Claims

1. A method of forming an aluminum alloy article by fusion processing, comprising:

obtaining an aluminum alloy precursor material in solid state form, the aluminum alloy precursor material having a chemical composition, in weight % of the aluminum alloy precursor material, comprising:

Al from 50% or greater;

Si from 0.40 to 0.80%;

Cu from 0.15 to 0.40%;

Mg from 2.5% to 5.0%;

Cr from 0.04 to 0.35%;

Ti from 0.0 to 0.15%;

Fe from 0.0 to 0.7%;

Mn from 0.0 to 0.15%; and

Zn from 0.0 to 0.005%;

exposing the aluminum alloy precursor material to at least one direct energy source sufficient to heat and liquefy the precursor material;

forming a melt pool with the liquefied precursor material on a substrate, wherein the forming the melt pool with the liquefied precursor material is performed as the at least one direct energy source and/or the substrate move relative to each other in a travel direction;

solidifying the melt pool to form the aluminum alloy article, the aluminum alloy article having a chemical composition, in weight % of the aluminum alloy forming the article, comprising:

Al from 50% or greater;

Si from 0.40 to 0.80%;

Cu from 0.15 to 0.40%;

Mg from 0.8 to 1.2%;

Cr from 0.04 to 0.35%;

Ti from 0.0 to 0.15%;

Fe from 0.0 to 0.7%;

Mn from 0.0 to 0.15%; and

Zn from 0.0 to 0.005%.

2. The method according to claim 1, wherein the aluminum alloy precursor material further comprises at least one additional grain refiner.

3. The method according to claim 2, wherein the at least one additional grain refiner includes at least one of boron, titanium-carbon, zirconium, vanadium, and scandium.

4. The method according to claim 3, wherein the boron is present, in weight percent of the aluminum alloy precursor material, from 0.001 to 0.05%;

more particularly, wherein the boron is present, in weight percent of the aluminum alloy precursor material, from 0.001 to 0.002%.

5. The method according to claim 3 or claim 4,

wherein the boron is combined with at least a portion of the titanium in the form of titanium diboride; and/or

wherein the titanium-carbon forms titanium carbide.

6. The method according to any of the preceding claims, wherein the titanium is present, in weight percent of the aluminum alloy precursor material, from 0.05 to 0.15%;

more particularly, wherein the titanium is present from 0.10 to 0.15%.

7. The method according to any of the preceding claims,

wherein the magnesium is present, in weight percent of the aluminum alloy precursor material, from 1.3 to 3.0%;

more particularly, wherein the magnesium is present from 1.5 to 3.0%; or

more particularly, wherein the magnesium is present from 2.0 to 3.0%.

8. The method according to any of the preceding claims, wherein the aluminum alloy precursor material is free of zinc.

9. A method of forming an aluminum alloy article by fusion processing, comprising:

obtaining an aluminum alloy precursor material in solid state form, wherein the aluminum alloy precursor material has a composition, in weight % of the aluminum alloy precursor material, consisting of:

Al from 50% or greater;

Si from 0.40 to 0.80%;

Cu from 0.15 to 0.40%;

Mg from greater than 1.2 to 5.0% or less;

Cr from 0.04 to 0.35%;

Ti from 0.05 to 0.15%;

Boron from 0.001 to 0.05%;

Fe from 0.0 to 0.7%;

Mn from 0.0 to 0.15%;

Zn from 0.0 to 0.005%; and

one or more other impurities from 0.0 to 0.05% for each of the one or more other impurities, wherein the total amount of the one or more other impurities is from 0.0 to 0.10%;

exposing the aluminum alloy precursor material to at least one direct energy source sufficient to heat and liquefy the precursor material;

forming a melt pool with the liquefied precursor material on a substrate, wherein the forming the melt pool with the liquefied precursor material is performed as the at least one direct energy source and/or the substrate move relative to each other in a travel direction;

solidifying the melt pool to form the aluminum alloy article, the aluminum alloy article having a chemical composition, in weight % of the aluminum alloy forming the article, comprising:

Al from 50% or greater;
Si from 0.40 to 0.80%;
Cu from 0.15 to 0.40%;
Mg from 0.8 to 1.2%;
Cr from 0.04 to 0.35%;
Ti from 0.0 to 0.15%;
Fe from 0.0 to 0.7%;
Mn from 0.0 to 0.15%; and
Zn from 0.0 to 0.005%.

10. The method according to any of the preceding claims, wherein the method is carried out without adding one or more materials that are independent of the supplied precursor material to the melt pool.

11. A method of forming an aluminum alloy article by fusion processing, comprising:

obtaining an aluminum alloy precursor material in solid state form, the aluminum alloy precursor material having a chemical composition, in weight % of the aluminum alloy precursor material, comprising:

Al from 50% or greater;
Si from 0.40% to 0.80%;
Cu from 0.15% to 0.40%;
Mg from greater than 1.2% to 5.0% or less;
Cr from 0.04% to 0.35%;
Ti from 0.0% to 0.15%;
Fe from 0.0% to 0.7%;
Mn from 0.0% to 0.15%; and
Zn from 0.0% to 0.005%;

exposing the aluminum alloy precursor material to at least one direct energy source sufficient to heat and liquefy the precursor material;

forming a melt pool with the liquefied precursor material on a substrate, wherein the forming the melt pool with the liquefied precursor material is performed as at least one of the at least one direct energy source or the substrate move relative to each other in a travel direction;

solidifying the melt pool to form the aluminum alloy article, the aluminum alloy article having a chemical composition, in weight % of the aluminum alloy forming the article, comprising:

Al from 50% or greater;

Si from 0.40% to 0.80%;

Cu from 0.15% to 0.40%;

Mg from 0.8% to 1.2%;

Cr from 0.04% to 0.35%;

Ti from 0.0% to 0.15%;

Fe from 0.0% to 0.7%;

Mn from 0.0% to 0.15%; and

Zn from 0.0% to 0.005%;

wherein the at least one direct energy source is a leading energy beam, and wherein the melt pool has a leading region and a trailing region;

wherein the leading region of the melt pool is proximal to the leading energy beam as the leading energy beam and/or the substrate move in the travel direction; and

wherein the trailing region of the melt pool trails the leading region as the leading energy beam and/or the substrate move in the travel direction;

the method further comprising:

exposing the trailing region of the melt pool to a trailing energy beam.

12. The method according to claim 11, wherein the trailing energy beam has a power level, power density, voltage potential, and/or current that is different than a power level, power density, voltage potential, and/or current of the leading energy beam.

13. The method according to claim 11 or claim 12, wherein the trailing energy beam is configured to disrupt formation of a dendritic microstructure in the trailing region of the melt pool; or is configured to agitate, stir, and/or redistribute liquid constituents in the trailing region of the melt pool for reducing hot cracking and/or porosity when the melt pool solidifies.

14. The method according to any of claims 11-13, wherein the trailing energy beam is configured in a concave pattern that opens toward the leading region of the melt pool.

15. The method according to any of claims 11-14, wherein the trailing energy beam is spaced apart from the leading energy beam at varying distances as the leading energy beam moves in a travel direction.

16. The method according to claim 15,

wherein the trailing energy beam follows the leading energy beam by a first distance at a first location along a path in the travel direction;

wherein the trailing energy beam follows the leading energy beam by a second distance at a second location along the path in the travel direction, the second distance being greater than the first distance; and

wherein the trailing energy beam cycles between the first distance and the second distance, and optionally one or more intermediate distances, as the leading energy beam moves in the travel direction.

17. The method according to claim 15 or claim 16,

wherein the distance between the trailing energy beam and the leading energy beam progressively increases to a first intermediate distance and a second intermediate distance before reaching the second distance;

wherein the second distance represents a maximum distance that the trailing energy beam is spaced apart from the leading energy beam;

wherein the first distance is at 25% of the maximum distance;

wherein the first intermediate distance is at 50% of the maximum distance;

wherein the second intermediate distance is at 75% of the maximum distance; and

wherein the trailing energy beam cycles back to the first distance after reaching the second distance.

18. The method according to claim 16 or claim 17, further including a step where, after the trailing energy beam is at the second distance and before the trailing energy beam cycles back to the first distance, the trailing energy beam is deactivated such that only the leading energy beam is utilized.

19. The method according to any of claims 11-18, wherein the leading energy beam is emitted from the same source as the trailing energy beam, the source emitting an emitted energy beam that is translated through a raster pattern including a leading energy beam pattern defined by the leading energy beam, and including a trailing energy beam pattern defined by the trailing energy beam.

20. The method according to any of the preceding claims, wherein the fusion process is conducted in a vacuum chamber; and

wherein a pressure level of the vacuum chamber is 100 microtorr or greater for reducing vaporization of at least one of the magnesium and the zinc.

21. The method according to any of the preceding claims, wherein the substrate is configured to support the liquefied precursor material as a molten pool deposit, the substrate providing a heat transfer medium for extracting heat from the molten pool deposit; and wherein a chill plate is in thermal communication with the substrate for maintaining a constant interpass temperature.

22. The method according to any of the preceding claims,

wherein the method is a welding process, including:

arc welding, wherein the at least one direct energy source is an electric arc;

electron beam welding, wherein the at least one direct energy source is an electron beam;

laser welding, wherein the at least one direct energy source is a laser beam; or

other welding processes in which a melt pool is produced and solidified; and

wherein the solidified aluminum alloy article is a weld.