included in the alloy in a cumulative amount of up to 1.0 wt. %. As one non-limiting example, one or more incidental elements may be added to the alloy during casting to reduce or restrict (and in some instances eliminate) ingot cracking due to, for example, oxide fold, pit and oxide patches. These types of incidental elements are generally referred to herein as deoxidizers. Examples of some deoxidizers include Ca, Sr, and Be. When calcium (Ca) is included in the alloy, it is generally present in an amount of up to about 0.05 wt. %, or up to about 0.03 wt. %. In some embodiments, Ca is included in the alloy in an amount of about 0.001-0.03 wt % or about 0.05 wt. %, such as 0.001-0.008 wt. % (or 10 to 80 ppm). Strontium (Sr) may be included in the alloy as a substitute for Ca (in whole or in part), and thus may be included in the alloy in the same or similar amounts as Ca. Traditionally, beryllium (Be) additions have helped to reduce the tendency of ingot cracking, though for environmental, health and safety reasons, some embodiments of the alloy are substantially Be-free. When Be is included in the alloy, it is generally present in an amount of up to about 20 ppm. Incidental elements may be present in minor amounts, or may be present in significant amounts, and may add desirable or other characteristics on their own without departing from the alloy described herein, so long as the alloy retains the desirable characteristics described herein. It is to be understood, however, that the scope of this disclosure should not/cannot be avoided through the mere addition of an element or elements in quantities that would not otherwise impact on the combinations of properties desired and attained herein.

[0015] The new aluminum alloys may contain low amounts of impurities. In one embodiment, a new aluminum alloy includes not greater than 0.15 wt. %, in total, of the impurities, and wherein the aluminum alloy includes not greater than 0.05 wt. % of each of the impurities. In another embodiment, a new aluminum alloy includes not greater than 0.10 wt. %, in total, of the impurities, and wherein the aluminum alloy includes not greater than 0.03 wt. % of each of the impurities.

[0016] The new aluminum alloys are generally substantially free of nickel, i.e., nickel is included only as an impurity, and generally at less than 0.04 wt. % Ni, or less than 0.01 wt. % Ni. The new aluminum alloys are generally substantially free of lithium, i.e., lithium is included only as an impurity, and generally at less than 0.04 wt. % Li, or less than 0.01 wt. % Li. The new aluminum alloys are generally substantially free of silver, i.e., silver is included only as an impurity, and generally at less than 0.04 wt. % Ag, or less than 0.01 wt. % Ag. The new aluminum alloys are generally substantially free of lead, i.e., lead is included only as an impurity, and generally at less than 0.04 wt. % Pb, or less than 0.01 wt. % Pb. The new aluminum alloys are generally substantially free of cadmium, i.e., cadmium is included only as an impurity, and generally at less than 0.04 wt. % Cd, or less than 0.01 wt. % Cd. The new aluminum alloys are generally substantially free of thallium, i.e., thallium is included only as an impurity, and generally at less than 0.04 wt. % Tl, or less than 0.01 wt. % Tl. The new aluminum

alloys are generally substantially free of scandium, i.e., scandium is included only as an impurity, and generally at less than 0.04 wt. % Sc, or less than 0.01 wt. % Sc.

ii. Methods of Production

[0017] The new aluminum alloys may be prepared in wrought form and in the appropriate temper. In one embodiment, a new aluminum alloy may be produced by casting (e.g., direct chill casting or continuously casting) into an ingot or strip followed by appropriate processing to achieve a variety of tempers, such as an H-temper as per ANSI H35.1 (2009), e.g., an H1, H2 or H3 temper. In one embodiment, a new aluminum alloy is processed to an "H1 temper." In another embodiment, a new aluminum alloy is processed to an "H2 temper." In yet another embodiment, a new aluminum alloy is processed to an "H3 temper."

[0018] In one embodiment, a new aluminum alloy is direct chill (DC) cast into ingot form. After conventional scalping, lathing or peeling (if needed) and homogenization (if needed) of the ingot, which homogenization may be completed before or after scalping, the ingot may be further processed by hot working the product. The product may then be optionally cold worked and/or optionally annealed. In one embodiment, processing into an H-temper sheet product comprises cold rolling to a final gauge and then partially annealing to achieve the H2 temper.

[0019] When the new aluminum alloys are processed into an H temper, their methods of production generally do not include (are absent of) solution heat treating or artificial aging. These steps add unnecessary costs and the H temper may achieve the necessary properties without such steps.

[0020] In other embodiments, the new aluminum alloys may be processed to a T temper, which would include solution heat treating followed by natural and/or artificial aging. The high magnesium silicide (Mg_2Si) content of the new alloys may facilitate improved strength in the T4 (naturally aged) or T6 (artificially aged) tempers, among other T tempers.

[0021] The new aluminum alloy products may have any suitable final gauge thickness. In one embodiment, a new aluminum alloy is in the form of a sheet having a thickness of from 0.4 to 4 mm. Other wrought product forms (e.g., plate, extrusions, forgings) may be utilized.

[0022] As noted above, the ingots used to produce the new aluminum alloys described herein may be at least partially derived from aluminum alloy scrap. For instance a method may comprise (a) creating an aluminum alloy ingot from aluminum-based scrap and (b) processing the aluminum alloy ingot into an appropriate wrought product form and temper, such as an H-temper sheet product having a thickness of from 0.4 to 4.0 mm.

[0023] As it relates to the above-referenced step (a) (i.e. creating an aluminum alloy ingot), this step (a) may comprise (i) mixing a first aluminum scrap material with another aluminum material to achieve a target ingot composition, (ii) prior to or after the mixing step, heating the first aluminum scrap material and the another aluminum material to create a molten aluminum alloy, and (iii) casting the molten aluminum alloy into the aluminum alloy ingot, wherein the aluminum alloy ingot achieves the target ingot composition. The another aluminum material may be at least one of (A) a second aluminum scrap material, (B) primary aluminum, and (C) mixtures thereof. The target ingot composition may be any of the compositions disclosed herein, including in the Compositions and Examples sections.

[0024] In one embodiment, at least one of the first aluminum scrap material and the second aluminum scrap material is 3xxx aluminum alloy scrap, 4xxx aluminum alloy scrap, 5xxx aluminum alloy scrap or 6xxx aluminum alloy scrap. In one embodiment, at least one of the first aluminum scrap material and the second aluminum scrap material is 3004 and/or 3104 aluminum alloy scrap. In another embodiment, at least one of the first aluminum scrap material and the second aluminum scrap material is 4343 aluminum alloy scrap. In yet another embodiment, at least one of the first aluminum scrap material and the second aluminum scrap material is 5052 and/or 5182 aluminum alloy scrap. In another embodiment, at least one of the first aluminum scrap material and the second aluminum scrap material is 6061, 6063, 6022, 6111, and/or 6013 aluminum alloy scrap.

[0025] In one embodiment, at least one of the first aluminum scrap material and the second aluminum scrap material is brazing scrap. Suitable brazing scrap materials may include composite alloys having cores and liners. The composite alloys may have, for instance, a 3xxx aluminum alloy core and a 4xxx aluminum alloy liner, or a 3xxx core and a 7xxx aluminum alloy liner, among others. The brazing scrap may be from tube stock, headers, or other heat exchanger materials, for instance.

[0026] In one embodiment, at least one of the first aluminum scrap material and the second aluminum scrap material is UBC (used beverage can) scrap. Suitable UBC scrap materials include those made from 3104 and/or 5182 aluminum alloys. In one embodiment, a UBC scrap material at least includes 3104 scrap. In another embodiment, a UBC scrap material at least includes 5182 scrap.

[0027] In one embodiment, at least one of the first and second aluminum scrap materials is automotive or industrial scrap (e.g., scrap of aluminum alloys 6061, 6063, 6022, 6111, and/or 6013).

[0028] In one embodiment, the first aluminum scrap material is at least one of a brazing scrap, used beverage can (UBC) scrap, and mixtures thereof, and the another aluminum material is a second aluminum scrap material, such as 3xxx, 4xxx, 5xxx, or 6xxx aluminum alloy scrap. In another embodiment, the first aluminum scrap material is at least one of a brazing scrap, used beverage can (UBC) scrap, and mixtures thereof, and the another aluminum material is primary aluminum. In one embodiment, the first aluminum scrap material is brazing scrap and the second aluminum scrap material is UBC scrap.

[0029] Due to the use of scrap, the aluminum alloy ingot may include appreciable amounts of scrap materials. In one embodiment, at least 30% of the ingot is derived from the first aluminum scrap material (i.e., at least 30% of the ingot comprises the first aluminum scrap material), the balance of the ingot being primary aluminum and/or other scrap materials. In another embodiment, at least 35% of the ingot is derived from the first aluminum scrap material. In yet another embodiment, at least 40% of the ingot is derived from the first aluminum scrap material. In another embodiment, at least 45% of the ingot is derived from the first aluminum scrap material. In yet another embodiment, at least 50% of the ingot is derived from the first aluminum scrap material. In another embodiment, at least 55% of the ingot is derived from the first aluminum scrap material. In yet another embodiment, at least 60% of the ingot is derived

from the first aluminum scrap material. In another embodiment, at least 65% of the ingot is derived from the first aluminum scrap material.

[0030] In one embodiment, the aluminum alloy ingot comprises at least two aluminum scrap materials (first and second scrap materials). In one embodiment, at least 50% of the ingot is derived from the first and second aluminum scrap materials (i.e., at least 50% of the ingot comprises the first and second aluminum scrap materials). In another embodiment, at least 55% of the ingot is derived from the first and second aluminum scrap materials. In yet another embodiment, at least 60% of the ingot is derived from the first and second aluminum scrap materials. In another embodiment, at least 65% of the ingot is derived from the first and second aluminum scrap materials. In yet another embodiment, at least 70% of the ingot is derived from the first and second aluminum scrap materials. In another embodiment, at least 75% of the ingot is derived from the first and second aluminum scrap materials. In yet another embodiment, at least 80% of the ingot is derived from the first and second aluminum scrap materials. In another embodiment, at least 85% of the ingot is derived from the first and second aluminum scrap materials. In yet another embodiment, at least 90% of the ingot is derived from the first and second aluminum scrap materials. In another embodiment, at least 94% of the ingot is derived from the first and second aluminum scrap materials. Additional scrap materials (third, fourth, fifth, etc.) may be used to produce any of the aluminum alloy ingots described in this paragraph.

[0031] Primary aluminum may be used with any mixture (s) of scrap to make the aluminum alloy ingot. In one embodiment, an aluminum alloy ingot include at least 1% primary aluminum. In another embodiment, an aluminum alloy ingot include at least 2% primary aluminum. In yet another embodiment, an aluminum alloy ingot include at least 3% primary aluminum. In another embodiment, an aluminum alloy ingot include at least 4% primary aluminum. In yet another embodiment, an aluminum alloy ingot include at least 5% primary aluminum. In another embodiment, an aluminum alloy ingot include at least 6% primary aluminum. In one embodiment, an aluminum alloy ingot includes not greater than 60% primary aluminum. In another embodiment, an aluminum alloy ingot includes not greater than 55% primary aluminum. In yet another embodiment, an aluminum alloy ingot includes not greater than 50% primary aluminum. In another embodiment, an aluminum alloy ingot includes not greater than 45% primary aluminum. In yet another embodiment, an aluminum alloy ingot includes not greater than 40% primary aluminum. In another embodiment, an aluminum alloy ingot includes not greater than 30% primary aluminum. In yet another embodiment, an aluminum alloy ingot includes not greater than 35% primary aluminum. In another embodiment, an aluminum alloy ingot includes not greater than 30% primary aluminum. In yet another embodiment, an aluminum alloy ingot includes not greater than 25% primary aluminum.

iii. Microstructure

[0032] As noted above, the new aluminum alloys may realize a unique microstructure. For instance, the new aluminum alloys may contain 50 vol. % or less of recrystallized grains, as determined using the Recrystallization Determination Procedure, described below. In one embodiment, a new aluminum alloy comprises not greater than 45 vol. % recrystallized grains. In another embodiment, a new aluminum alloy comprises not greater than 40 vol. % recrystallized grains. In yet another embodiment, a new aluminum alloy comprises not greater than 35 vol. % recrystallized grains. In another embodiment, a new aluminum alloy product comprises not greater than 30 vol. % recrystallized grains. In yet another embodiment, a new aluminum alloy comprises not greater than 25 vol. % recrystallized grains. In another embodiment, a new aluminum alloy product comprises not greater than 20 vol. % recrystallized grains. In yet another embodiment, a new aluminum alloy comprises not greater than 15 vol. % recrystallized grains. In another embodiment, a new aluminum alloy product comprises not greater than 10 vol. % recrystallized grains. In one embodiment, a new aluminum alloy comprises at least 1 vol. % recrystallized grains. In another embodiment, a new aluminum alloy product comprises at least 3 vol. % recrystallized grains. In yet another embodiment, a new aluminum alloy product comprises at least 5 vol. % recrystallized grains.

[0033] As noted above, a new aluminum alloy may realize an Mg_2Si area percent of at least 0.5%. In one embodiment, a new aluminum alloy realizes an Mg_2Si area percent of at least 0.6%. In another embodiment, a new aluminum alloy realizes an Mg_2Si area percent of at least 0.7%. In yet another embodiment, a new aluminum alloy realizes an Mg_2Si area percent of at least 0.8%. In another embodiment, a new aluminum alloy realizes an Mg_2Si area percent of at least 0.9%. In yet another embodiment, a new aluminum alloy realizes an Mg_2Si area percent of at least 1.0%. In another embodiment, a new aluminum alloy realizes an Mg_2Si area percent of at least 1.1%. In yet another embodiment, a new aluminum alloy realizes an Mg_2Si area percent of at least 1.2%.

[0034] As noted above, a new aluminum alloy may realize an average Mg_2Si particle area of at least 0.5 particles per square micrometer. In one embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 0.75 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 1.0 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 1.25 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 1.5 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 1.75 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 2.0 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 2.25 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 2.5 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 2.75 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 3.0 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 3.25 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average Mg_2Si particle area of at least 3.5 particles per square micrometer.

[0035] As noted above, a new aluminum alloy may realize a constituent area percent of at least 0.5%. In one embodiment, a new aluminum alloy realizes a constituent area percent of at least 0.75%. In another embodiment, a new aluminum alloy realizes a constituent area percent of at least 1.0%. In yet another embodiment, a new aluminum alloy realizes a constituent area percent of at least 1.25%. In another embodiment, a new aluminum alloy realizes a constituent area percent of at least 1.5%. In yet another embodiment, a new aluminum alloy realizes a constituent area percent of at least 1.75%. In another embodiment, a new aluminum alloy realizes a constituent area percent of at least 2.0%. In yet another embodiment, a new aluminum alloy realizes a constituent area percent of at least 2.25%. In another embodiment, a new aluminum alloy realizes a constituent area percent of at least 2.5%. In yet another embodiment, a new aluminum alloy realizes a constituent area percent of at least 2.75%.

[0036] As noted above, a new aluminum alloy may realize an average constituent particle area of at least 0.5 particles per square micrometer. In one embodiment, a new aluminum alloy realizes an average constituent particle area of at least 0.75 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 1.0 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 1.25 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 1.5 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 1.75 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 2.0 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 2.25 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 2.5 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 2.75 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 3.0 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 3.25 particles per square micrometer. In another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 3.5 particles per square micrometer. In yet another embodiment, a new aluminum alloy realizes an average constituent particle area of at least 3.75 particles per square micrometer.

[0037] As noted above, a new aluminum alloy may realize at least one of the following microstructural characteristics: (i) not greater than 50 vol. % recrystallized grains, (ii) an Mg_2Si area percent of at least 0.5%, (iii) an average Mg_2Si particle area of at least 0.5 particles per square micrometer, (iv) a constituent area percent of at least 0.5%, and (v) an average constituent particle area of at least 0.5 particles per square micrometer. In one embodiment, a new aluminum alloy realizes at least two of microstructural characteristics (i)-(v). In another embodiment, a new aluminum alloy realizes at least three of microstructural characteristics (i)-(v). In another embodiment, a new aluminum alloy realizes at least four of microstructural characteristics (i)-(v). In another embodiment, a new aluminum alloy realizes all of microstructural characteristics (i)-(v).

iv. Microstructure Assessment Procedure

[0038] The following procedures and definitions apply to measuring microstructure features (e.g., percent recrystallization, constituent and Mg_2Si content) for products made in accordance with the present patent application.

a. Mg_2Si and Constituent Particle Measurements

[0039] "Constituent area fraction" (cf) and "Mg_2Si area fraction" are the area fractions covered by constituent particles or Mg_2Si, respectively, divided by the total area examined in a two-dimensional cross section prepared by standard metallographic sample preparation methods.

[0040] "Constituent area percent" and "Mg_2Si are percent" is determined by multiplying their respective area fractions by 100%.

[0041] "Constituent particle area" and "Mg_2Si particle area" are the area of constituent particles and Mg_2Si particles, respectively, measured in the specimen.

[0042] "Average constituent particle area" and "Average Mg_2Si particle area" are the average area of every constituent particle or Mg_2Si particle, respectively.

[0043] To measure constituent and Mg_2Si area fractions and particle areas, backscattered electron images should be taken at 500× on an Apreo S Field Emission Gun (Thermo Fisher Scientific, Waltham, MA, U.S.A) scanning electron microscope, or equivalent, to image constituents and Mg_2Si particles. The images should be taken using an accelerating voltage 10 kV. Beam current should be 3.2 nanoamps. The working distance should be 10 mm, the dwell time should be 5 microseconds, and the line averaging should be 3. Thirty images are to be collected from metallographically polished specimens for each alloy at t/2. Image analysis is to be used to quantify the images. The pixel size for quantifying constituent and MgSi particles is 0.083 microns. For constituents, only particles containing at least 50 pixels are to be counted, with a threshold of 99 and a minimum intensity mean of 115. For each constituent particle, the number of pixels is converted to a particle area and to a particle effective diameter. For Mg_2Si particles, only particles containing at least 15 pixels are to be counted, with a threshold of 73 and the mean intensity of all pixels in the particle is not below 65. For each Mg_2Si particle, the number of pixels is converted to a particle area and to a particle effective diameter. For calculations based on average particles, only particles that are fully included in the image area are included in the calculation.

b. Recrystallization Determination Procedure

[0044] "Percent recrystallized" and the like means the volume percent of a wrought aluminum alloy product having recrystallized grains. The amount of recrystallized grains is determined by EBSD (electron backscatter diffraction) analysis of a suitable number of SEM micrographs of the wrought aluminum alloy product, as per this Recrystallization Determination Procedure. Generally at least 5 micrographs should be analyzed.

[0045] "Recrystallized grains" means those grains of a crystalline microstructure that meet the "first grain criteria", defined below, and as measured using the OIM (Orientation Imaging Microscopy) sampling procedure, described below.

[0046] The OIM analysis is to be completed through the full thickness of the sheet sample on the L-ST plane, using the OIM sample procedure, below. The size of the sample to

be analyzed will generally vary by gauge. Prior to measurement, the OIM samples are prepared by standard metallographic sample preparation methods. For example, the OIM samples are metallographically prepared and then vibratory polished (e.g., using 0.05 micron colloidal silica).

[0047] The "OIM sample procedure" is as follows:

[0048] The software used is APEX EBSD Collection Software, Version 2 (EDAX Inc., New Jersey, U.S.A.), or equivalent, which is connected to a Velocity EBSD camera (EDAX Inc., New Jersey, U.S.A.), or equivalent. The SEM is an APREO S Field Emission Gun (Thermo Fisher Scientific. Waltham, MA, U.S.A.), or equivalent.

[0049] OIM run conditions are 68° tilt with a 18 mm working distance and an accelerating voltage of 15 kV with dynamic focusing and an instrument-specified beam current of 51 nA (nanoamps). The mode of collection is hexagonal grid. A selection is made such that orientations are collected in the analysis (i.e., Hough peaks information is not collected). The area size per scan (i.e., the frame) is 2.0 mm by 1 mm for 2 mm gauge samples at 0.25 micron steps at 80×. Different frame sizes can be used depending upon gauge. The collected data is output in an *.osc file. This data may be used to calculate the volume fraction of first type grains, as described below.

[0050] Calculation of volume fraction of first type grains: The volume fraction of first type grains is calculated using the data of the *.osc file and the OIM Analysis Software (EDAX Inc., New Jersey, U.S.A.), version 8.1.0, or equivalent. Prior to calculation, two-step data cleanup may be performed. First, for any points whose confidence index is below a threshold of 0.08, a neighbor orientation correlation clean-up is performed. Second, a grain dilation clean-up is performed for any grain smaller than 3 data points. Then, the amount of first type grains is calculated by the software using the first grain criteria (below).

[0051] First grain criteria: Grain average misorientation (GAM) is calculated. All of "apply partition before calculation", "include edge grains", and "ignore twin boundary definitions" should be required. Any grain whose GAM is ≤1° is a first type grain.

[0052] "First grain volume" (FGV) means the volume fraction of first type grains of the crystalline material.

[0053] "Percent Recrystallized" is determined via the formula: FGV*100%.

[0054] The term "grain" has the meaning defined in ASTM E112 §3.2.2, i.e., "the area within the confines of the original (primary) boundary observed on the two-dimensional plane of-polish or that volume enclosed by the original (primary) boundary in the three-dimensional object".

[0055] "Grain size" is calculated by the following equation:

$$d_i = \text{square root}\left(\frac{4Ai}{\pi}\right)$$

[0056] wherein A_i is the area of the individual grain as measured using commercial software OIM Analysis Software, version 8.1.0 or equivalent; and

[0057] wherein d_i is the calculated individual grain size assuming the grain is a circle.

[0058] "Area weighted average grain size" is calculated by the following equation:

$$d\text{-}bar = \left(\sum_{i=1}^{n} A_i d_i\right) / \left(\sum_{i=1}^{n} d_i\right)$$

[0059] wherein A_i is the area of each individual grain as measured using commercial software OIM Analysis Software, version 8.1.0 or equivalent;

[0060] wherein d_i is the calculated individual grain size assuming the grain is a circle; and

[0061] wherein d-bar is the area weighted average grain size.

v. Properties

[0062] As noted above, despite potentially being scrap-based, the new aluminum alloy products described herein may realize relatively high mechanical properties and/or good corrosion resistance.

[0063] In one embodiment, a new aluminum alloy sheet product realize a tensile yield strength (longitudinal) of at least 35 ksi. In another embodiment, a new aluminum alloy sheet product realize a tensile yield strength (longitudinal) of at least 36 ksi. In yet another embodiment, a new aluminum alloy sheet product realize a tensile yield strength (longitudinal) of at least 37 ksi. In another embodiment, a new aluminum alloy sheet product realize a tensile yield strength (longitudinal) of at least 38 ksi. In yet another embodiment, a new aluminum alloy sheet product realize a tensile yield strength (longitudinal) of at least 39 ksi. In another embodiment, a new aluminum alloy sheet product realize a tensile yield strength (longitudinal) of at least 40 ksi.

[0064] In one embodiment, a new aluminum alloy sheet product realize a longitudinal (L) elongation of at least 3.0%. In another embodiment, a new aluminum alloy sheet product realize a longitudinal (L) elongation of at least 3.5%. In yet another embodiment, a new aluminum alloy sheet product realize a longitudinal (L) elongation of at least 4.0%. In another embodiment, a new aluminum alloy sheet product realize a longitudinal (L) elongation of at least 4.5%. In yet another embodiment, a new aluminum alloy sheet product realize a longitudinal (L) elongation of at least 5.0%.

[0065] In one embodiment, a new aluminum alloy sheet product realizes at least equivalent ASTM G85 corrosion resistance as compared to a conventional AA3004 sheet product of equivalent gauge.

vi. Product Applications

[0066] The new aluminum alloys described herein may be used in a variety of product applications, such as in automotive or industrial sheet products. In one embodiment, the new aluminum alloys are sheet products used in the construction of van trailers (e.g., dry box or refrigerated van trailers used in commercial transportation).

vii. Definitions

[0067] "Wrought aluminum alloy product" means an aluminum alloy product that is hot worked after casting, and includes rolled products (sheet or plate), forged products, and extruded products.

[0068] "Hot working" such as by hot rolling means working the aluminum alloy product at elevated temperature, and generally at least 121.1° C. (250° F.). Strain-hardening is

restricted/avoided during hot working, which generally differentiates hot working from cold working.

[0069] "Cold working" such as by cold rolling means working the aluminum alloy product at temperatures that are not considered hot working temperatures, generally below about 121.1° C. (250° F.) (e.g., at ambient).

[0070] Temper definitions are per ANSI H35.1 (2009), entitled "American National Standard Alloy and Temper Designation Systems for Aluminum," published by The Aluminum Association.

[0071] Strength and elongation are measured in accordance with ASTM E8/E8M-21 and B557-15.

viii. Miscellaneous

[0072] These and other aspects, advantages, and novel features of this new technology are set forth in part in the description that follows and will become apparent to those skilled in the art upon examination of the descriptions herein, or may be learned by practicing one or more embodiments of the technology provided for by the present disclosure.

[0073] Among those benefits and improvements that have been disclosed, other objects and advantages of this invention will become apparent from the descriptions herein. 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 is intended to be illustrative, and not restrictive.

[0074] 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, various embodiments of the invention may be readily combined, without departing from the scope or spirit of the invention.

[0075] 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, unless the context clearly dictates otherwise. The meaning of "in" includes "in" and "on", unless the context clearly dictates otherwise.

[0076] 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, unless the context clearly requires otherwise, the various steps may be carried out in any desired order, and any applicable steps may be added and/or eliminated.

DETAILED DESCRIPTION

Example 1

[0077] Several lab-scale aluminum alloy ingots were produced, the compositions of which are shown in Table 1, below. Alloys XA39-XA46 are experimental alloys. Aluminum alloy 3004 (AA3004) is a conventional alloy. Alloy 0437 is a conventional alloy sold by Arconic Corp. under that same name.

TABLE 1

Compositions of Example 1 Alloys (wt. %)*

Alloy No.	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
XA39	1.69	0.52	0.32	1.11	1.10	0.09	0.20	0.05
XA40	1.24	0.53	0.32	1.14	1.09	0.10	0.20	0.05
XA41	0.77	0.55	0.33	1.09	1.11	0.09	0.21	0.05
XA42	1.23	0.51	0.57	1.12	1.11	0.09	0.21	0.05
XA43	1.27	0.54	0.33	1.18	1.74	0.09	0.20	0.06
XA44	0.77	0.54	0.56	1.07	1.08	0.09	0.21	0.05
XA45	1.23	0.51	0.56	1.11	1.71	0.09	0.21	0.05
XA46	1.23	0.51	0.33	0.79	1.69	0.09	0.20	0.06
AA3004	0.24	0.40	0.13	1.07	1.05	0.02	0.04	0.03
0437	1.70	0.42	0.29	0.75	0.44	0.09	0.10	0.05

*The balance of the alloys was aluminum and unavoidable impurities.

[0078] After casting, the alloys were conventionally scalped/peeled and homogenized. The alloys were then hot rolled to an intermediate gauge and then cold rolled to a final gauge of approximately 1 mm, and then partially annealed to achieve a H291 temper.

[0079] As noted in ANSI H35.1 (2009) an H-temper is defined as "strain-hardened (wrought products only)." As per ANSI H35.1, the H-temper designation "applies to products that have their strength increased by strain-hardening, with or without supplementary thermal treatments to produce some reduction in strength. The H is always followed by two or more digits." In other words, an H-Temper aluminum alloy product is not subjected to precipitation hardening (e.g., by solution heat treatment, then quenching and then natural or artificial aging), which is a thermal treatment that increases strength.

[0080] The "H2 temper" is defined as "strain-hardened and partially annealed." As per ANSI H35.1, an "H2 temper" designation applies to products that are strain-hardened more than the desired final amount and then reduced in strength to the desired level by partial annealing-the number following this designation indicates the degree of strain-hardening remaining after the product has been partially annealed. The H291 temper is a common H2 temper and is used to achieve certain minimum strength and elongation values for conventional alloys such as AA3004 and AA5052. See U.S. Patent Application Publication No. 2009/0159160.

[0081] The mechanical properties of the alloys in the H291 temper were tested, the results of which are shown in Table 2, below.

TABLE 2

Mechanical Properties of H291 Temper Example 1 Alloys

Alloy No.	UTS (ksi)	TYS (ksi)	Elong (%)
XA39	35.2	31.6	2.8
XA40	37.4	33.4	4.3
XA41	44.3	39.7	5.1
XA42	42.4	37.8	5.3
XA43	43.4	39.0	5.1
XA44	42.5	37.8	4.6
XA45	41.7	37.2	4.1
XA46	40.9	36.8	4.7
3004	42.4	38.6	5.4
0437	33.8	30.4	4.5

[0082] As shown, despite having compositions useful for employing scrap, invention alloys XA41-XA43 show a comparable strength-elongation relationship to that of AA3004. Alloys XA44-XA46 realize a slightly lower strength-elongation relationship. Alloys XA39-40 realize low strength compared to AA3004.

[0083] Samples of the alloys were also tested for painted corrosion resistance. Specifically, the alloys were cleaned and then painted in accordance with conventional aluminum alloy painting procedures. The painted alloys were then subject to MASTMAASIS testing in accordance with ASTM G85, Annex A2 "Cyclic Acidified Salt For (Spray) Testing" for 28 days. Overall, the new alloys achieved similar or better corrosion properties as compared to conventional AA3004. These results were unexpected given the copper content of the new alloys, which generally exceeded 0.30 wt. % Cu.

[0084] A scrap friendliness evaluation was also undertaken by comparing the likely aluminum alloy scrap that may be used to produce the alloy to the target alloy composition for each of alloys XA41-XA46. The most scrap friendly alloys were XA42-43, each of which could likely be produced using 48-85% (XA42) or 48-96% (by weight) of common scrap, such as brazing scrap and/or common 6xxx aluminum alloy scrap (e.g., AA6061 and/or AA6063 scrap).

[0085] An analysis of free silicon (Free-Si) and its effect on properties was also undertaken. The amount of free silicon (Free-Si) was determined by estimating the amount of silicon occupied by iron (Fe), manganese (Mn), and chromium (Cr) in the alloy using the following formula:

$$\text{Free-Si}\,(wt.\,\%) = \text{Total Si}\,(wt.\,\%) - \left([\text{Fe} + \text{Mn} + \text{Cr}]\right)/4)$$

The results are shown in Table 3, below.

TABLE 3

Comparison of Mg:Free-Si ratio to mechanical properties

Alloy No.	Si (wt. %)	Free-Si	Mg (wt. %)	Mg:Free-Si	Cu (wt. %)	TYS (ksi)	Elong (%)
XA39	1.69	1.26	1.10	0.87	0.32	31.6	2.8
XA40	1.24	0.80	1.09	1.37	0.32	33.4	4.3
XA41	0.77	0.34	1.11	3.29	0.33	39.7	5.1
XA42	1.23	0.80	1.11	1.39	0.57	37.8	5.3
XA43	1.27	0.82	1.74	2.13	0.33	39.0	5.1
XA44	0.77	0.35	1.08	3.13	0.56	37.8	4.6

TABLE 3-continued

Comparison of Mg:Free-Si ratio to mechanical properties

Alloy No.	Si (wt. %)	Free-Si	Mg (wt. %)	Mg:Free-Si	Cu (wt. %)	TYS (ksi)	Elong (%)
XA45	1.23	0.80	1.71	2.13	0.56	37.2	4.1
XA46	1.23	0.88	1.69	1.92	0.33	36.8	4.7

[0086] As shown, alloys with a Mg:Free-Si ratio above 1:1 and closer to the 1.73:1 weight ratio of Mg:Free-Si may realize improved performance. Alloys with lower silicon (e.g., around 0.77 wt. % Si) and/or lower Free-Si may realize lower mechanical properties. Additional copper may facilitate increased mechanical properties.

Example 2

[0087] Based on the Example 1 results, alloys XA42-43 were down selected for plant scale testing. The plant scale XA42-43 alloys were processed to the H291 temper and in generally the same manner as described in Example 1, but using industrial scale ingots and rolling equipment. The compositions and mechanical properties of the alloys are provided in Tables 4-5, below. Results from conventional AA3004 samples are also shown below.

TABLE 4

Compositions of Example 2 Alloys (wt. %)*

Alloy #	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
XA42 (plant)	1.31	0.43	0.54	1.08	1.06	0.01	0.11	0.07
XA43 (plant)	1.32	0.52	0.30	1.08	1.68	0.03	0.05	0.04
AA3004 (typical)	0.28	0.51	0.13	1.11	1.05	0.05	0.11	0.02

TABLE 5

Mechanical Properties of H291 Temper Example 2 Alloys

Alloy	Free-Si	Mg:Free-Si	UTS (ksi)	TYS (ksi)	Elong (%)
XA42 (Plant)	0.93	1.140	38.0	33.4	6.9
XA43 (Plant)	0.9125	1.841	40.6	36.4	5.3
AA3004			42.9	38.7	5.6

[0088] Again, despite having compositions useful for employing scrap, the XA42-43 alloys realize generally similar mechanical properties to that of conventional AA3004. It is expected that the plant produced alloys (XA42-XA43) would also realize achieved similar or better corrosion properties as compared to conventional AA3004, which is unexpected given the copper content of the new alloys. Accordingly, when made from scrap, the new alloys may realize a significant cost advantage over conventional alloys while still achieving commercially valuable characteristics.

[0089] A microscopy analysis was also completed on the Example 2 alloys in accordance with the Microstructure Assessment Procedure, described herein. The results are shown in Table 6, below.

TABLE 6

Microscopy Data					
Alloy	Percent Recryst. (ReX %)	Mg_2Si Area Fraction	Mg_2Si Particle Area (μm^2) (Ave.)	Constituent Area Fraction	Constituent Particle Area (μm^2) (Ave.)
XA42 (Plant)	13	1.22	3.66	2.92	3.86
XA43 (Plant)	14	2.06	3.50	3.35	3.84
AA3004	5	0.15	0.45	2.88	3.75

[0090] As shown, the invention alloys have little recrystallization but with large Mg_2Si and constituent area fractions and particle areas.

[0091] While various embodiments of the present disclosure have been described in detail, it is apparent that modifications and adaptations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present disclosure.

What is claimed is:

1. An aluminum alloy sheet product comprising:

from 1.05 to 1.55 wt. % Si;

from 0.85 to 2.10 wt. % Mg;

from 0.15 to 0.75 wt. % Cu;

from 0.20 to 0.90 wt. % Fe;

from 0.5 to 1.5 wt. % Mn;

from 0.01 to 0.15 wt. % Ti;

up to 0.4 wt. % Zn;

up to 0.25 wt. % of any of Cr, Zr and V; and

up to 0.05 wt. % Ni;

the balance being aluminum, incidental elements and impurities;

wherein the aluminum alloy sheet product has a thickness of from 0.4 to 4 mm;

wherein the aluminum alloy sheet product realizes at least one of the following:

(i) not greater than 50 vol. % recrystallized grains;

(ii) an Mg_2Si area percent of at least 0.5%;

(iii) an average Mg_2Si particle area of at least 0.5 particles per square micrometer;

(iv) a constituent area percent of at least 0.5%; and

(v) an average constituent particle area of at least 0.5 particles per square micrometer.

2. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product includes at from 1.15 to 1.40 wt. % Si.

3. The aluminum alloy sheet product claim **2**, wherein the aluminum alloy sheet product includes from 0.90 to 1.90 wt. % Mg.

4. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product includes from 0.25 to 0.60 wt. % Cu.

5. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product includes from 0.30 to 0.75 wt. % Fe.

6. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product includes from 0.65 to 1.35 wt. % Mn.

7. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes not greater than 25 vol. % recrystallized grains.

8. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes an Mg_2Si area percent of at least 0.7%.

9. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes an average Mg_2Si particle area of at least 1.0 particles per square micrometer.

10. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes a constituent area percent of at least 1.0%.

11. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes an average constituent particle area of at least 1.0 particles per square micrometer.

12. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes a longitudinal (L) tensile yield strength of at least 35 ksi.

13. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes a longitudinal (L) elongation of at least 3.0%.

14. The aluminum alloy sheet product of claim **1**, wherein the aluminum alloy sheet product realizes at least equivalent ASTM G85 corrosion resistance as compared to a conventional AA3004 sheet product of equivalent gauge.

15. A method of making an aluminum alloy sheet product comprising:

(a) creating an aluminum alloy ingot from aluminum-based scrap, wherein the creating comprises:

(i) mixing a first aluminum scrap material with another aluminum material to achieve a target ingot composition, wherein the another aluminum material is at least one of (A) a second aluminum scrap material and (B) primary aluminum;

(ii) prior to or after the mixing step, heating the first aluminum scrap material and the another aluminum material to create a molten aluminum alloy; and

(iii) casting the molten aluminum alloy into the aluminum alloy ingot, wherein the aluminum alloy ingot achieves the target ingot composition, wherein the target ingot composition is:

from 1.05 to 1.55 wt. % Si;

from 0.85 to 2.10 wt. % Mg;

from 0.15 to 0.75 wt. % Cu;

from 0.20 to 0.90 wt. % Fe;

from 0.5 to 1.5 wt. % Mn;

from 0.01 to 0.15 wt. % Ti;

up to 0.4 wt. % Zn;

up to 0.25 wt. % of any of Cr, Zr and V; and

up to 0.05 wt. % Ni;

the balance being aluminum, incidental elements and impurities; and

(b) processing the aluminum alloy ingot into an H-temper sheet product having a thickness of from 0.4 to 4.0 mm.

16. The method of claim **15**, wherein the processing the aluminum alloy ingot into an H-temper sheet product comprises cold rolling to a final gauge and then partially annealing to achieve an H2 temper.

17. The method of claim **15**, wherein the first aluminum scrap material is selected from the group consisting of brazing scrap, used beverage can (UBC) scrap, and mixtures thereof.

18. The method of claim **15**, wherein at least 30% of the ingot comprises the first aluminum scrap material.

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