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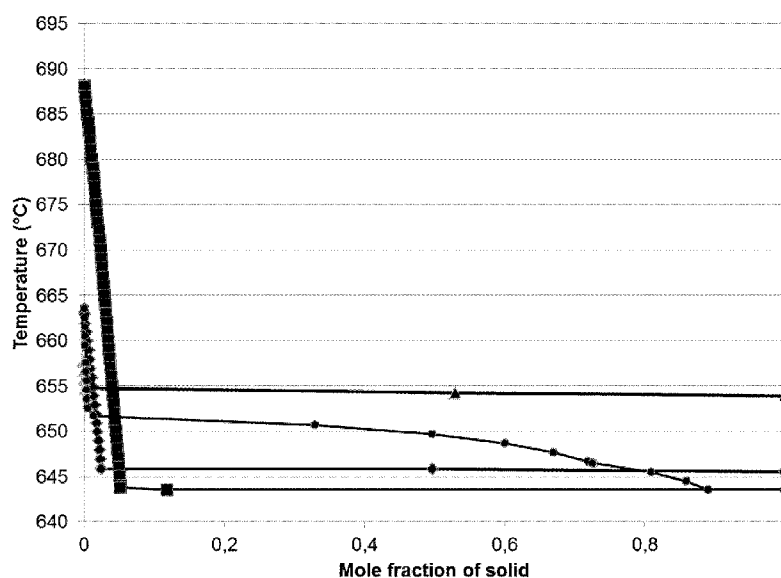


FIG. 1

(57) Abstract: The present disclosure concerns a cast aluminum alloy for making cast aluminum products, especially using high-pressure vacuum die casting operations. The cast aluminum alloy comprises, in weight percent: Ni between about 1.5 and about 6.5; Si between about 0.10 and 1.5; Mg between about 0.10 and about 3; Fe up to about 0.2; Mn up to about 0.65; Ti up to about 0.12; V up to about 0.15; Zr up to about 0.15; Mo up to about 0.15; Cr up to about 0.01; Sr up to about 0.02; and the balance being aluminum and unavoidable impurities.

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FOUNDRY ALLOYS FOR HIGH-PRESSURE VACUUM DIE CASTING**CROSS-REFERENCE TO RELATED APPLICATIONS**

This is application claims priority from US application number 62/796,735 filed on January 25, 2019 and herewith incorporated in its entirety.

5 TECHNOLOGICAL FIELD

This application relates to foundry alloys exhibiting acceptable strength properties once cast.

BACKGROUND

Alloying of commercially pure aluminum alloy may create solid solution or individual phases that greatly improve tensile strength due to solid solution strengthening and precipitation
10 strengthening. However, the electrical conductivity may drop because of the enhanced scattering of free electrons at solute atoms and precipitates. For electrical applications, it is a challenge to find a favorable combination of high electrical conductivity with enhanced mechanical properties in the alloy design and development.

In addition, for application requiring high-pressure vacuum die casting, it is important that the
15 alloy achieves appropriate fluidity to be cast in a mold and exhibit limited hot tearing and die soldering.

It would be desirable to obtain an aluminum alloy having improved cast properties, for example, improved fluidity and increased resistance towards hot tearing. Alternatively or in combination, it would be desirable to obtain an aluminum conductor alloy having improved
20 electrical conductivity without substantially decreasing its mechanical properties.

BRIEF SUMMARY

The present disclosure provides using Ni in a low Si aluminum foundry alloy to increase its fluidity during casting, limit hot tearing during high-pressure vacuum die casting operations and/or to increase die soldering resistance during high-pressure vacuum die casting
25 operations.

According to a first aspect, the present disclosure provides a foundry alloy comprising, in weight percent:

Ni	between about 1.5 and about 6.5;
Si	between about 0.10 and 1.5;
30 Mg	between about 0.10 and about 3;
Fe	up to about 0.2;

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Mn up to about 0.65;
 Ti up to about 0.12;
 V up to about 0.15;
 Zr up to about 0.15;
 5 Mo up to about 0.15;
 Cr up to about 0.01;
 Sr up to about 0.02; and

the balance being aluminum and unavoidable impurities.

In an embodiment, the foundry alloy comprises more than about 2.0 Ni. In another
 10 embodiment, the foundry alloy comprises between about 2.5 and about 6.5 Ni. In still another
 embodiment, the foundry alloy comprises between about 1.8 and about 3.0 Ni. In yet another
 embodiment, the foundry alloy comprises between 0.15 and 0.90 Si. In still a further
 embodiment, the foundry alloy comprises between 0.3 and 0.75 Si. In yet another
 15 embodiment, the foundry alloy comprises Mg at a weight percentage as determined by
 formula (I):

$$\%Mg \leq -1.218 \cdot \ln(\%Si) + 0.89 \quad (I)$$

wherein %Mg is the weight percent of Mg; and

%Si is the weight percent of Si.

In an embodiment, the foundry alloy comprises between about 0.15 and about 1.8 Mg. In still
 20 another embodiment, the foundry alloy comprises between about 0.30 and about 1.0 Mg. In
 yet another embodiment, the foundry alloy comprises up to about 0.10 Fe. In yet another
 embodiment, the foundry alloy comprises between about 0.45 and about 0.65 Mn. In still a
 further embodiment, the foundry alloy comprises up to about 0.01 Mn. In yet another
 embodiment, the foundry alloy comprises between about 0.02 and about 0.12 Ti. In yet a
 25 further embodiment, the foundry alloy comprises up to about 0.01 Ti. In yet another
 embodiment, the foundry alloy comprises between about 0.01 and about 0.15 V. In still a
 further embodiment, the foundry alloy comprises up to about 0.01 V. In yet another
 embodiment, the foundry alloy comprises between about 0.01 and about 0.15 Zr. In still
 another embodiment, the foundry alloy comprises up to about 0.01 Zr. In still a further
 30 embodiment, the foundry alloy comprises between about 0.01 and about 0.15 Mo. In another
 embodiment, the foundry alloy comprises up to about 0.01 Mo. In still yet another
 embodiment, the foundry alloy comprises between about 0.005 and about 0.02 Sr. In a

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further embodiment, the foundry alloy comprises an excess of Mg over a weight percent ratio of Mg:Si of more than about 2:1. In yet a further embodiment, especially when the aluminum alloy is intended to be used in electrical applications, the foundry alloy comprises Mn, Cr, Ti and V at a weight percentage as determined by formula (II):

$$5 \quad \%Mn + \%Cr + \%Ti + \%V \leq 0.025 \text{ (II)}$$

wherein %Mn is the weight percent of Mn;

%Cr is the weight percent of Cr;

%Ti is the weight percent of Ti; and

%V is the weight percent of V.

10 According to a second aspect, the present disclosure provides a process for improving at least one casting property of a first aluminum alloy for making a first aluminum product when compared to a cast aluminum alloy for making a cast aluminum product. The process comprising combining Ni with the first aluminum alloy to provide the cast aluminum alloy. The first aluminum alloy comprises, in weight percent:

15 Si between about 0.10 and 1.5;

Mg between about 0.10 and about 3;

Fe up to about 0.2;

Mn up to about 0.65;

Ti up to about 0.12;

20 V up to about 0.15;

Zr up to about 0.15;

Mo up to about 0.15;

Cr up to about 0.01;

Sr up to about 0.02; and

25 the balance being aluminum and unavoidable impurities. In the process of the present disclosure, the modified aluminum alloy comprises between about 1.5 and about 6.5 Ni. In an embodiment, at least one casting property is an increase in fluidity during casting, a reduction in hot tearing and/or an increase in die soldering resistance during high-pressure vacuum die casting. In an embodiment, the modified aluminum alloy comprises at least about
30 2.0 Ni. In another embodiment, the modified aluminum alloy comprises between about 2.5 and about 6.5 Ni. In another embodiment, the modified aluminum alloy has an excess of Mg

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over a weight percent ratio of Mg:Si of more than about 2:1. In still another embodiment, the modified aluminum alloy comprises between about 1.8 and about 3.0 Ni. In another embodiment, the first aluminum alloy comprises between 0.15 and 0.90 Si. In a further embodiment, the first aluminum alloy comprises between 0.3 and 0.75 Si. In yet another embodiment, the first aluminum alloy comprises Mg at a weight percentage as determined by formula (I):

$$\%Mg \leq -1.218 \cdot \ln(\%Si) + 0.89 \quad (I)$$

wherein %Mg is the weight percent of Mg; and

%Si is the weight percent of Si.

In a further embodiment, the first aluminum alloy comprises between about 0.15 and about 1.8 Mg. In still another embodiment, the first aluminum alloy comprises between about 0.30 and about 1.0 Mg. In yet another embodiment, the first aluminum alloy comprises up to about 0.10 Fe. In still a further embodiment, the first aluminum alloy comprises between about 0.45 and about 0.65 Mn. In another embodiment, the first aluminum alloy comprises up to about 0.01 Mn. In still another embodiment, the first aluminum alloy comprises between about 0.02 and about 0.12 Ti. In yet another embodiment, the first aluminum alloy comprises up to about 0.01 Ti. In an embodiment, the first aluminum alloy comprises between about 0.01 and about 0.15 V. In another embodiment, the first aluminum alloy comprises up to about 0.01 V. In still a further embodiment, the first aluminum alloy comprises between about 0.01 and about 0.15 Zr. In yet another embodiment, the first aluminum alloy comprises up to about 0.01 Zr. In yet a further embodiment, the first aluminum alloy comprises between about 0.01 and about 0.15 Mo. In still yet another embodiment, the first aluminum alloy comprises up to about 0.01 Mo. In an embodiment, the first aluminum alloy comprises between about 0.005 and about 0.02 Sr. In yet another embodiment, especially when the modified aluminum alloy is intended to be used in electrical applications, the first aluminum alloy comprises Mn, Cr, Ti and V at a weight percentage as determined by formula (II):

$$\%Mn + \%Cr + \%Ti + \%V \leq 0.025 \quad (II)$$

wherein %Mn is the weight percent of Mn;

%Cr is the weight percent of Cr;

%Ti is the weight percent of Ti; and

%V is the weight percent of V.

According to a third aspect, the present disclosure provides a modified cast aluminum alloy made from the process described herein.

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According to a fourth aspect, the present disclosure provides a process for making a cast aluminum product, the process comprising casting the cast aluminum alloy described or the modified cast aluminum alloy described in a mold. In an embodiment, the process comprises submitting the cast aluminum alloy or the modified die cast aluminum alloy to high-pressure vacuum die casting. In another embodiment, the process of claim further comprises a post-cast heat treatment step, such as, for example, a T6 temper or a T5 temper.

According to a fifth aspect, the present disclosure provides a cast aluminum product comprising the cast aluminum alloy described herein or the modified cast aluminum alloy described herein. In some embodiment, the cast aluminum product can be made by the process described herein. In an embodiment, the cast aluminum product is electrically conductive. In another embodiment, the cast aluminum product is a rotor.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus generally described the nature of the invention, reference will now be made to the accompanying drawings, showing by way of illustration, a preferred embodiment thereof, and in which:

Figure 1 illustrates the Scheil solidification curves for Al-6%Ni (◆), Al-1.8%Fe (▲), Al-1.8%Fe-1%Ni (●) and Al-5%Ni-1.8%Fe (■) alloys. Results are shown as the temperature in function of the mole fraction of solid.

Figure 2 provides the mechanical properties of the various alloys in as-cast temper. Results are shown for the ultimate tensile strength (UTS in MPa, first column for each alloy tested, left axis), the yield strength (YS in MPa, second column for each alloy tested, left axis), quality index (QI in MPa, grey column for each alloy tested) or elongation (% elong, empty column for each alloy tested) for the different alloy in as-cast temper.

Figure 3 shows the effect of magnesium and silicon content on the as-cast mechanical properties. Results are shown for the yield strength (◆, in MPa, left axis) and elongation (EI, ■, in percent, right axis) in function of the content (weight percent) of magnesium and silicon used.

Figure 4 provides the mechanical properties of the various alloys in T5 temper (aged for 1h at 210°C). Results are shown for the ultimate tensile strength (UTS in MPa, first column for each alloy tested, left axis), the yield strength (YS in MPa, second column for each alloy tested, left axis), quality index (QI in MPa, grey column for each alloy tested) or elongation (% elong, empty column for each alloy tested) for the different alloy in T5 temper.

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Figure 5 shows a microscopic view of the AlNi₂Si_{0.15}Mg_{0.15} alloy as cast temper. Scale bar = 20 μ m.

Figure 6 shows a microscopic view of the AlNi₂Si_{0.3}Mg_{0.6} alloy as cast temper. Scale bar = 20 μ m. Arrows point to undissolved Mg₂Si from solidification.

5 **Figure 7** provides the mechanical properties of the various alloys in T6 temper (solution heat treated for 1h at 460°C or 500°C, fast air quenched at 5°C/s, natural aging at room temperature for 12h, aged for 2.5h at 185°C). Results are shown for the ultimate tensile (UTS in MPa, first column for each alloy tested, left axis), the yield strength (YS in MPa, second column for each alloy tested, left axis), quality index (QI in MPa, grey column for each alloy tested) or elongation (% elong, empty column for each alloy tested) for the different alloy in T6 temper.

15 **Figure 8** shows the effect of magnesium and silicon content on the T6 mechanical properties. Results are shown for the yield strength (YS, $\blacklozenge$, in MPa, left axis) and elongation (El, $\blacksquare$, in percent, right axis) in function of the content of magnesium and silicon (weight percent) used.

Figure 9 shows a microscopic view of the AlNi₂Si_{0.15}Mg_{0.15} alloy in T6 temper. Scale bar = 20 μ m.

Figure 10 shows a microscopic view of the AlNi₂Si_{0.15}Mg_{0.3} alloy in T6 temper. Scale bar = 20 μ m.

20 **Figure 11** shows a microscopic view of the AlNi₂Si_{0.3}Mg_{0.3} alloy in T6 temper. Scale bar = 20 μ m.

Figure 12 shows a microscopic view of the AlNi₂Si_{0.3}Mg_{0.6} alloy in T6 temper. Scale bar = 20 μ m.

25 **Figure 13** shows a microscopic view of the AlNi₂Si_{0.3}Mg_{0.6}Mn alloy in T6 temper. Scale bar = 20 μ m.

Figure 14 shows a microscopic view of the AlNi₂Si_{0.5}Mg_{0.5} alloy in T6 temper. Scale bar = 30 μ m.

Figure 15 shows a microscopic view of the AlNi₂Si_{0.9}Mg_{0.8} alloy in T6 temper. Scale bar = 30 μ m.

30 **Figure 16** shows the electrical conductivity (%IACS) of the tested type alloys in function of the Mg+Si content (weight percent) of the alloy in T6 temper.

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Figure 17 shows the electrical conductivity (%IACS) of the tested type alloys in function of the yield strength (in MPa) of the alloy in T6 temper.

Figure 18 provides the mechanical properties of the various alloys in T6 temper (solution heat treated for 1h or 2h at 500°C, fast air quenched at 5°C/s, natural aging at room temperature for 12h, aged for 2.5h at 185°C). Results are shown for the ultimate tensile (UTS in MPa, first column for each alloy tested, left axis), the yield strength (YS in MPa, second column for each alloy tested, left axis), quality index (QI in MPa, grey column for each alloy tested) or elongation (% elong, empty column for each alloy tested) for the different alloy in T6 temper.

Figure 19 provides the mechanical properties of the various alloys in T6 temper (solution heat treated for 1h or 2h at 500°C, fast air quenched at 5°C/s, natural aging at room temperature for 12h, aged for 2.5h at 185°C). Results are shown for the ultimate tensile strength (UTS in MPa for 1h solid line with ♦, UTS in MPa for 2h line with x), the yield strength (YS in MPa for 1h solid line with ■, US in MPa for 2h line with *), elongation (% elong for 1h solid line with ▲, % elong for 2h line with ●).

Figure 20 provides the electrical conductivity (%IACS) of the various alloys in T6 temper (solution heat treated for 1h or 2h at 500°C, fast air quenched at 5°C/s, natural aging at room temperature for 12h, aged for 2.5h at 185°C) in function of the yield strength (in MPa) of the alloy. The yield strength results for the same alloy with a 1h treatment shown with ♦ and a 2h treatment shown with ■ are linked by a line for comparison.

Figure 21 provides the mechanical properties of the various alloys in F temper. Results are shown for the ultimate tensile (UTS in MPa, first column for each alloy tested, left axis), the yield strength (YS in MPa, second column for each alloy tested, left axis), quality index (QI in MPa, grey column for each alloy tested) or elongation (% elong, empty column for each alloy tested) for the different alloy in F temper.

Figure 22 provides the mechanical properties of the various alloys in T5 temper (aged for 1h at 210°C). Results are shown for the ultimate tensile (UTS in MPa, first column for each alloy tested, left axis), the yield strength (YS in MPa, second column for each alloy tested, left axis), quality index (QI in MPa, grey column for each alloy tested) or elongation (% elong, empty column for each alloy tested) for the different alloy in T5 temper.

Figure 23 provides the mechanical properties of the various alloys in T6 temper (solution heat treated for 1h at 500°C, fast air quenched at 5°C/s, natural aging at room temperature for 12h, aged for 2.5h at 185°C). Results are shown for the ultimate tensile (UTS in MPa, first column for each alloy tested, left axis), the yield strength (YS in MPa, second column for

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each alloy tested, left axis), quality index (QI in MPa, grey column for each alloy tested) or elongation (% elong, empty column for each alloy tested) for the different alloy in T6 temper.

Figure 24 shows a microscopic view of AlNi3Si0.3Mg0.6 in F temper. Scale bar = 20 μ m.

Figure 25 shows a microscopic view of AlNi3Si0.3Mg0.6 in T6 temper. Scale bar = 20 μ m.

- 5 **Figure 26** shows the electrical conductivity (%IACS) in function of the Ni content (wt. %) in T6 temper.

Figure 27 shows a hot tearing mold in high pressure vacuum die casting (HPVDC).

Figure 28 shows a hot tearing index (HTI) sensitivity map with the wt. % of Mg in function of the wt. % of Si. The HTI range of values are specified within the areas.

10 **DETAILED DESCRIPTION**

The present disclosure concerns the use of Ni in Al-Si-Mg alloys (such as 6xxx alloys) to provide a cast or foundry alloy. In some embodiment, the foundry alloy of the present disclosure can be used in high-pressure vacuum die casting to provide cast aluminum products. The presence of Ni in the foundry alloy of the present disclosure does not
15 substantially impact the Mg_2Si precipitation strengthening mechanism of the alloy (as Ni is inert with respect to Mg and Si and is not expected to impact the formation of Mg_2Si precipitates), advantageously it allows the alloy to be cast, limits hot tearing and improves die soldering resistance when the foundry alloy is submitted to high-pressure vacuum die casting. In some embodiments, the foundry alloy of the present disclosure also exhibits
20 increased electrical conductivity as well as substantially similar mechanical properties (especially strength and ductility) when compared to control alloys (such as A365.1 alloys).

In the context of the present disclosure, Ni can be added to aluminum alloys intended to be used in casting applications. For example, Ni can be added to the wrought alloys of the 3xxx, 5xxx or 6xxx series to create a foundry alloy. In some specific embodiments, Ni can be
25 added to the wrought alloys of the 6xxx series to create a foundry alloy. Ni can also be added to aluminum alloys intended to be used in high-pressure vacuum die casting applications to limit hot tearing and/or die soldering. For example, Ni can be added to alloys of 2xxx, 3xxx, 4xxx, 5xxx or 6xxx series to limit hot tearing and/or die soldering during high-pressure vacuum die casting applications. In still another embodiment, Ni can be added to alloys of
30 6xxx series to limit hot tearing and/or die soldering during high-pressure vacuum die casting applications. In the context of the present disclosure, Ni should be provided at a minimal weight percentage (e.g., 1.5, 1.8, 2.0, 2.5 or above 2.5) which will allow casting, and, in some

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embodiments, especially prevent die soldering in high-pressure vacuum die casting operations.

Ni can be added, at a weight percentage of between about 1.5 and about 6.5 to the foundry alloy of the present disclosure. In an embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4. In yet another embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2, 4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2, 2.1, 2.0, 1.9, 1.8, 1.7 or 1.6. In yet a further embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of between about 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4 and about 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2, 4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2, 2.1, 2.0, 1.9, 1.8, 1.7 or 1.6.

In a further embodiment, Ni is present in the foundry alloy at a weight percentage higher than about 2.0. As shown in the Examples below, including Ni at a weight percentage above 2.0 limits hot tearing and increases die soldering resistance. In such embodiment, Ni can be present in the foundry alloy at a weight percentage higher than about 2.0 and equal to or lower than about 6.5. In further embodiments, Ni can be present in the foundry alloy at a weight percentage higher than about 2.0 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4. In still another embodiment, Ni can be present in the foundry alloy at a weight percentage equal to or lower than about 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2, 4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2 or 2.1. In still yet another embodiment, Ni can be present in the foundry alloy at a weight percentage higher than about 2.0 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4 and equal to or lower than about 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2,

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4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2 or 2.1.

In still another embodiment, Ni is present in the foundry alloy at a weight percentage between about 1.8 and 3.0. In an embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8 or 2.9. In yet another embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 3.0, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2, 2.1, 2.0 or 1.9. In yet a further embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of between about 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8 or 2.9 and about 3.0, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2, 2.1, 2.0 or 1.9.

In yet another embodiment, Ni can be added, at a weight percentage of between about 2.5 and about 6.5 to the foundry alloy of the present disclosure. In an embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4. In yet another embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2, 4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7 or 2.6. In yet a further embodiment, Ni is present in the foundry alloy of the present disclosure at a weight percentage of between about 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4 and about 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2, 4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7 or 2.6.

In a further embodiment, Ni is present in the foundry alloy at a weight percentage higher than about 2.5. In such embodiment, Ni can be present in the foundry alloy at a weight percentage higher than about 2.5 and equal to or lower than about 6.5. In further embodiments, Ni can be present in the foundry alloy at a weight percentage higher than about 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4. In still another embodiment, Ni can be present in the foundry alloy at a weight percentage equal to or lower than about 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2, 4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7

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or 2.6. In still yet another embodiment, Ni can be present in the foundry alloy at a weight percentage higher than about 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.0, 6.1, 6.2, 6.3 or 6.4 and equal to or lower than about 6.5, 6.4, 6.3, 6.2, 6.1, 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2, 5.1, 5.0, 4.9, 4.8, 4.7, 4.6, 4.5, 4.4, 4.3, 4.2, 4.1, 4.0, 3.9, 3.8, 3.7, 3.6, 3.5, 3.4, 3.3, 3.2, 3.1, 3.0, 2.9, 2.8, 2.7 or 2.6.

The foundry alloy of the present disclosure also includes Si and Mg. In the foundry alloy of the present disclosure, Si and Mg form precipitates (Mg₂Si particles for example) which are expected to provide some of the mechanical properties (especially strength and ductility) of cast aluminum products comprising the cast aluminum alloy of the present disclosure. As it is known in the art, the solubility of Si and Mg in the aluminum matrix are co-dependent. In some embodiments, the Mg/Si atomic ratio is between 1 to 2. In some embodiment, the Mg weight percent is related to the Si weight percent in the aluminum alloy of the present disclosure as follows:

$$\%Mg \leq -1.218 \cdot \ln(\%Si) + 0.89 \quad (I)$$

In some embodiments, when the cast aluminum product is in T6 temper, the Mg and Si content are related as indicated in Formula (I). In some embodiment, when the cast aluminum product is in F temper, the Mg/Si atomic ratio is closer to 1.

In further embodiments, Mg is present in excess a Mg:Si (weight percent) ratio of 2:1. In some embodiments, the ratio Mg:Si is higher than about 2:1. This may be beneficial, in some embodiments, to reduce the hot tearing index of the aluminum alloy.

Si is present in the foundry alloy of the present disclosure at a weight percentage between about 0.10 and about 1.5. It is important that the foundry alloys of the present disclosure include at least about 0.10 Si so as to form precipitates with Mg and no more than about 1.5 Si so as to provide acceptable electrical properties (such as electrical conductivity) and to avoid silicon eutectic formation.

In an embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 1.10, 1.20, 1.30 or 1.40. In another embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 1.50, 1.40, 1.30, 1.20, 1.10, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20. In yet another embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of between about 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00,

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1.10, 1.20, 1.30 or 1.40 and about 1.50, 1.40, 1.30, 1.20, 1.10, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20.

In an embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage between about 0.15 and about 0.90. In an embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 0.15, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70 or 0.80. In another embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20. In yet another embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of between about 0.15, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70 or 0.80 and about 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20.

In yet another embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage between about 0.30 and about 0.75. In an embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 0.30, 0.40, 0.50, 0.60 or 0.70. In another embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 0.75, 0.70, 0.60, 0.50 or 0.40. In yet another embodiment, Si is present in the foundry alloy of the present disclosure at a weight percentage of between about 0.30, 0.40, 0.50, 0.60 or 0.70 and about 0.75, 0.70, 0.60, 0.50 or 0.40.

Mg is present in the foundry alloy of the present disclosure at a weight percentage between about 0.10 and about 3.0. It is important that the foundry alloys of the present disclosure include at least about 0.10 Mg so as to form precipitates with Si and no more than about 3.0 Mg so as to provide acceptable electrical properties (such as electrical conductivity). In an embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40, 1.50, 1.60, 1.70, 1.80, 1.90, 2.00, 2.10, 2.20, 2.30, 2.40, 2.50, 2.60, 2.70, 2.80 or 2.90. In another embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 3.00, 2.90, 2.80, 2.70, 2.60, 2.50, 2.40, 2.30, 2.20, 2.10, 2.00, 1.90, 1.80, 1.70, 1.60, 1.50, 1.40, 1.30, 1.20, 1.10, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20. In yet another embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of between about 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40, 1.50, 1.60, 1.70, 1.80, 1.90, 2.00, 2.10, 2.20, 2.30, 2.40, 2.50, 2.60, 2.70, 2.80 or 2.90 and about 3.00, 2.90, 2.80, 2.70, 2.60, 2.50, 2.40, 2.30, 2.20, 2.10, 2.00, 1.90, 1.80, 1.70, 1.60, 1.50, 1.40, 1.30, 1.20, 1.10, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20.

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In an embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage between about 0.15 and about 1.8. In an embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 0.15, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40, 1.50, 1.60 or 1.70. In another embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 1.80, 1.70, 1.60, 1.50, 1.40, 1.30, 1.20, 1.10, 1.00, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20. In yet another embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of between about 0.15, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40, 1.50, 1.60 or 1.70 and about 1.80, 1.70, 1.60, 1.50, 1.40, 1.30, 1.20, 1.10, 1.00, 0.90, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30 or 0.20.

In an embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage between about 0.3 and about 1.0. In an embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of at least about (e.g., a minimum of) 0.30, 0.40, 0.50, 0.60, 0.70, 0.80 or 0.90. In another embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of no more than about (e.g., a maximum of) 1.00, 0.90, 0.80, 0.70, 0.60, 0.50 or 0.40. In yet another embodiment, Mg is present in the foundry alloy of the present disclosure at a weight percentage of between about 0.30, 0.40, 0.50, 0.60, 0.70, 0.80 or 0.90 and about 1.00, 0.90, 0.80, 0.70, 0.60, 0.50 or 0.40.

In the alloys of the present disclosure, Fe is not included as an alloying element of the foundry alloy of the present disclosure and, if detected, is only present as an impurity or a trace element. The presence of Fe would be detrimental to the alloys of the present disclosure since it is expected to favor brittle AlFeSi phases. However, since Fe is a known impurity in aluminum smelting operations, a weight percent of a maximum of 0.20 Fe is expected in some primary aluminum. In some embodiments, Fe is present in the foundry alloy of the present disclosure at a weight percentage equal to or less than 0.2, 0.19, 0.18, 0.17, 0.16, 0.15, 0.14, 0.13, 0.12, 0.11 or 0.10. In some additional embodiment, Fe is present in the foundry alloy at a weight percentage equal to or less than 0.10.

In some additional embodiments, the foundry alloy of the present disclosure can include Mn. Mn can be used, for example, to limit die soldering during high-pressure casting operations. However, because the presence of Mn can be detrimental to the electrical conductivity of aluminum products comprising the cast aluminum alloy, when present, Mn is present in the foundry alloy of the present disclosure a weight percentage of no more than 0.65. In some embodiments, Mn is present in the foundry alloy of the present disclosure at a weight

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percentage between about 0.45 and 0.65. In some embodiments, Mn is present in the foundry alloy of the present disclosure at a weight percentage equal to or lower than about 0.01. In some additional embodiments, the foundry alloy of the present disclosure can exclude Mn as an alloying element.

5 In some further embodiments, the foundry alloy of the present disclosure can include Ti. Ti can be used, for example, as a grain refiner. However, because the presence of Ti can be detrimental to the electrical conductivity of aluminum products comprising the cast aluminum alloy, when present, Ti is present in the foundry alloy of the present disclosure at a weight percentage of no more than 0.12. In some embodiment, Ti is present in the foundry alloy of
10 the present disclosure at a weight percentage between about 0.02 and 0.12. In some additional embodiments, Ti is present in the foundry alloy of the present disclosure at a weight percentage equal to or lower than about 0.01. In some additional embodiments, the foundry alloy of the present disclosure can exclude Ti as an alloying element.

In some further embodiments, the foundry alloy of the present disclosure can include V. V
15 can be used, for example, to increase the mechanical properties of a cast aluminum product comprising the cast aluminum alloy of the present disclosure. However, because the presence of V can be detrimental to the electrical conductivity of aluminum products comprising the cast aluminum alloy, when present, V is present in the foundry alloy of the present disclosure at a weight percentage of no more than 0.15. In some embodiments, V is
20 present in the foundry alloy of the present disclosure at a weight percentage between about 0.02 and 0.15. In some embodiments, V is present in the foundry alloy of the present disclosure at a weight percentage of equal to or lower than about 0.01. In some additional embodiments, the foundry alloy of the present disclosure can exclude V as an alloying element.

25 In some further embodiments, the foundry alloy of the present disclosure can include Zr. Zr can be used, for example, to increase the mechanical properties of a cast aluminum product comprising the cast aluminum alloy of the present disclosure. Zr can be present in the foundry alloy of the present disclosure at a weight percentage of no more than 0.15. In some
30 embodiments, Zr is present in the foundry alloy of the present disclosure at a weight percentage between about 0.01 and 0.15. In some further embodiments, Zr is present in the foundry alloy of the present disclosure at a weight percentage equal to or lower than about 0.01. In some additional embodiments, the foundry alloy of the present disclosure can exclude Zr as an alloying element.

In some further embodiments, the foundry alloy of the present disclosure can include Mo. Mo
35 can be used, for example, to increase the mechanical properties of a cast aluminum product

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comprising the cast aluminum alloy of the present disclosure. Mo can be present in the foundry alloy of the present disclosure at a weight percentage of no more than 0.15. In some embodiment, Mo is present in the foundry alloy of the present disclosure at a weight percentage between about 0.01 and 0.15. In some further embodiments, Mo is present in the foundry alloy of the present disclosure at a weight percentage equal to or lower than about 0.01. In some additional embodiments, the foundry alloy of the present disclosure can exclude Mo as an alloying element.

In some further embodiments, the foundry alloy of the present disclosure can include Sr. Sr can be used, for example, to modify the structure of the cast aluminum alloy of the present disclosure. Sr can be present in the foundry alloy of the present disclosure at a weight percentage of no more than 0.02. In alternative embodiments, Sr may be a voluntary addition to the aluminum alloy. For example, Sr is present in the foundry alloy of the present disclosure at a weight percentage between about 0.005 and 0.02

In the alloys of the present disclosure, Cr is not included as an alloying element of the foundry alloy of the present disclosure and, if detected, is only present as an impurity or a trace element. The presence of Cr would be detrimental to the alloys of the present disclosure since it is detrimental to the electrical conductivity of the foundry alloy. In some embodiments, Cr is present in the foundry alloy of the present disclosure at a weight percentage equal to or less than (e.g., up to) about 0.01.

In the alloys of the present disclosure, Cu is not included as an alloying element of the foundry alloy of the present disclosure and, if detected, is only present as an impurity or a trace element. The presence of Cu would be detrimental to the foundry alloys of the present disclosure since it is not inert with respect to Ni and the MgSi particles of the foundry alloy. The foundry alloy of the present disclosure exclude Cu as an alloying element.

In some embodiments of the foundry alloys of the present disclosure, it is preferable that the content of Mn, Cr, Ti and V be limited so as to preserve electrical conductivity. As such, the content of Mn, Cr, Ti and V can follow formula (II):

$$\%Mn + \%Cr + \%Ti + \%V \leq 0.025 \text{ (II)}$$

wherein %Mn is the weight percentage of Mn;

%Cr is the weight percentage of Cr;

%Ti is the weight percentage of Ti; and

%V is the weight percentage of V.

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In embodiments in which the foundry alloy is intended to be used in electrical applications or is required to have a specific electrical conductivity, the foundry alloy can include B as an optional alloying element. B can be used, for example, to precipitate the Ti and V content of the alloy. In some embodiments, the presence of B can improve the electrical conductivity by 1% IACS.

A grain refiner, such as titanium, titanium boride, or titanium carbide may be optionally included in the aluminum alloys of the present disclosure to solidify aluminum alloys with a fully equiaxed, fine grain structure. In an embodiment, the grain refiner is in the form of Ti, TiB or TiC. When TiB is used as a grain refiner, this may result in a B content of up to 0.05 wt. % in the alloy. When TiC is used as a grain refiner, this may result in a C content of up to 0.01 wt. % in the alloy.

The balance of the aluminum alloy of the present disclosure is aluminum (Al) and unavoidable impurities. In an embodiment, each impurity is present, in weight percent, at a maximum of about 0.03 and the total unavoidable impurities is present, in weight percent, at less than about 0.10 (in weight percent).

The cast aluminum alloy of the present disclosure can be submitted to various casting operations including, but not limited to high-pressure vacuum die casting (HPVDC) so as to provide cast aluminum product. The presence of Ni in the cast aluminum alloy of the present disclosure can increase the fluidity of the alloy (when compared to a corresponding alloy lacking Ni) which in return can allow foundry operations (such as, for example, high-pressure casting operations). In some embodiments, the presence of Ni in the cast aluminum alloy of the present disclosure can reduce hot tearing and/or increase die soldering resistance during high-pressure casting operations (when compared to a corresponding alloy lacking Ni).

The cast aluminum alloys of the present disclosure can be submitted to HPVDC operations to provide cast aluminum products. In an embodiment of the present disclosure, the cast aluminum products made from the aluminum alloys of the present disclosure by HPVDC exhibit a substantially similar ultimate tensile strength, yield strength, quality index and/or percent elongation than a corresponding aluminum product, made by HPVDC, but with a control aluminum alloy (from example a A365.1 alloy) as well as an increased electrical conductivity that the control alloy.

The present disclosure also provides a process for making an aluminum product comprising the cast aluminum alloy described herein. The process comprises working the aluminum alloy or the modified aluminum alloy described herewith or the foundry ingot described herewith in the aluminum product. The working step can include casting the aluminum alloy

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directly into a cast product or intermediary ingots intended for remelting. As such, in the context of the present disclosure, the term "aluminum product" can refer to a final cast products (such as a rotor for example) or to an intermediary ingot which can further be remelted into a differently shaped aluminum product. In embodiments in which aluminum product is a cast product, the process can also exclude any post-cast treatment (e.g., it can be provided as cast or F temper). Alternatively, the process can include a post-cast heat treatment, such as, for example, a T5, T6 or T7 treatment (e.g., solution heat treatment and artificial aging steps). In the embodiments in which the aluminum product is a cast product, the latter can be an automotive part, such as a chassis or a rotor.

In some embodiments, when the cast aluminum product is not submitted to a post-cast heat treatment and is in a F temper. In such embodiment, the cast aluminum product can have a quality index of at least about 185 MPa. Still in such embodiment, the cast aluminum product can have a quality index of at least about 185, 190, 195 or 200 MPa. Still in such embodiment, the cast aluminum product can have a yield of at least about 75, 80, 85, 90, 95 or 100 MPa. Still in such embodiment, the cast aluminum product can have a UTS of at least about 200, 205, 210, 215 or 220 MPa. Still in such embodiment, the cast aluminum product can have an elongation of at least about 6.5, 7, 7.5 or 8 %.

In some additional embodiments, when the cast aluminum product is submitted to a T5 temper it has a quality index of at least about 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250 or 255 MPa. In an embodiment in which the T5 temper includes an artificial aging at 210°C for 1h, it has a quality index of at least about 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250 or 255 MPa. In such embodiment, the cast aluminum product can have a UTS of at least about 220, 225, 230, 235, 240 or 245 MPa. Still in such embodiment, the cast aluminum product can have a yield of at least about 130, 135, 140, 145, 150, or 155. Yet still in such embodiment, the cast aluminum product can have an elongation of at least about 5, 5.5 or 6 %.

In some additional embodiments, when the cast aluminum product is submitted to a T6 temper, it has a quality index of at least about 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295, 300, 305, 310 or 315 MPa. In further embodiments the cast aluminum product submitted to a T6 temper has a yield of at least about 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, or 245 MPa. In yet further embodiments the cast aluminum product submitted to a T6 temper has a UTS of at least about 250, 255, 260, 265, 270, 275 or 280 MPa. In yet additional further embodiments, the aluminum product submitted to a T6 temper has an elongation of at least about 5.5, 6, 6.5 or 7 %. In the embodiment in which the T6

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temper includes a solution heat treatment at 460°C for 1h, air quenching at a rate of 5°C/s followed by 12 hours of natural aging at room temperature and artificial aging at 185°C for 2.5h, the cast aluminum product can have a quality index of at least about 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295 or 300 MPa. In the embodiment in which the T6 temper includes a solution heat treatment at 500°C for 1h, air quenching at a rate of 5°C/s followed by 12 hours of natural aging at room temperature and artificial aging at 185°C for 2.5h, the cast aluminum product can have a quality index of at least about 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295 or 300 MPa.

10 In some additional embodiments, the electrical conductivity of an aluminum product in T6 temper is at least 40%, 41%, 42%, 43%, 44% or 45% IACS.

The present invention will be more readily understood by referring to the following examples which are given to illustrate the invention rather than to limit its scope.

EXAMPLE I – HOT TEARING REDUCTION

15 Three alloys were selected based on their potential to present an eutectic reaction (as calculated using Thermocalc): Al-Fe, Al-Ni and Al-Fe-Ni. As can be seen on their phase diagrams (Thermocalc software, database TCAL5), the three systems present an eutectic reaction which is understood to increase fluidity and limit hot tearing. Scheil solidification curves, also determined using Thermocalc, were performed at the eutectic chemistry for the three systems and are presented in Figure 1.

Due to their eutectic reactions, the three systems reduce the solidus temperature of aluminum. The low solidus temperature and the eutectic solidification is expected to provide good fluidity. Concerning hot tearing, the three alloy systems show relatively small solidification intervals (5 to 50°C) and flat solidification curves between 87 and 94% solid. As such, low hot tearing sensitivity is predicted. Finally, die soldering tendencies were deemed good for high pressure die casting in light of the ternary diagram (Mondolfo L.F., Aluminum Alloys Structure & Properties, 1976, p. 532) and observations made during cast trials. From these experiments, it is understood that, above 2% nickel, a ternary iron intermetallic compound will form on the die surface thus reducing die soldering.

30 EXAMPLE II – CHARACTERIZATION OF NI-COMPRISING ALLOYS

Al-Ni-Mg-Si alloys (see chemistry in Table 1) were cast on a 250t Buhler machine. Prior to casting, each variant was degassed using argon for 20 minutes. Fluxing was performed once per day (once every two alloys) using Promag SI at a rate of 0.5 g of salt per kg of aluminum.

Table 1. Alloy chemistries. The presence of trace amounts of Ti, B and V was also determined in these alloys.

Alloy	Si	Mg	Ni	Fe	Mn	Ti	B	V
AlNi ₂ Si _{0.15} Mg _{0.15}	0.16	0.13	2.0	0.09	0.01	0.052	0.0002	0.010
AlNi ₂ Si _{0.15} Mg _{0.3}	0.16	0.27	2.0	0.09	0.01	0.055	0.0001	0.010
AlNi ₂ Si _{0.3} Mg _{0.3}	0.32	0.27	1.9	0.09	0.01	0.054	0.0003	0.010
AlNi ₂ Si _{0.3} Mg _{0.6}	0.32	0.58	1.9	0.09	0.01	0.060	0.0001	0.010
AlNi ₂ Si _{0.3} Mg _{0.6} Mn	0.29	0.59	1.8	0.09	0.69	0.055	0.0003	0.011
AlNi ₂ Si _{0.3} Mg _{0.6} MnB	0.29	0.56	1.8	0.09	0.68	0.006	0.0083	0.001
AlNi ₂ Si _{0.5} Mg _{0.5}	0.45	0.48	2.1	0.09	<0.01	0.049	0.0004	0.010
AlNi ₂ Si _{0.9} Mg _{0.8}	0.75	0.71	2.1	0.10	<0.01	0.048	0.0001	0.010
AlNi ₂ Si _{1.1} Mg ₁	1.05	1.01	2.1	0.10	<0.01	0.044	0.0000	0.010
AlNi ₂ Si _{1.5} Mg _{1.5}	1.62	1.56	2.0	0.11	<0.01	0.043	0.0000	0.010

The as-cast plates underwent one week of natural aging at room temperature prior to mechanical testing or heat treatment. Two distinct heat treatments were performed: an artificial aging at 210°C for 1h (T5 temper) and a solution heat treatment at 500°C for 1h, air quenched at a rate of 5°C/s followed by 12 hours of natural aging at room temperature and artificial aging at 185°C for 2.5h (T6 temper). ASTM E8 full size flat tensile bars were cut from the plates after heat treatment.

As shown in Figure 2, in the as-cast temper, A365.1 provides the best combination of strength and ductility. For the other alloys, incremental amount of magnesium and silicon increased gradually the strength while reducing the ductility. Figure 3 shows the impact of silicon and magnesium on the alloy strength and ductility.

The mechanical properties in the T5 temper show the same trend than in the as-cast temper. Incremental amount of magnesium and silicon increase gradually the strength while reducing the ductility (Figure 4). The reduction of ductility is explained by the presence of Mg₂Si constituents that form during solidification. Figures 5 and 6 show the progression of Mg₂Si in the as-cast structure from alloy AlNi₂Si_{0.15}Mg_{0.15} to AlNi₂Si_{0.3}Mg_{0.6} (Mg₂Si appears dark black).

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As shown in Figure 7, A365.1 still provides the best mechanical properties in the T6 temper. However, alloy AlNi2Si0.3Mg0.6 provides almost equivalent mechanical properties than A365.1. Incremental amount of magnesium and silicon increase gradually the strength while reducing the ductility. Figure 8 shows the impact of silicon and magnesium on the alloy strength and ductility in the T6 temper.

The solution heat treatment at 500°C for 1h allowed the dissolution of most of the Mg₂Si constituents. At magnesium level over 0.5%, some Mg₂Si is still visible in the microstructure as seen in Figures 9 to 15.

When considering exclusively the mechanical properties, A365.1 is still the highest performing alloy. However, the 6xxx type alloys can provide similar mechanical properties than A365.1 with a more dilute chemistry which will provide higher electrical conductivity. The measured electrical conductivities are presented in Table 2. Two A365.1 variants were used for comparison, A365.1A (0.31% Mg) and A365.1B (0.79% Mg). The impact of magnesium and silicon content on the electrical conductivity is presented in Figures 16 and 17.

Table 2. Electrical conductivity of the tested alloys.

Alloy	Temper	Electrical conductivity (%IACS)
A365.1A	T6	39.8
A365.1B		39.5
AlNi2Si0.15Mg0.15		51.7
AlNi2Si0.15Mg0.3		49.7
AlNi2Si0.3Mg0.3		49.7
AlNi2Si0.3Mg0.6		47.8
AlNi2Si0.3Mg0.6Mn		30.5
AlNi2Si0.3Mg0.6MnB		31.3
AlNi2Si0.5Mg0.5		46.3
AlNi2Si0.9Mg0.8		46.2

The magnesium content of A365.1 used for mechanical property measurement is situated between A365.1A and A365.1B. Therefore, the electrical conductivity of A365.1 would be between 39.5 and 39.8 %IACS. Due to the high silicon content of A365.1 alloys and the need

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for manganese to avoid die soldering, the electrical conductivity of A365.1 alloys is much lower than the tested alloys. Therefore, alloy AlNi₂Si_{0.3}Mg_{0.6} which provides similar mechanical properties than A365.1, but much higher electrical conductivity would be suitable for high strength and high electrical conductivity applications.

- 5 Electrical conductivity follows an inversion relationship with the magnesium and silicon content as well as yield strength. Electrical conductivity decreases in aluminum with higher alloying elements. Therefore, the more dilute variant provides the highest electrical conductivity, but the lowest strength.

- 10 The addition of manganese drastically reduces the electrical conductivity of the alloy. It is therefore not recommended to use manganese to prevent die soldering for both mechanical properties and electrical conductivity.

Boron can be used to precipitate the titanium and vanadium content of the alloy. In some embodiments, boron treatment can improve the electrical conductivity by 1% IACS.

EXAMPLE III – EFFECTS OF SOLUTION HEAT TREATMENT

- 15 Remaining as-cast plates from Example II on a 250-t Buhler machine were used to further study the impact of solution heat treatment on the mechanical and electrical properties of the 6xxx series alloys of Table 3.

Table 3. Alloy chemistries.

Alloy	Si	Mg	Ni	Fe	Mn	Ti	B	V	Mg ₂ Si solvus temperature (°C)
AlNi ₂ Si _{0.15} Mg _{0.15}	0.16	0.13	2.0	0.009	0.01	0.052	2x10 ⁻⁴	0.010	380
AlNi ₂ Si _{0.15} Mg _{0.3}	0.16	0.27	2.0	0.009	0.01	0.055	1x10 ⁻⁴	0.010	408
AlNi ₂ Si _{0.3} Mg _{0.3}	0.32	0.27	2.0	0.009	0.01	0.054	3x10 ⁻⁴	0.010	431
AlNi ₂ Si _{0.3} Mg _{0.6}	0.32	0.58	1.9	0.009	0.01	0.060	1x10 ⁻⁴	0.010	480
AlNi ₂ Si _{0.5} Mg _{0.5}	0.45	0.48	2.1	0.009	<0.01	0.049	4x10 ⁻⁴	0.010	480
AlNi ₂ Si _{0.9} Mg _{0.8}	0.75	0.71	2.1	0.010	<0.01	0.048	1x10 ⁻⁴	0.010	527

- 20 As shown in Figures 18 and 19, a solution heat treatment at 500 °C, for 1 h, air quenched at a rate of 5° C/s followed by 12 hours of natural aging at room temperature and artificial aging

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at 185 °C, for 2.5 h (T6 temper), was not sufficient to dissolve entirely all the Mg₂Si formed during solidification. Therefore, a solution heat treatment at 500 °C, for 2 hours, was performed while maintaining the same quenching and aging cycle (Figures 18 and 19).

A longer solution heat treatment had a positive impact on all alloys tested. Yield strength was improved by 15 to 25 MPa with no impact on elongation. Furthermore, the impact of solution heat treatment time on the electrical conductivity is presented in Figure 20.

A longer solution heat treatment had statistically no impact on the electrical conductivity of all the alloys tested except for alloy AlNi2Si0.9Mg0.8. A longer solution heat treatment would therefore be favored to increase strength without impacting the electrical conductivity.

EXAMPLE IV – EFFECT OF NICKEL CONTENT

From the Al-Ni phase diagram and die casting trials (Example I), it was determined that above 2 % nickel, good die soldering resistance can be achieved. The 6xxx alloys presented in Table 3 contain sufficient nickel to prevent die soldering, but low values to reduce cost. Nonetheless, increasing the nickel content can be done if further die soldering or fluidity is needed. Alloys with higher nickel content were cast to confirm that nickel does not interfere with Mg₂Si precipitation. The alloy chemistries are presented in Table 4.

Table 4. Alloy chemistries

Alloy	Si	Mg	Ni	Fe	Mn	Ti	B	V
AlNi2Si0.3Mg0.6	0.32	0.58	1.9	0.09	0.01	0.060	1x10 ⁻⁴	0.010
AlNi2.5Si0.3Mg0.6	0.30	0.64	2.4	0.09	<0.01	0.048	5x10 ⁻⁴	0.011
AlNi3Si0.3Mg0.6	0.34	0.68	2.9	0.09	<0.01	0.050	5x10 ⁻⁴	0.011
AlNi3.5Si0.3Mg0.6	0.33	0.76	3.5	0.09	<0.01	0.057	4x10 ⁻⁴	0.011

The mechanical properties from the alloys in Table 4 are presented in figures 21 to 23.

In the F temper (Figure 21), the strength increased while elongation decreased from alloy AlNi2Si0.3Mg0.6 to alloy AlNi3.5Si0.3Mg0.6. The change in mechanical properties can be associated with the increasing amount of nickel, but also to the increased level of magnesium. The yield strength increased from 10 to 15 MPa for every 0.5 % Ni increase between the 2 % and 3 % nickel alloys. The mechanical properties stabilized between the 3 % and 3.5 % nickel alloys.

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A similar pattern was observed in the T5 temper (Figure 22). The strength increased was between 15 to 20 MPa for every 0.5 % Ni increase between the 2 % and 3 % nickel alloys, and the mechanical properties stabilized between the 3 % and 3.5 % nickel alloys.

In the T6 temper (Figure 23), the strength increased by 40 MPa from alloy AlNi2Si0.3Mg0.6 to alloy AlNi3Si0.3Mg0.6. However, the elongation was stable. A higher level of nickel had therefore no impact on the alloy ductility in the T6 temper.

The reduction in ductility observed in the F and T5 temper and the stable ductility in the T6 temper could be explained by the nickel eutectic morphology. Without wishing to be bound by theory, it is believed that during solution heat treatment, the sharp Al-Ni particles from the F temper spheroidize. This could improve the ductility as seen in Figures 24 and 25. The nickel can therefore be tailored to the die soldering and fluidity needed for the application.

The impact of nickel content on the electrical conductivity, in the T6 temper (500°C-1h, 185°C-2.5h), is presented in Figure 26. From 2 to 3 % nickel, the electrical conductivity does not statistically change.

EXAMPLE V – HOT TEARING TEST

The 6xx series alloys are currently not used in the foundry industry due to the high hot tearing potential of these alloys. In order to optimize the 6xx+Ni alloys, hot tearing trials were performed on a Buhler high-pressure die casting press. A specific mold, as shown in Figure 27, was designed to quantify hot tearing during hot tearing mold in high pressure vacuum die casting (HPVDC). The mould contains four thin sections surrounded by risers. The bar's lengths are 50, 100, 150 and 200 mm.

Each bar was inspected for cracks after casting according to four criteria:

- crack position (near to the low riser, near to the high riser, in the riser),
- crack length (complete, partial or fine crack),
- crack severity (through the thickness or not), and
- presence or absence of cracks over the length of the bar.

Each crack was quantified using the parameters of Table 5.

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Table 5. Parameters to quantify cracks

Parameter name	Meaning	Score
B	Near low riser	1
H	Near high riser	1
M	In riser	1
D	Through the thickness	2
ND	Not through the thickness	1
C	Complete	2
P	Partial	1
TP	Fine	-1
FT	Crack in the bar	0

Each bar is given a score calculated as follows. If a crack appears, it is given the score from Table 5. If no cracks are visible for the specific parameter, a score of 0 is given. Then the following calculations are performed using the following formulas.

$$C_b = B(D + ND + C + P + TP) + H(D + ND + C + P + TP) + M$$

"n" castings were produced. Therefore, an average value was calculated for each bar:

$$C_{mb} = \frac{\sum_{n=1}^N C_{bn}}{N}$$

Finally, a global hot tearing index was calculated for the alloy:

$$C_{alloy} = \sum_{b=1}^{b=4} b C_{mb}$$

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Where “b” is the rating given to the bars. The 50-mm bar is given the highest “b” rating because a crack in the small section reveals a more critical level of hot tearing sensitivity. The b ratings are summarized in the following Table 6.

Table 6. b rating for each bar

Bar length (mm)	b rating
200	1
150	2
100	3
50	4

5

The ternary alloys of Table 7 were characterized. The results are presented in Figure 28.

Table 7. Alloy chemistries characterized in the present Example.

	Ni (%)	Si (%)	Mg (%)
Alloys	2.0	0.15	0.15
			0.30
			0.60
			1.20
		0.30	0.15
			0.30
			0.60
			1.20
		0.60	0.15
			0.30
			0.60
			1.20
		1.20	0.15
			0.30

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			0.60
			1.20

Lower hot tearing index (HTI) is beneficial while alloys with high HTI will be prone to cracking during solidification. The HTI of the alloys tested varied from 10 to 45. For a magnesium content below 0.6 %, the HTI increased with the increase of silicon content to a maximum value between 0.3 and 0.6 % Si. Higher silicon (around 1.2 %) reduced the HTI. For a magnesium content above 0.6 %, the silicon content had a lesser impact on the HTI.

From Example III, peak strength was obtained for alloys $\text{AlNi}_2\text{Si}_{0.3}\text{Mg}_{0.6}$ and $\text{AlNi}_2\text{Si}_{0.5}\text{Mg}_{0.5}$ where the silicon and magnesium content are around 1 %. The optimal strength and electrical conductivity ratio were obtained with a Mg:Si ratio between 2:1 and 1:1. This ratio is linked to the precipitation of MgSi and Mg_2Si . However, these alloys presented a high hot tearing index. From Figure 28, higher magnesium content was more beneficial to improve the HTI than higher silicon content. For example, for alloy $\text{AlNi}_2\text{Si}_{0.3}\text{Mg}_{0.6}$, the HTI was 30 to 35. By increasing the Mg content to 1.2 %, the HTI reduced drastically to 10-15. An increase in silicon content to 1.2 % would have reduced the HTI to only 25-30.

High magnesium content is therefore preferred for castability. However, magnesium will impact the electrical conductivity of the alloy. Excess magnesium would reduce the electrical conductivity by 5 % IACS ("Properties, Physical Metallurgy, and Phase Diagrams, Vol 1, Aluminium", Van Horn, K. R., e.d., (American Society for Metals:1967), p.174). Chemistry optimization must be done to obtain good castings while maintaining good electrical conductivity. These optimizations are done depending on the casting's morphology.

While the invention has been described in connection with specific embodiments thereof, it will be understood that the scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

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WHAT IS CLAIMED IS:

1. A foundry alloy comprising, in weight percent:
 - Ni between about 1.5 and about 6.5;
 - Si between about 0.10 and 1.5;
 - Mg between about 0.10 and about 3;
 - Fe up to about 0.2;
 - Mn up to about 0.65;
 - Ti up to about 0.12;
 - V up to about 0.15;
 - Zr up to about 0.15;
 - Mo up to about 0.15;
 - Cr up to about 0.01;
 - Sr up to about 0.02; and
 the balance being aluminum and unavoidable impurities.
2. The foundry alloy of claim 1 comprising more than about 2.0 Ni.
3. The foundry alloy of claim 1 or 2 comprising between about 2.5 and about 6.5 Ni.
4. The foundry alloy of claim 1 comprising between about 1.8 and about 3.0 Ni.
5. The foundry alloy of any one of claims 1 to 4 comprising between 0.15 and 0.90 Si.
6. The foundry alloy of any one of claims 1 to 5 comprising between 0.3 and 0.75 Si.
7. The foundry alloy of any one of claims 1 to 6 comprising Mg at a weight percentage as determined by formula (I):

$$\%Mg \leq -1.218 \cdot \ln(\%Si) + 0.89 \quad (I)$$
 wherein %Mg is the weight percent of Mg; and
 %Si is the weight percent of Si.
8. The foundry alloy of any one of claims 1 to 7 comprising between about 0.15 and about 1.8 Mg.
9. The foundry alloy of any one of claims 1 to 8 comprising between about 0.30 and about 1.0 Mg.

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10. The foundry alloy of any one of claims 1 to 9 comprising up to about 0.10 Fe.
11. The foundry alloy of any one of claims 1 to 10 comprising between about 0.45 and about 0.65 Mn.
12. The foundry alloy of any one of claims 1 to 10 comprising up to about 0.01 Mn.
13. The foundry alloy of any one of claims 1 to 12 comprising between about 0.02 and about 0.12 Ti.
14. The foundry alloy of any one of 1 to 12 comprising up to about 0.01 Ti.
15. The foundry alloy of any one of claims 1 to 14 comprising between about 0.01 and about 0.15 V.
16. The foundry alloy of any one of claims 1 to 14 comprising up to about 0.01 V.
17. The foundry alloy of any one of claims 1 to 16 comprising between about 0.01 and about 0.15 Zr.
18. The foundry alloy of any one of claims 1 to 16 comprising up to about 0.01 Zr.
19. The foundry alloy of any one of claims 1 to 18 comprising between about 0.01 and about 0.15 Mo.
20. The foundry alloy of any one of claims 1 to 18 comprising up to about 0.01 Mo.
21. The foundry alloy of any one of claims 1 to 20 comprising between about 0.005 and about 0.02 Sr.
22. The foundry alloy of any one of claims 1 to 21, comprising Mn, Cr, Ti and V at a weight percentage as determined by formula (II):

$$\% \text{Mn} + \% \text{Cr} + \% \text{Ti} + \% \text{V} \leq 0.025 \text{ (II)}$$

wherein %Mn is the weight percent of Mn;

%Cr is the weight percent of Cr;

%Ti is the weight percent of Ti; and

%V is the weight percent of V.

23. The foundry alloy of any one of claims 1 to 22, comprising an excess of Mg over a weight percent ratio of Mg:Si of more than about 2:1.
24. A process for improving at least one casting property of a first aluminum alloy for making a first aluminum product when compared to a cast aluminum alloy for making a cast aluminum product, the process comprising combining Ni with the first

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aluminum alloy to provide the cast aluminum alloy, wherein the first aluminum alloy comprises, in weight percent:

Si between about 0.10 and 1.5;

Mg between about 0.10 and about 3;

Fe up to about 0.2;

Mn up to about 0.65;

Ti up to about 0.12;

V up to about 0.15;

Zr up to about 0.15;

Mo up to about 0.15;

Cr up to about 0.01;

Sr up to about 0.02; and

the balance being aluminum and unavoidable impurities; wherein the modified aluminum alloy comprises between about 1.5 and about 6.5 Ni.

25. The process of claim 24, wherein the at least one casting property is an increase in fluidity during casting.
26. The process of claim 24 or 25, wherein the casting property is a reduction in hot tearing or an increase in die soldering resistance during high-pressure vacuum die casting.
27. The process of any one of claims 24 to 26, wherein the modified aluminum alloy comprises at least about 2.0 Ni.
28. The process of any one of claims 24 to 27, wherein the modified aluminum alloy comprises between about 2.5 and about 6.5 Ni.
29. The process of any one of claims 24 to 26, wherein the modified aluminum alloy comprises between about 1.8 and about 3.0 Ni.
30. The process of any one of claims 24 to 29, wherein the first aluminum alloy comprises between 0.15 and 0.90 Si.
31. The process of any one of claims 24 to 30, wherein the first aluminum alloy comprises between 0.3 and 0.75 Si.

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32. The process of any one of claims 24 to 31, wherein the first aluminum alloy comprises Mg at a weight percentage as determined by formula (I):

$$\%Mg \leq -1.218 \cdot \ln(\%Si) + 0.89 \text{ (I)}$$

wherein %Mg is the weight percent of Mg; and

%Si is the weight percent of Si.

33. The process of any one of claims 24 to 32, wherein the first aluminum alloy comprises between about 0.15 and about 1.8 Mg.
34. The process of any one of claims 24 to 33, wherein the first aluminum alloy comprises between about 0.30 and about 1.0 Mg.
35. The process of any one of claims 24 to 34, wherein the first aluminum alloy comprises up to about 0.10 Fe.
36. The process of any one of claims 24 to 35, wherein the first aluminum alloy comprises between about 0.45 and about 0.65 Mn.
37. The process of any one of claims 24 to 36, wherein the first aluminum alloy comprises up to about 0.01 Mn.
38. The process of any one of claims 24 to 37, wherein the first aluminum alloy comprises between about 0.02 and about 0.12 Ti.
39. The process of any one of claims 24 to 37, wherein the first aluminum alloy comprises between up to about 0.01 Ti.
40. The process of any one of claims 24 to 39, wherein the first aluminum alloy comprises between about 0.01 and about 0.15 V.
41. The process of any one of claims 24 to 39, wherein the first aluminum alloy comprises up to about 0.01 V.
42. The process of any one of claims 24 to 41, wherein the first aluminum alloy comprises between about 0.01 and about 0.15 Zr.
43. The process of any one of claims 24 to 41, wherein the first aluminum alloy comprises up to about 0.01 Zr.
44. The process of any one of claims 24 to 43, wherein the first aluminum alloy comprises between about 0.01 and about 0.15 Mo.
45. The process of any one of claims 24 to 43, wherein the first aluminum alloy comprises up to about 0.01 Mo.

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46. The process of any one of claims 24 to 45, wherein the first aluminum alloy comprises between about 0.005 and about 0.02 Sr.
47. The process of any one of claims 24 to 46, wherein the first aluminum alloy comprises Mn, Cr, Ti and V at a weight percentage as determined by formula (II):

$$\% \text{Mn} + \% \text{Cr} + \% \text{Ti} + \% \text{V} \leq 0.025 \text{ (II)}$$

wherein %Mn is the weight percent of Mn;
 %Cr is the weight percent of Cr;
 %Ti is the weight percent of Ti; and
 %V is the weight percent of V.

48. The process of any one of claims 24 to 47, wherein the modified aluminum alloy comprises an excess of Mg over a weight percent ratio of Mg:Si of more than about 2:1.
49. A modified cast aluminum alloy made from the process of any one of claims 24 to 48.
50. A process for making a cast aluminum product, the process comprising casting the cast aluminum alloy of any one of claims 1 to 23 or the modified cast aluminum alloy of claim 49 in a mold.
51. The process of claim 50, further comprising submitting the cast aluminum alloy or the modified cast aluminum alloy to high-pressure vacuum die casting.
52. The process of claim 50 or 51, further comprising a post-cast heat treatment step.
53. The process of claim 52, wherein the post-cast heat treatment is a T6 temper.
54. The process of claim 52, wherein the post-cast heat treatment is a T5 temper.
55. A cast aluminum product comprising the cast aluminum alloy of any one of claims 1 to 22 or the modified cast aluminum alloy of claim 49.
56. A cast aluminum product made by the process of any one of claims 24 to 54.
57. The cast aluminum product of claim 55 or 56 being electrically conductive.
58. The cast aluminum product of any one of claims 55 to 57 being a rotor.

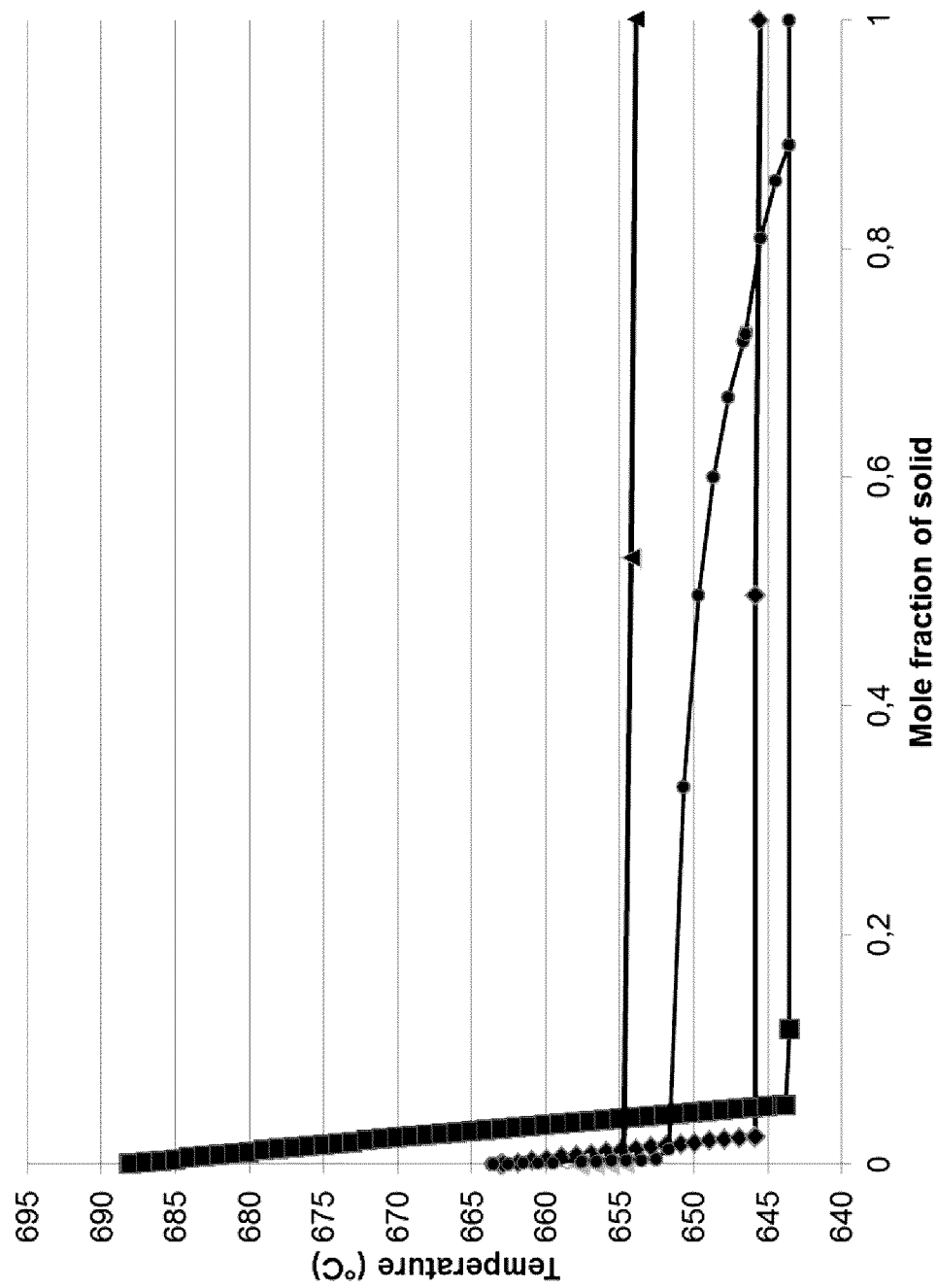


FIG. 1

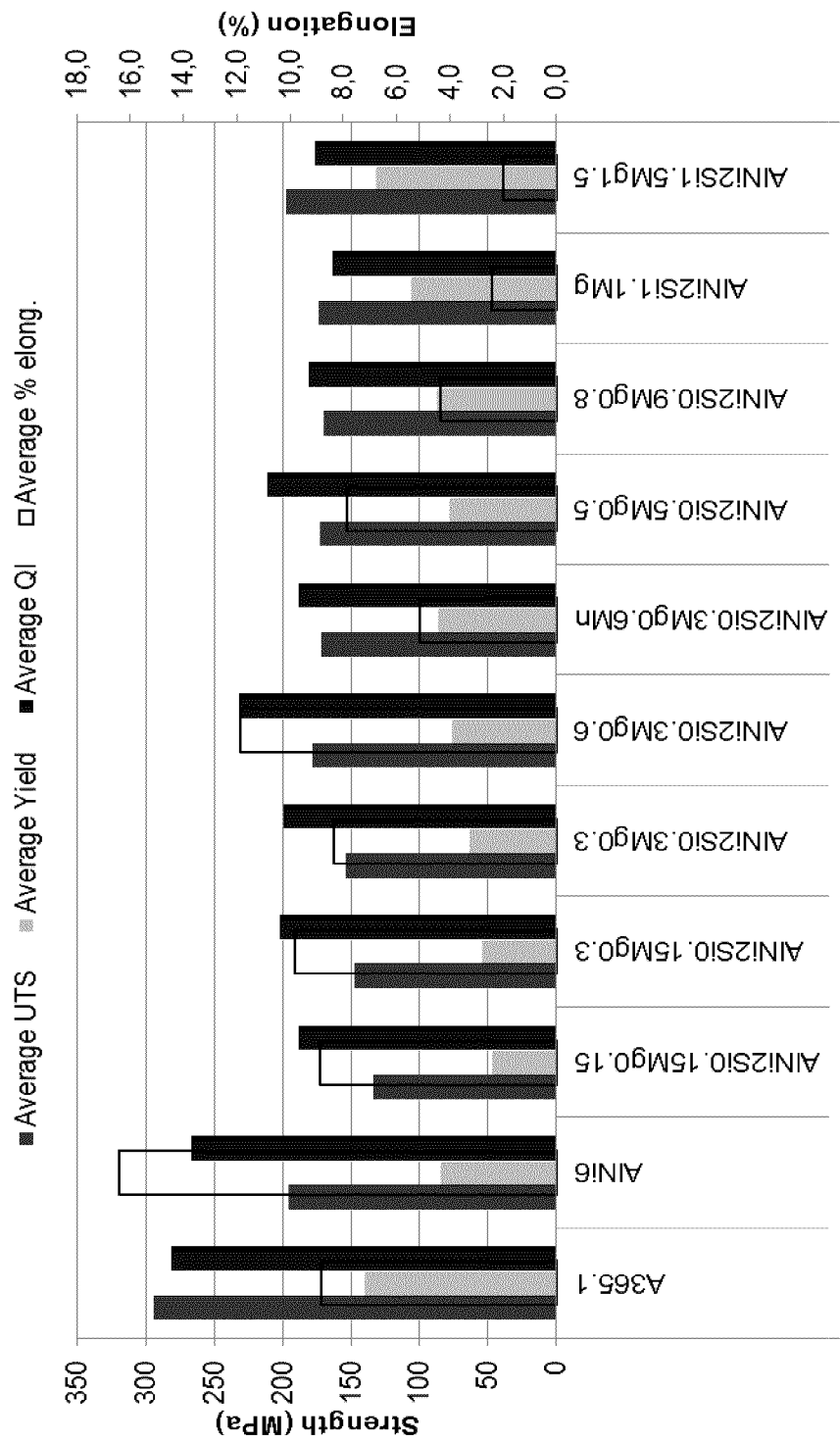


FIG. 2

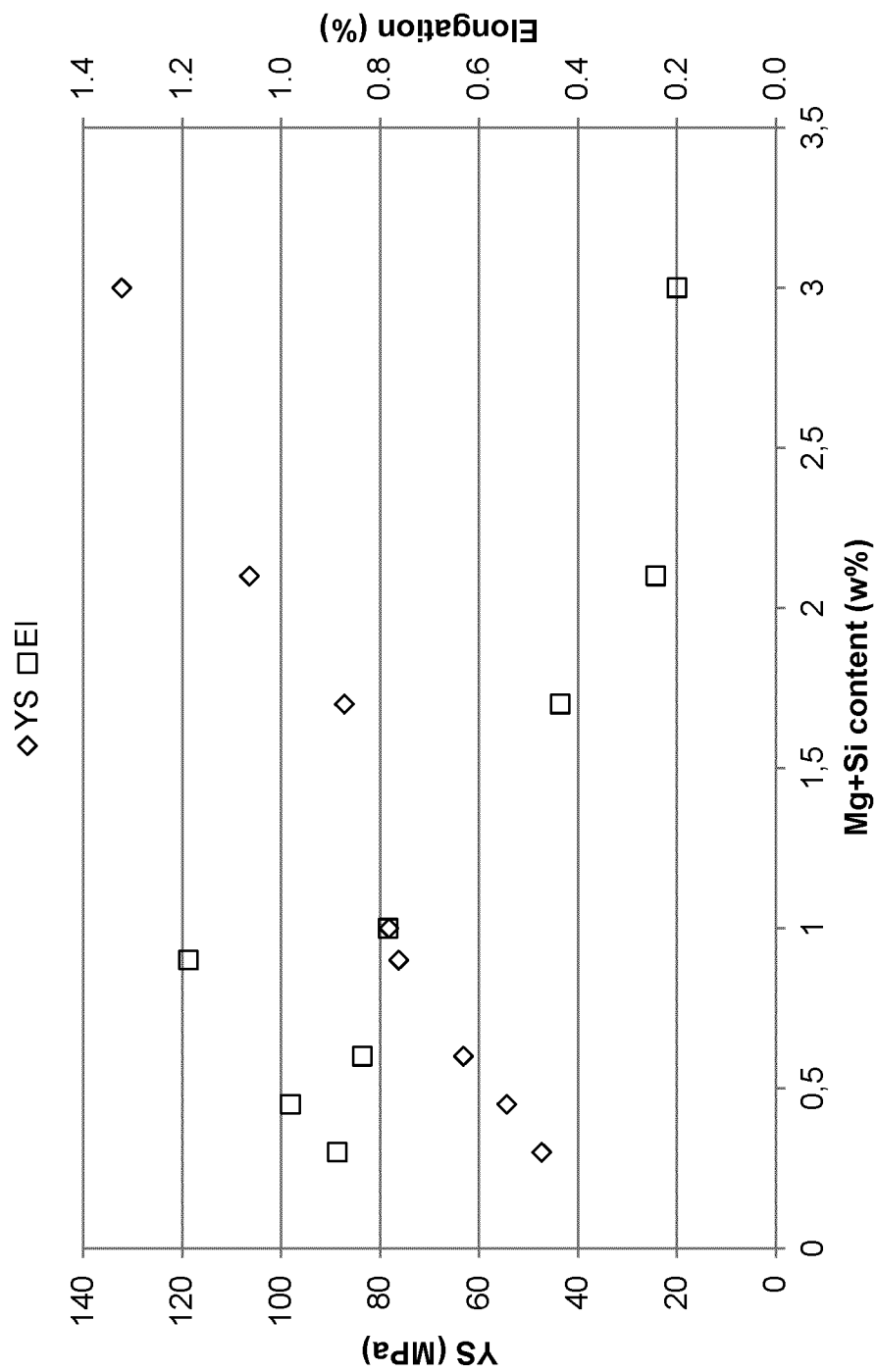


FIG. 3

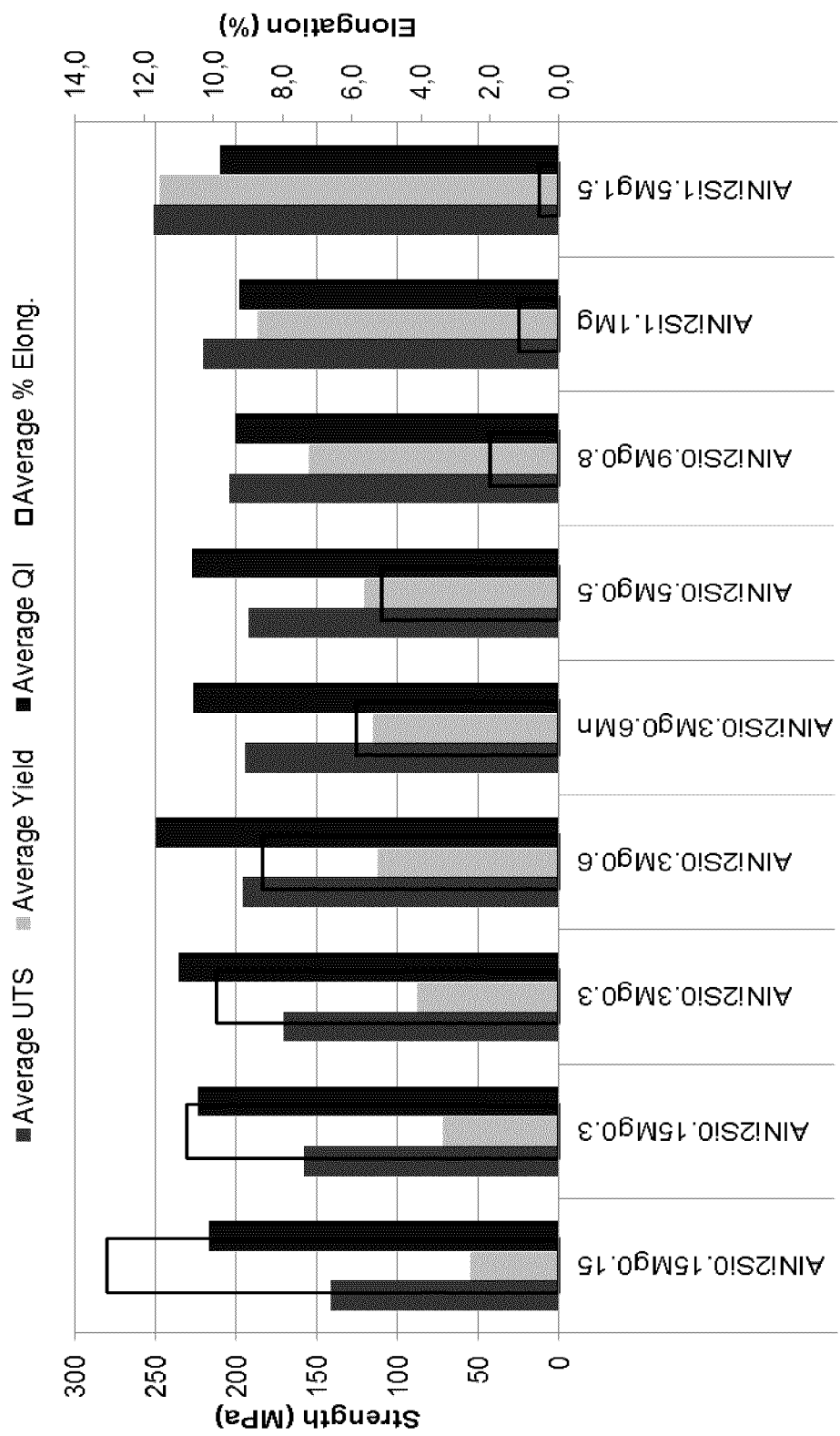


FIG. 4

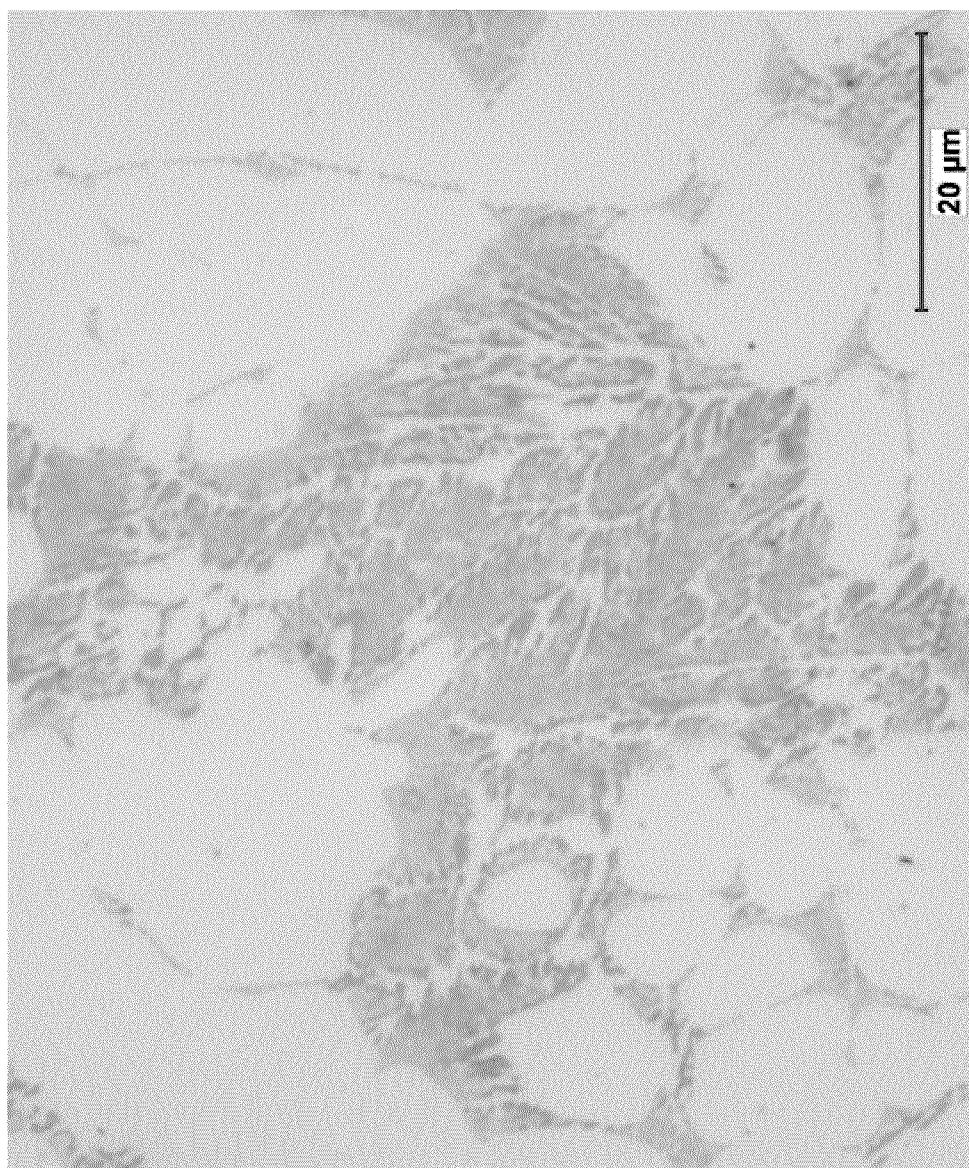


FIG. 5

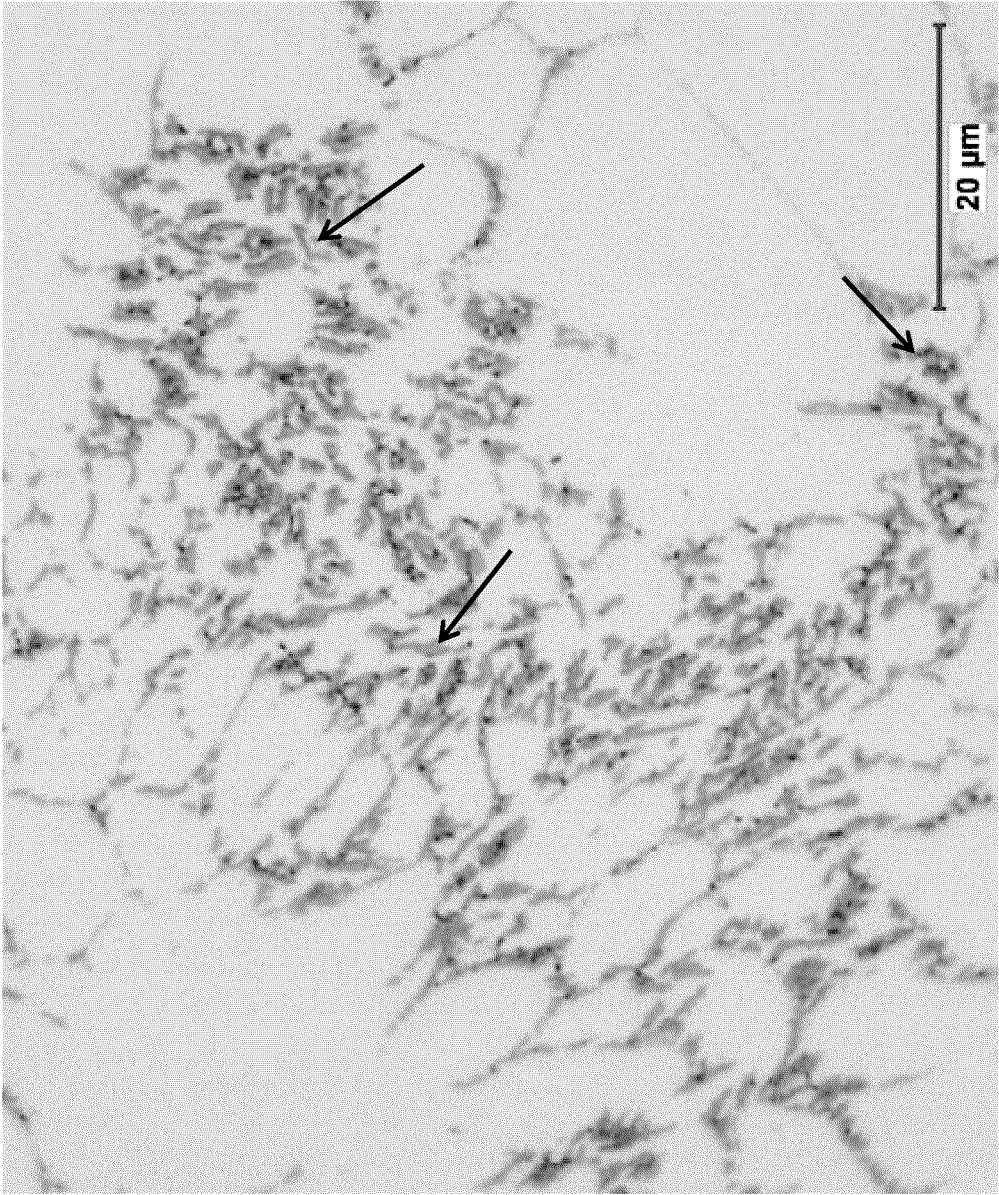


FIG. 6

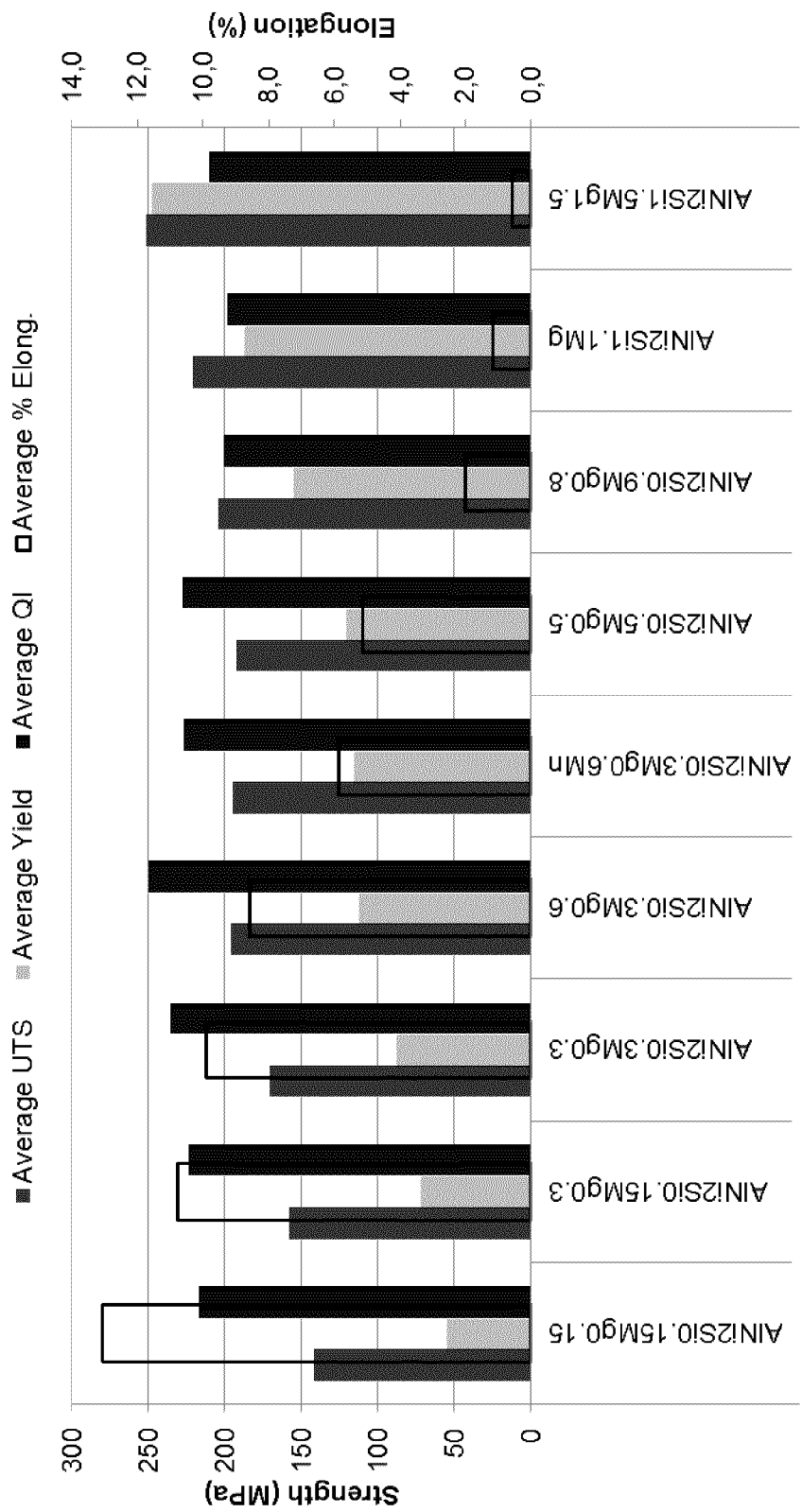


FIG. 7

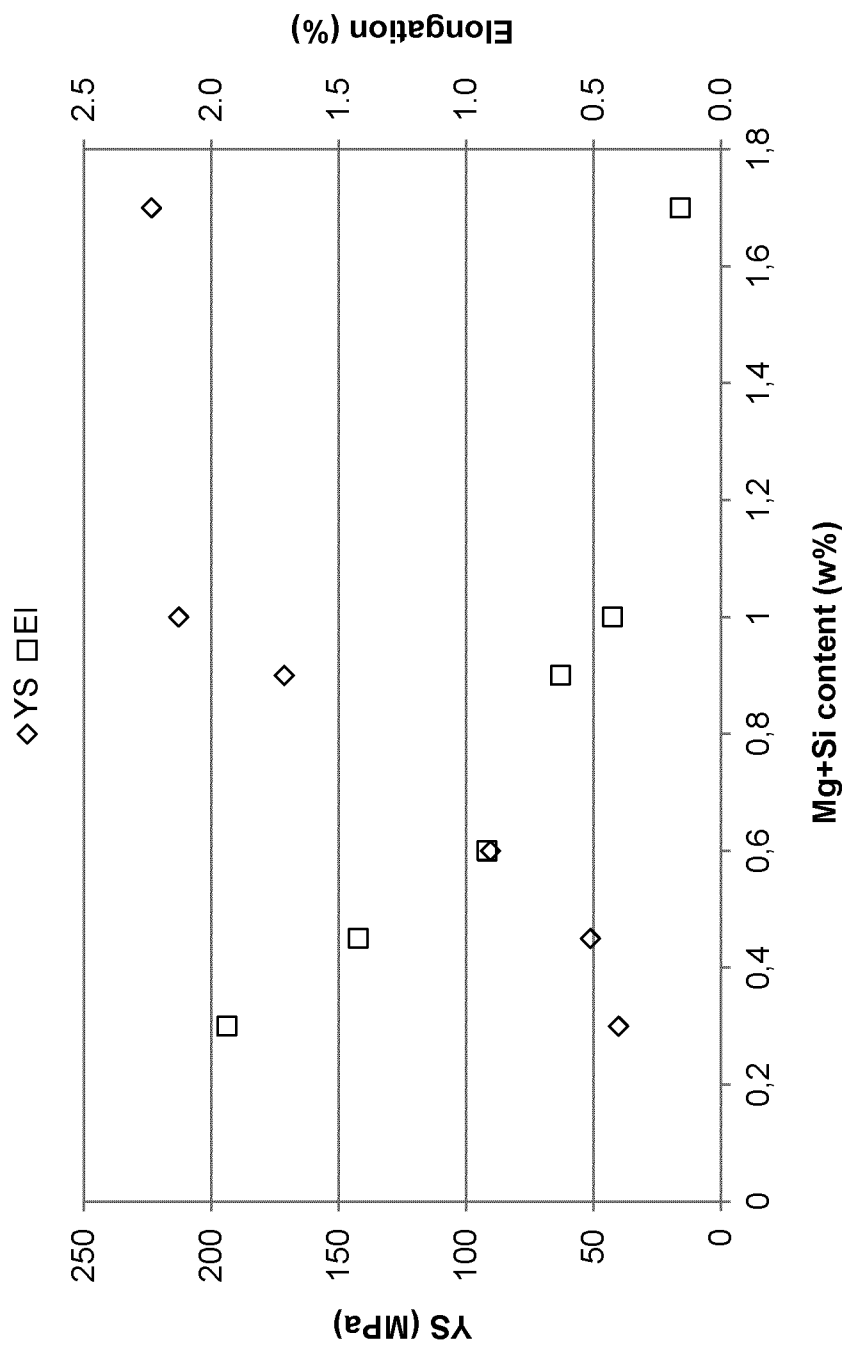


FIG. 8

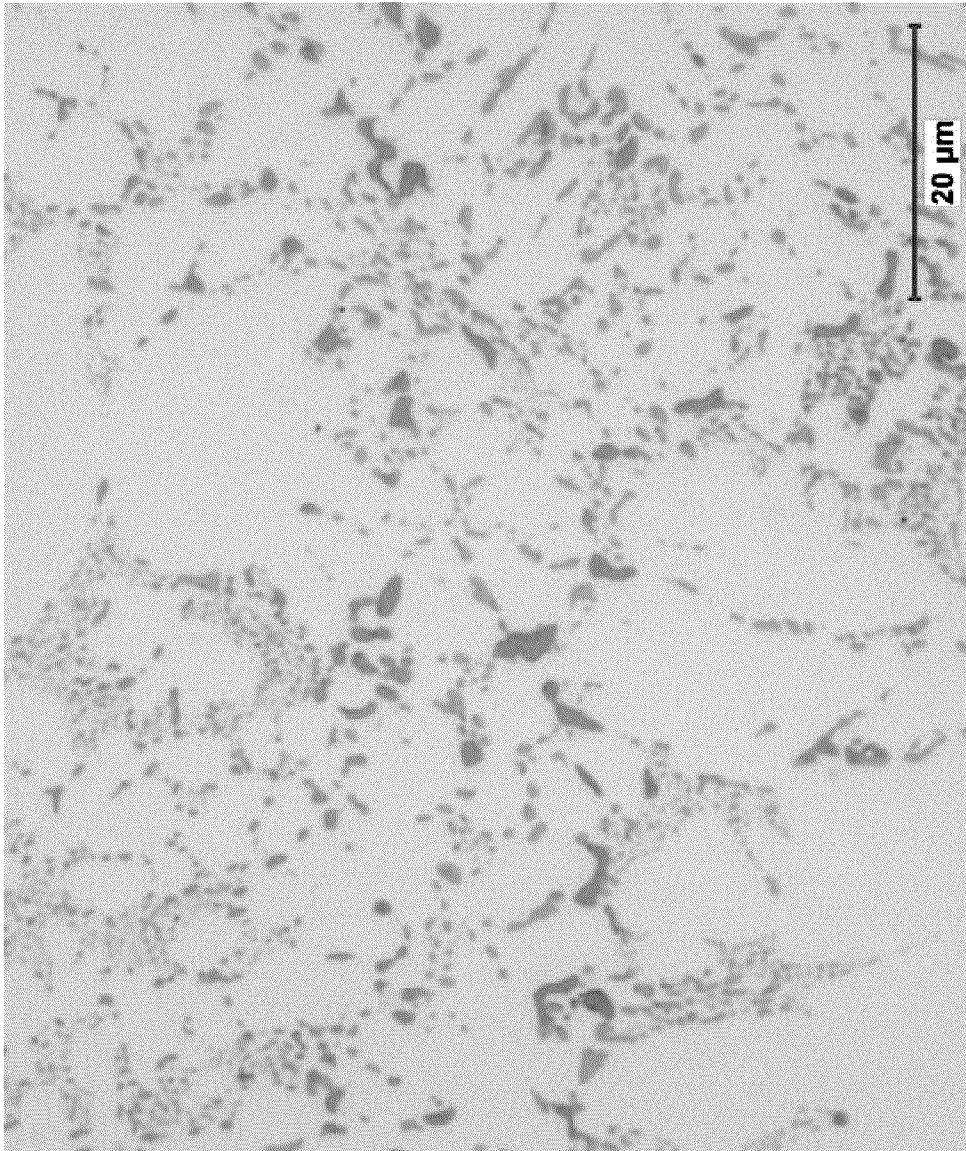


FIG. 9

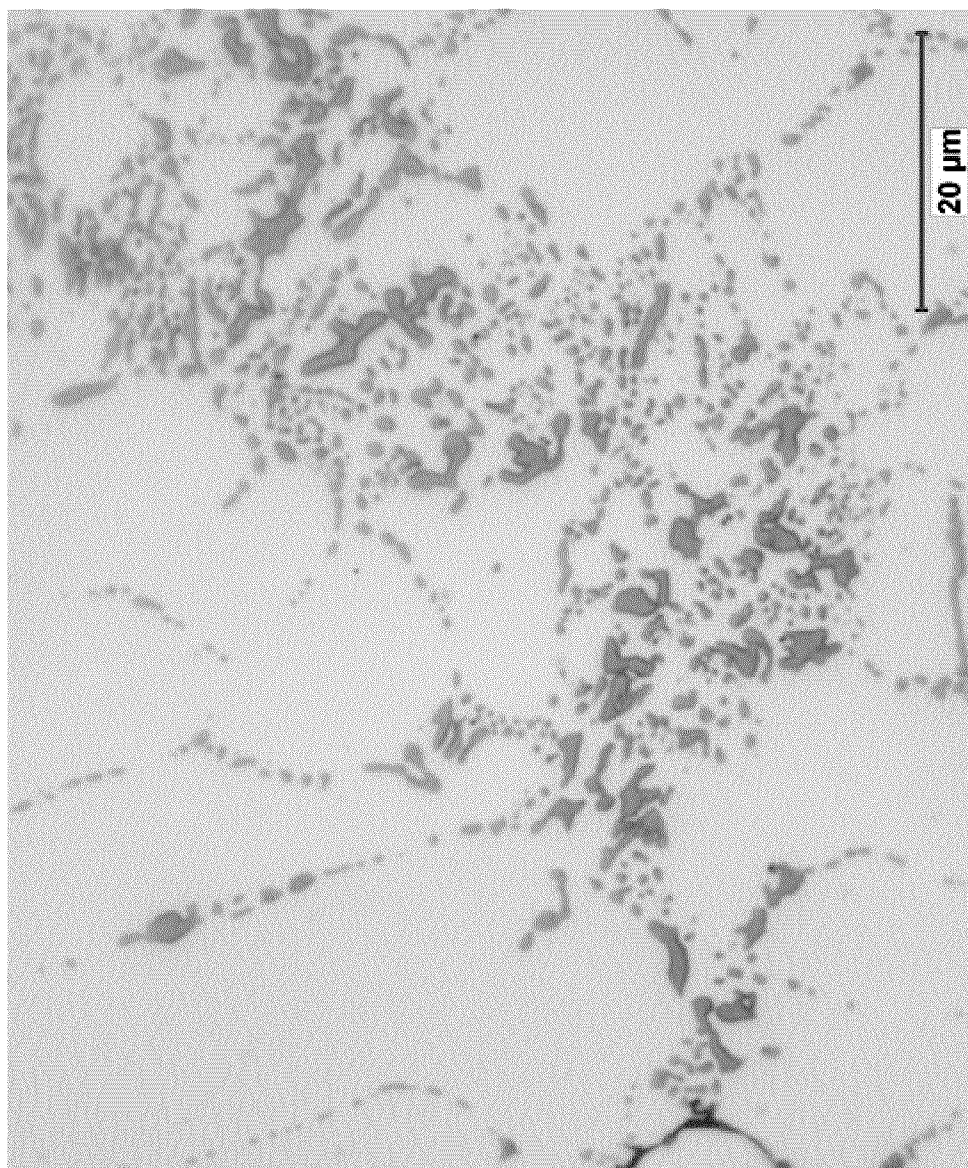


FIG. 10

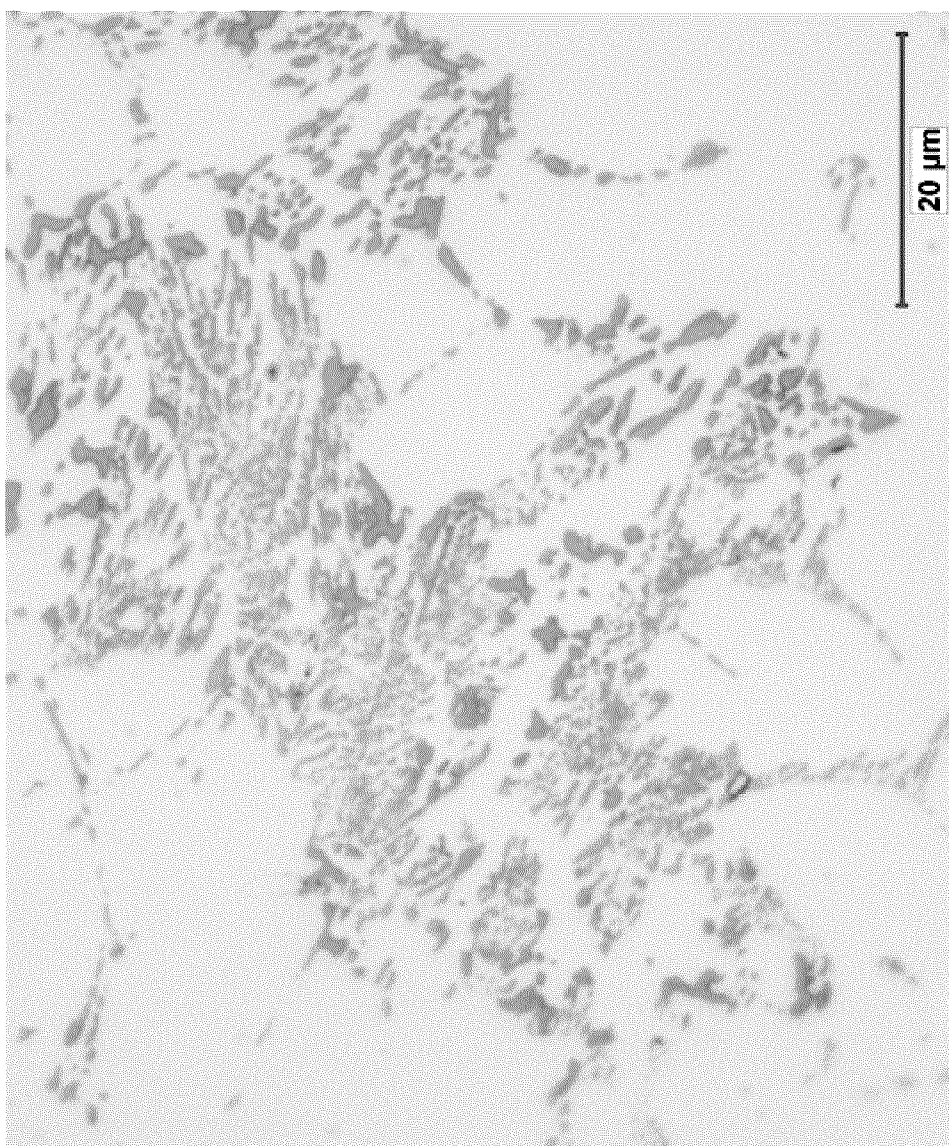


FIG. 11

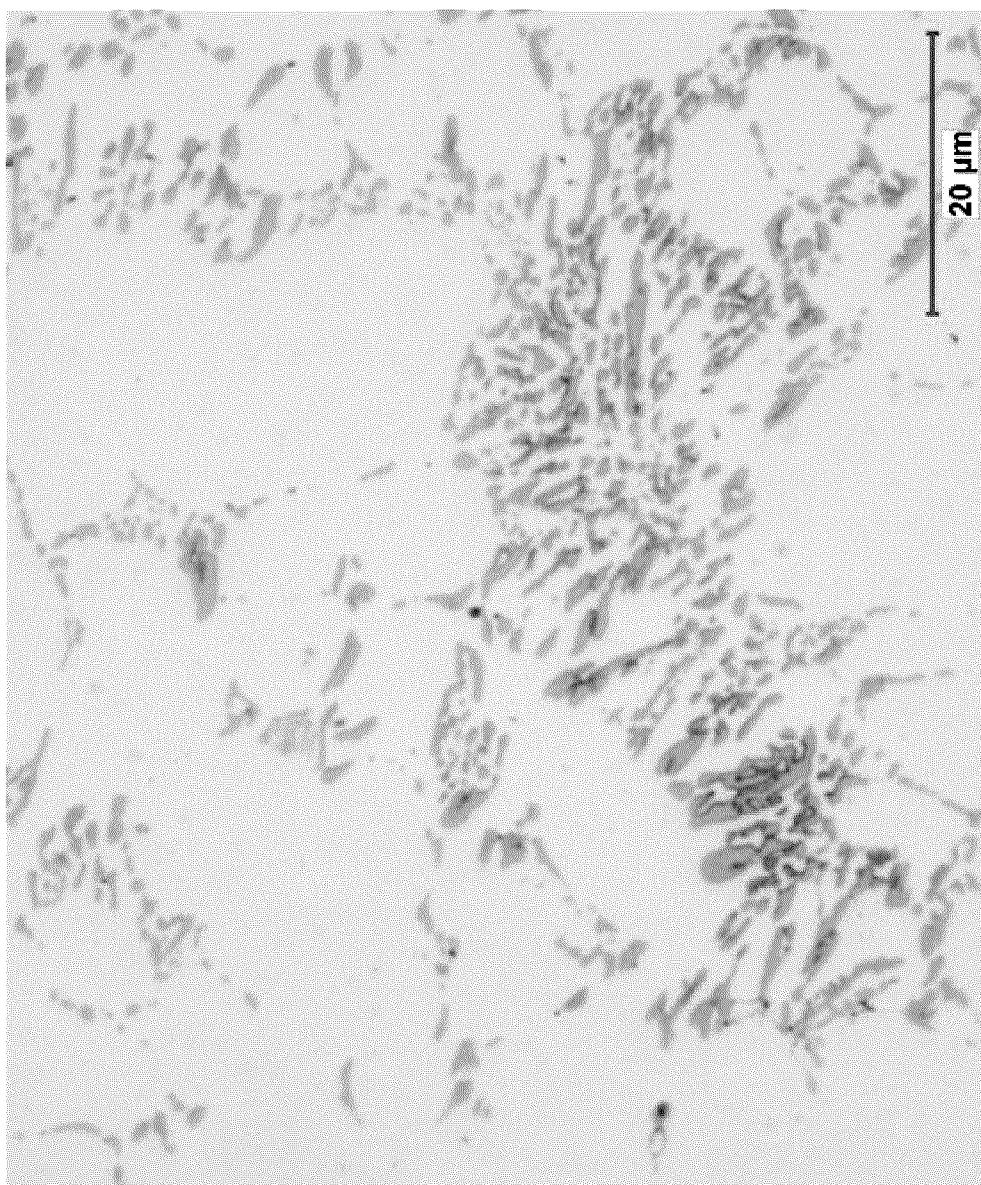


FIG. 12

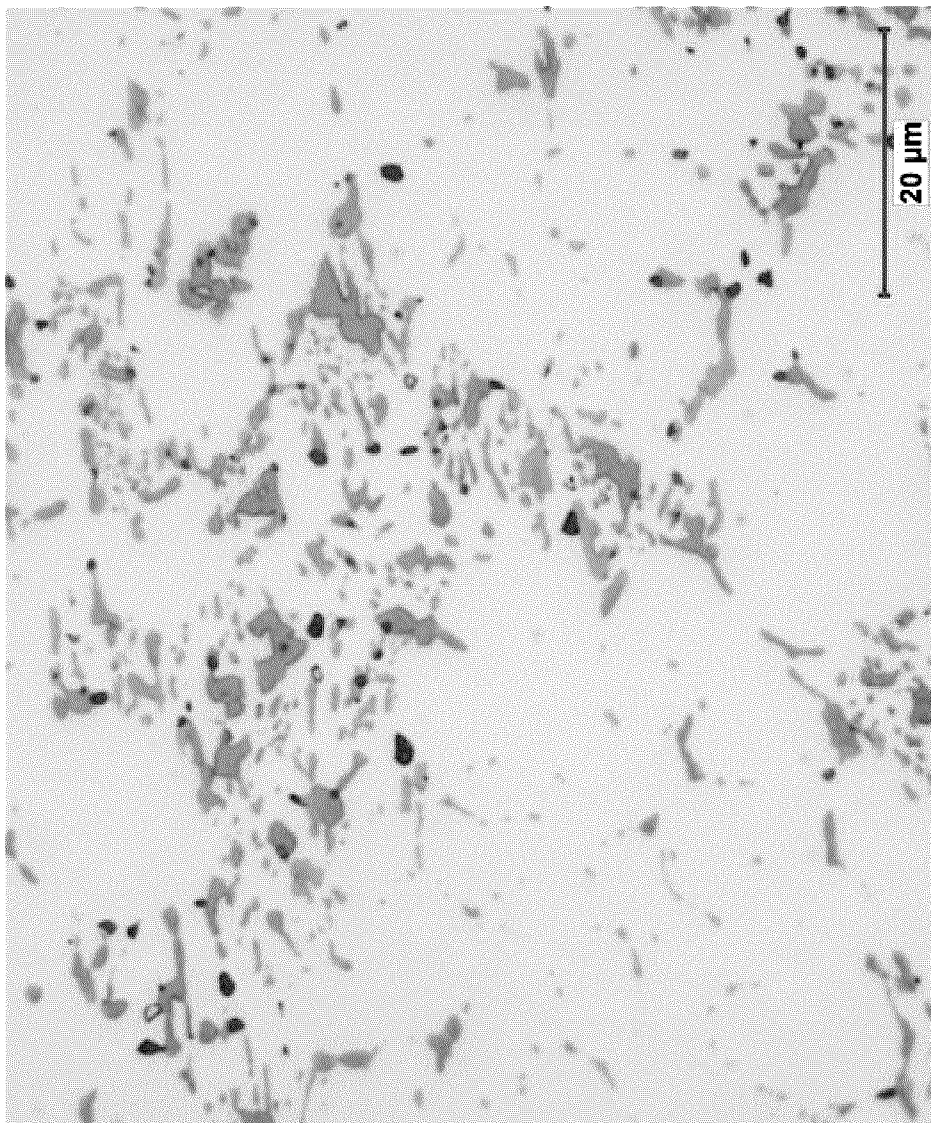


FIG. 13

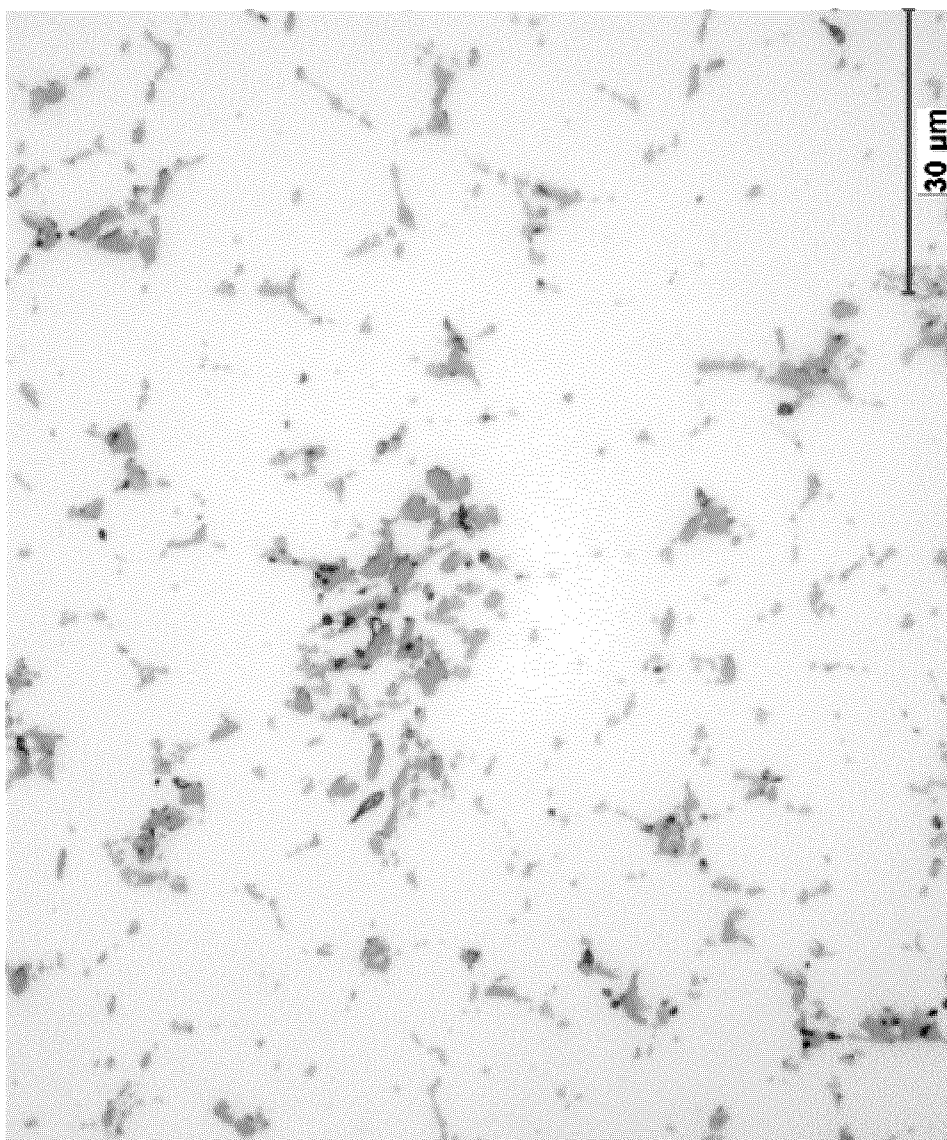


FIG. 14

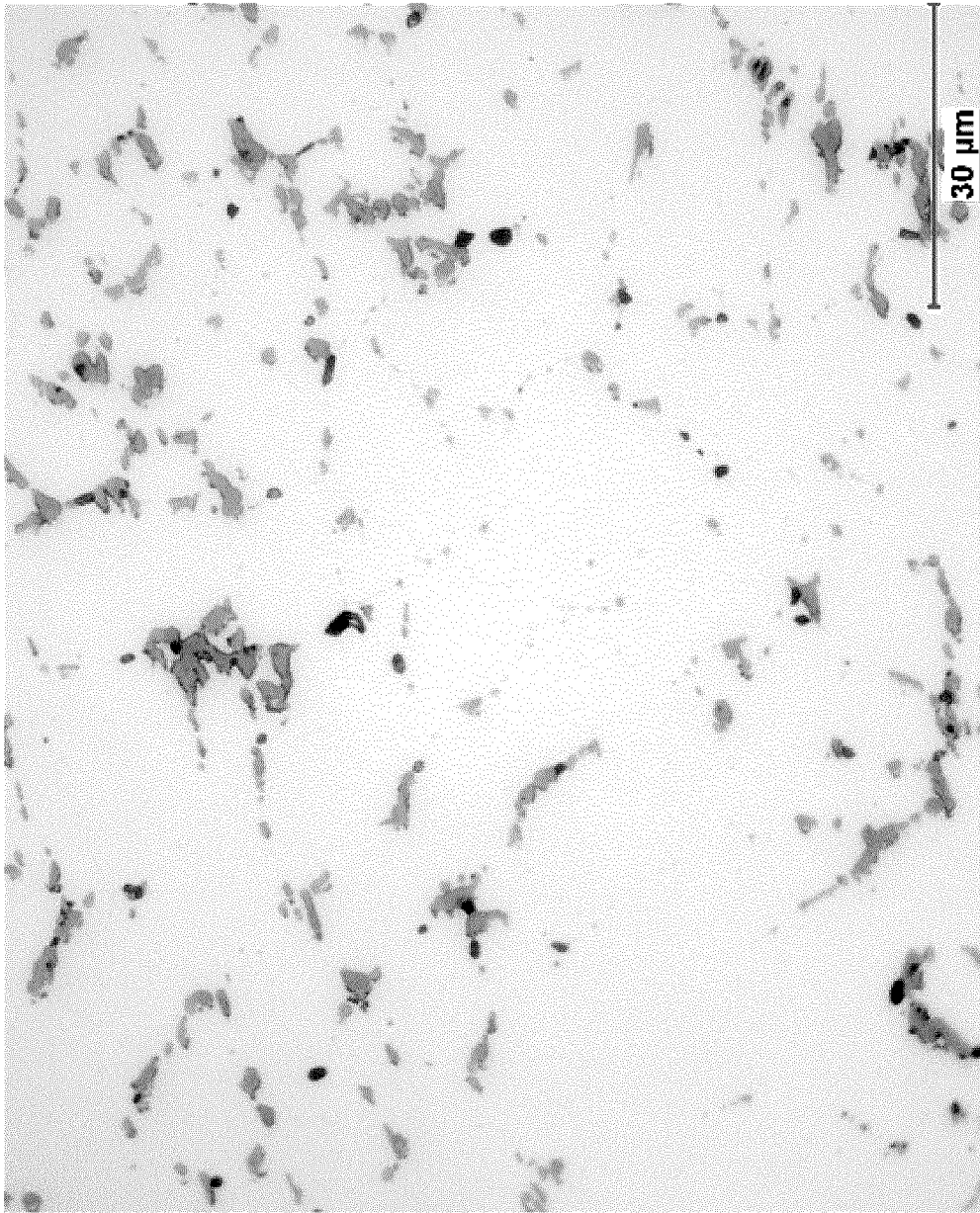


FIG. 15

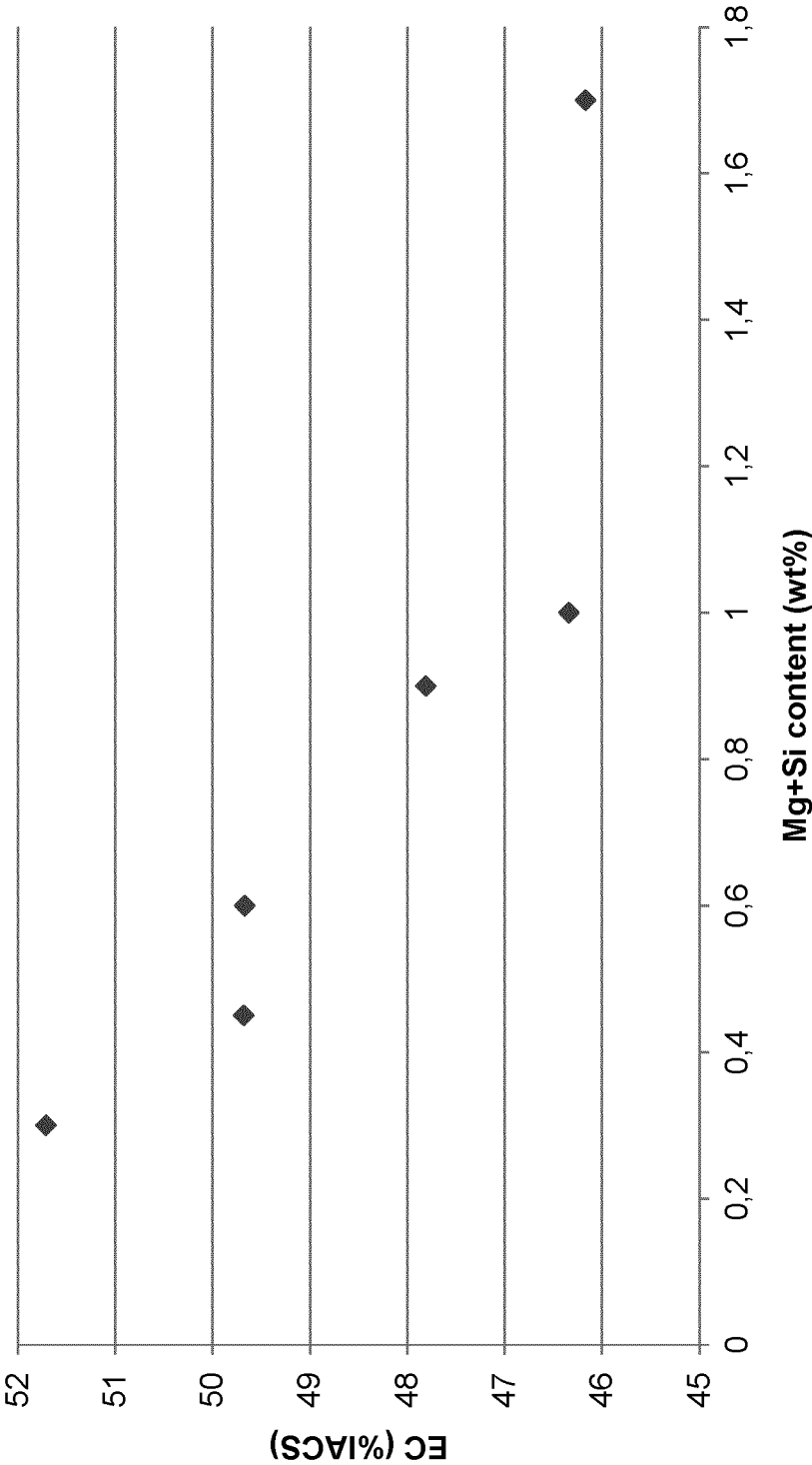


FIG. 16

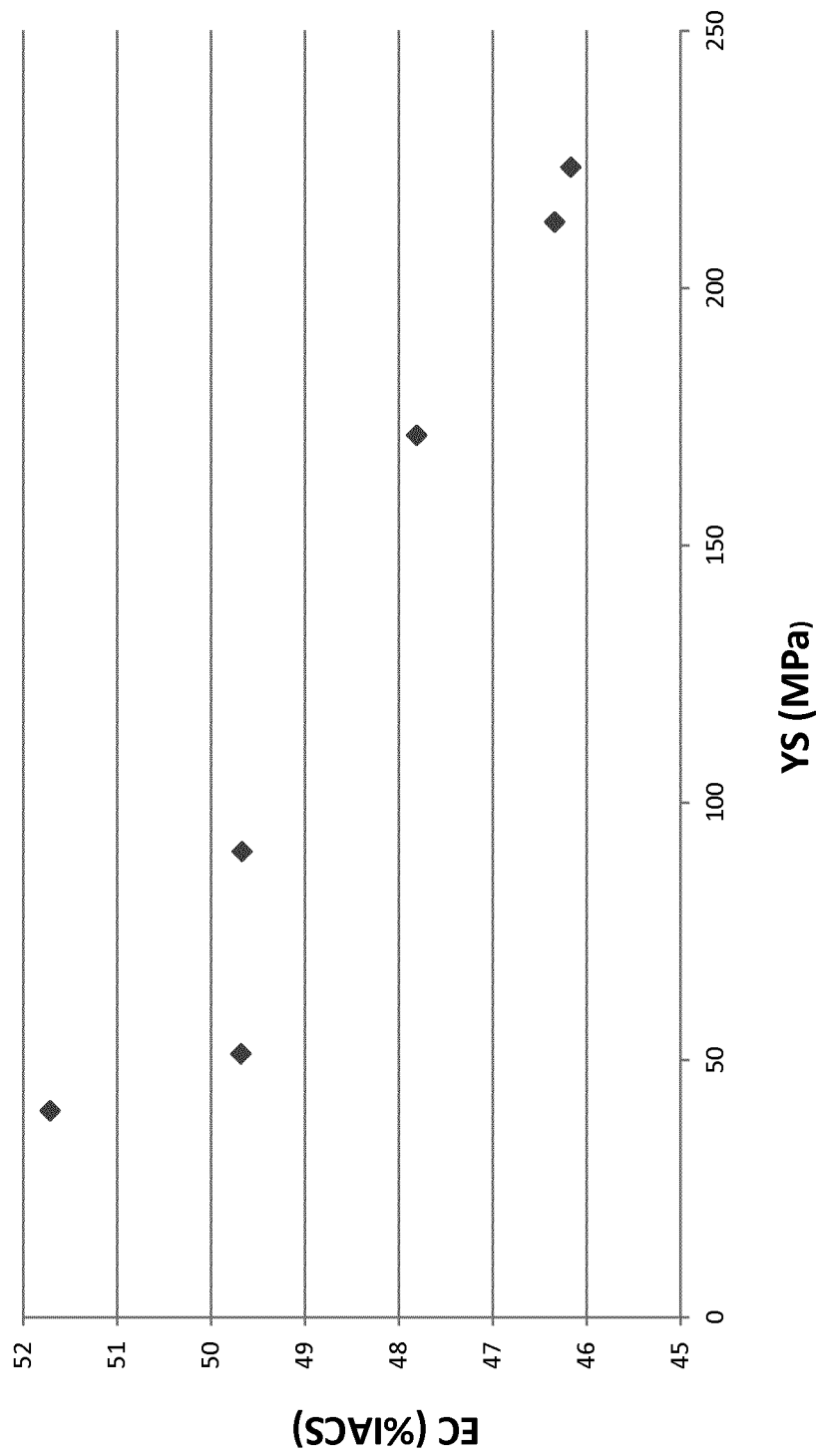


FIG. 17

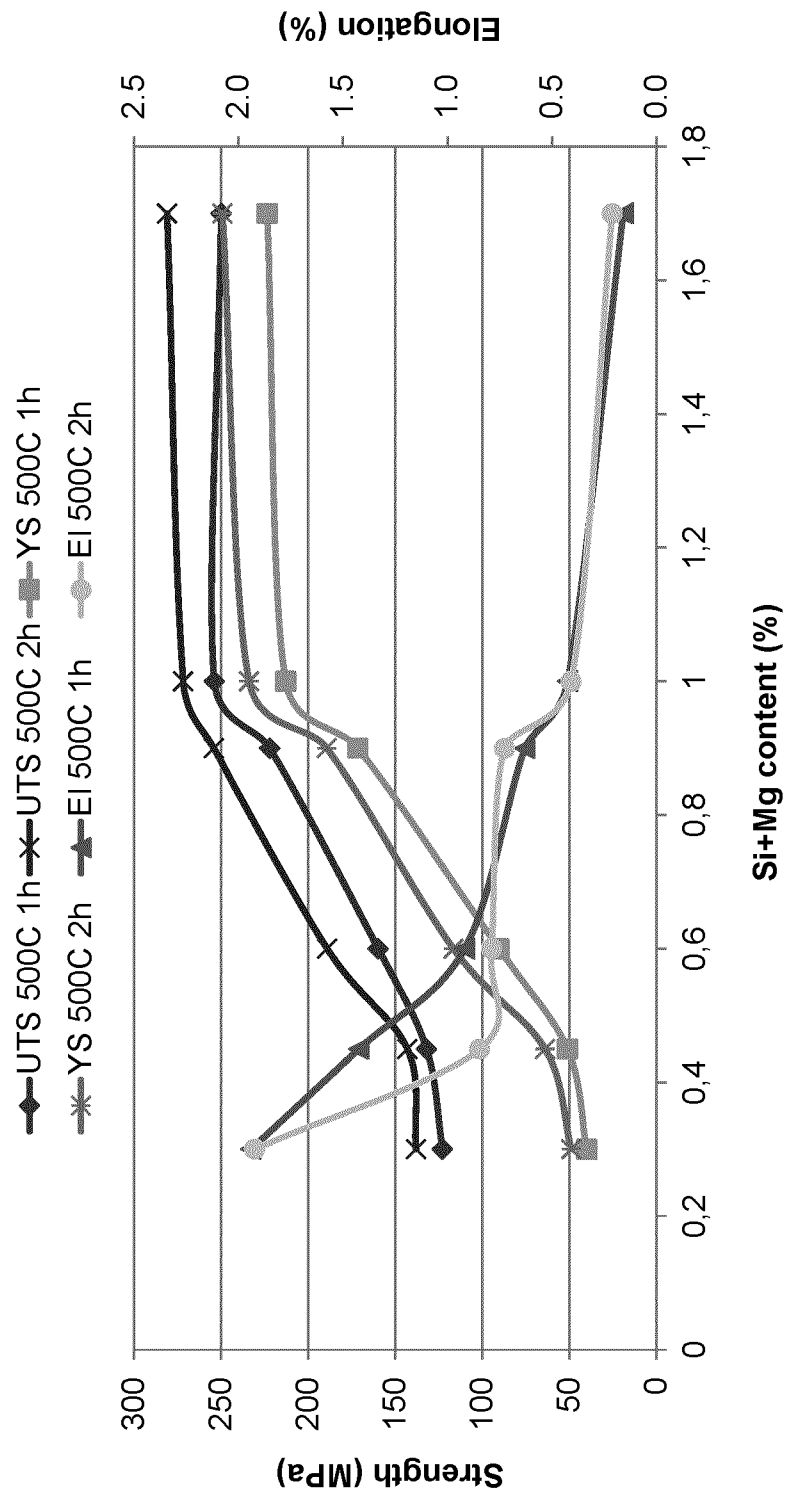


FIG. 19

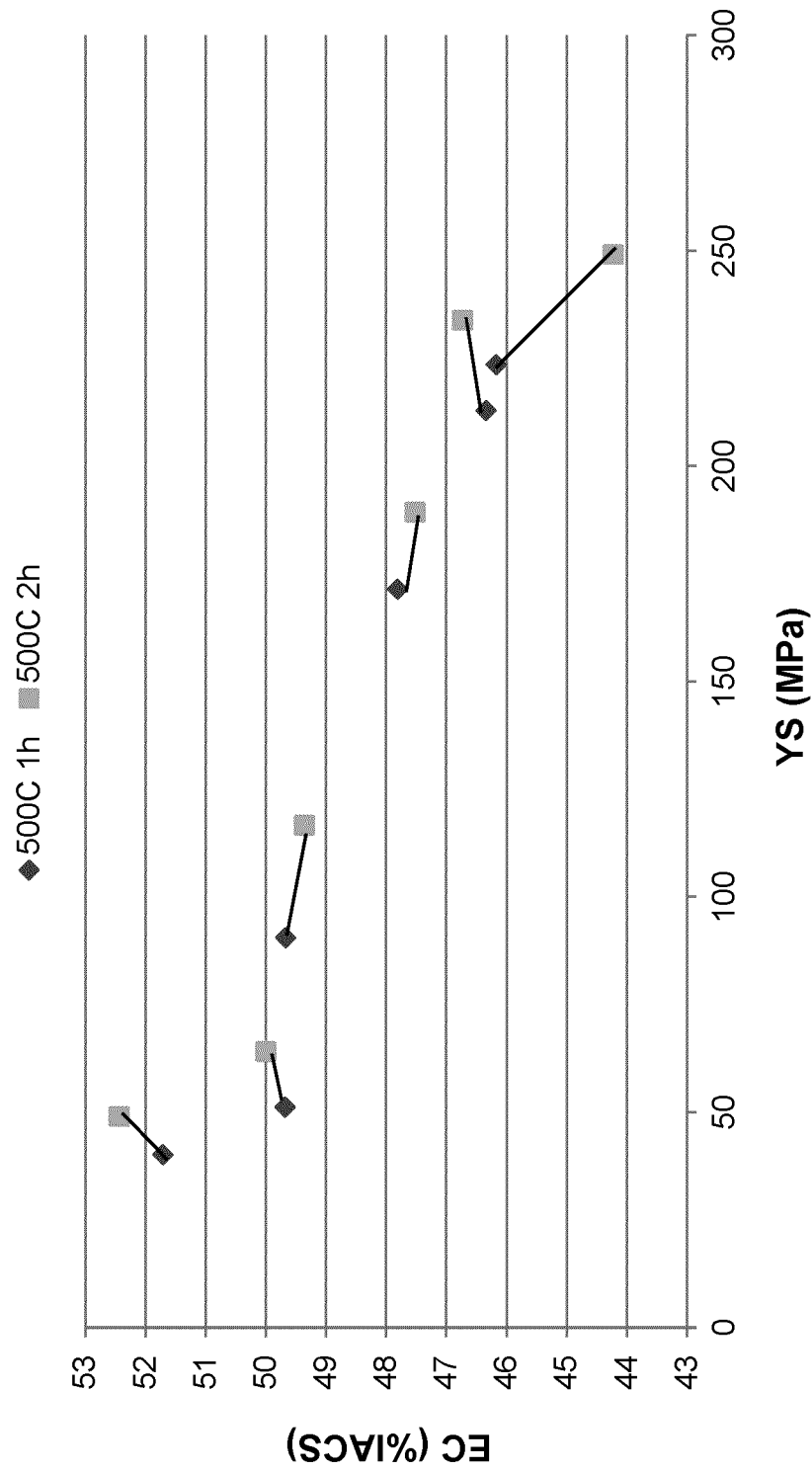


FIG. 20

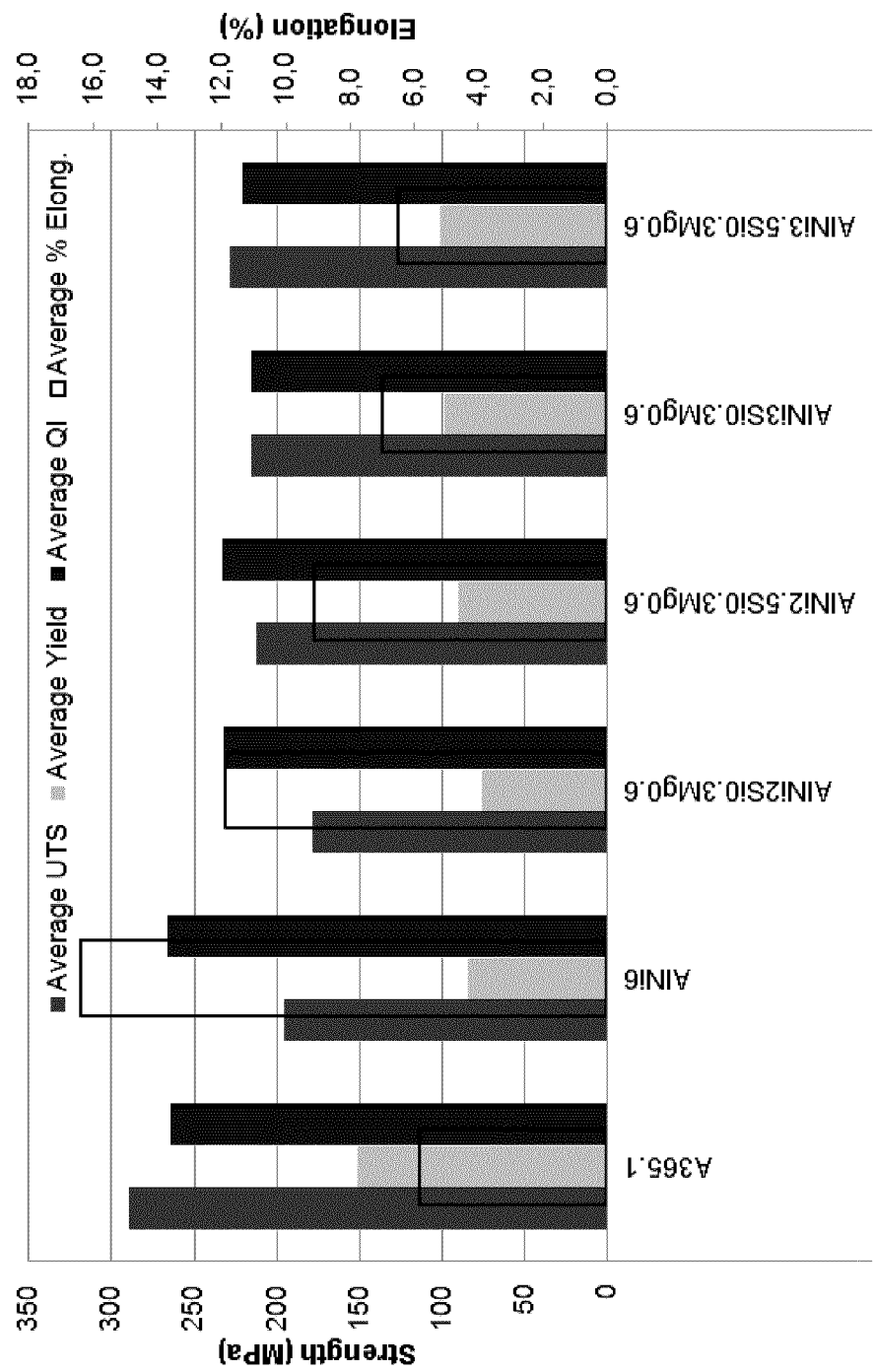


FIG. 21

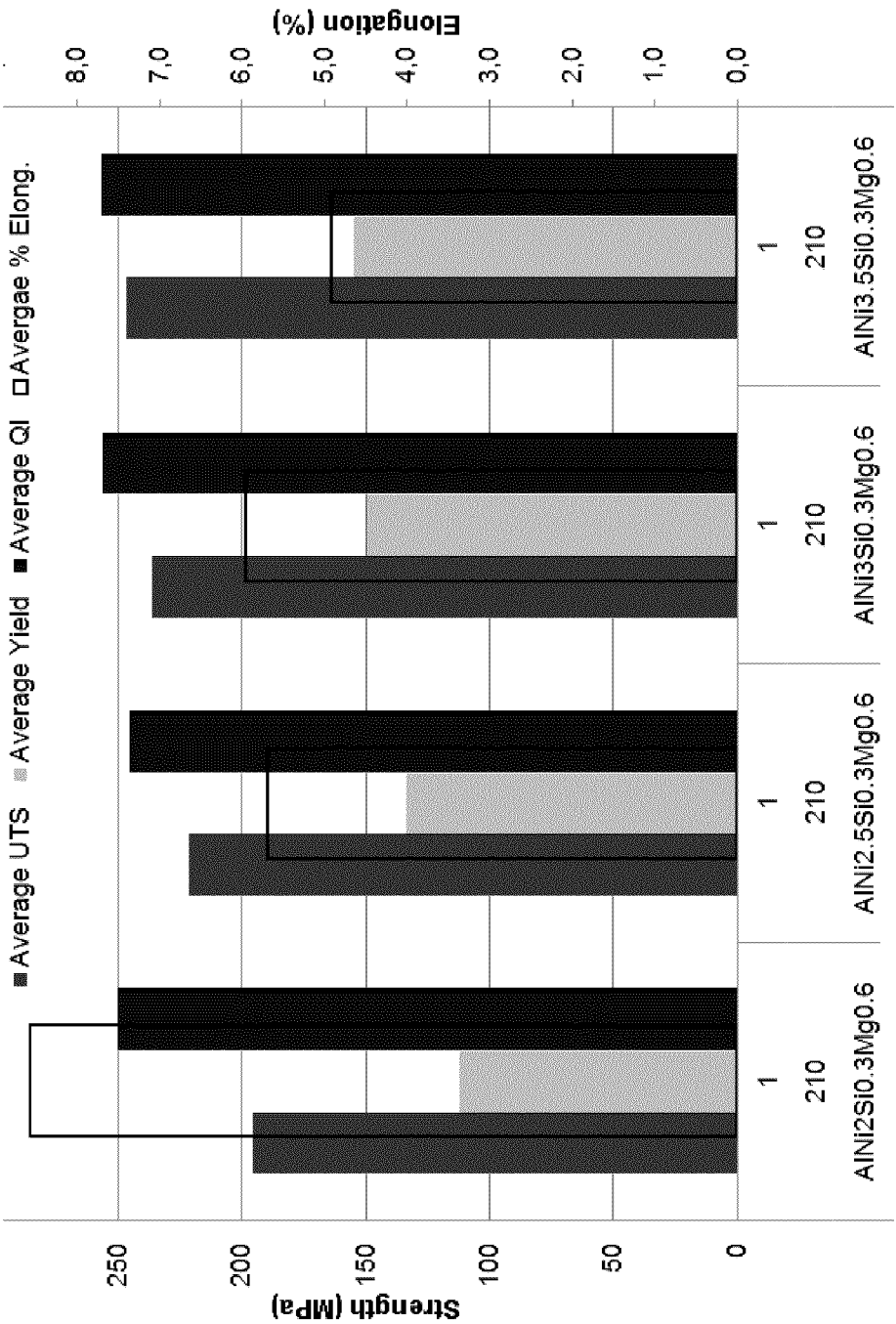


FIG. 22

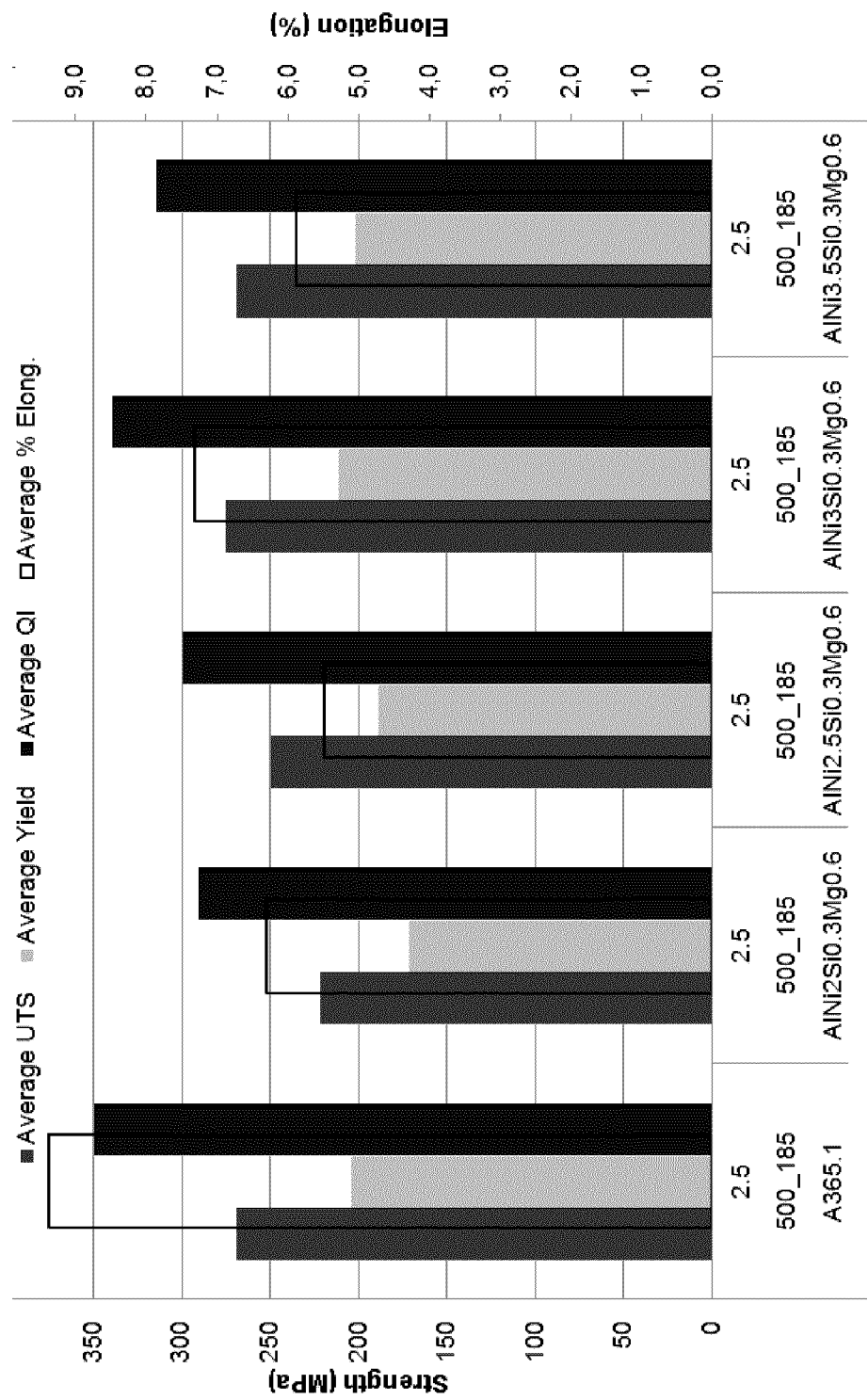


FIG. 23

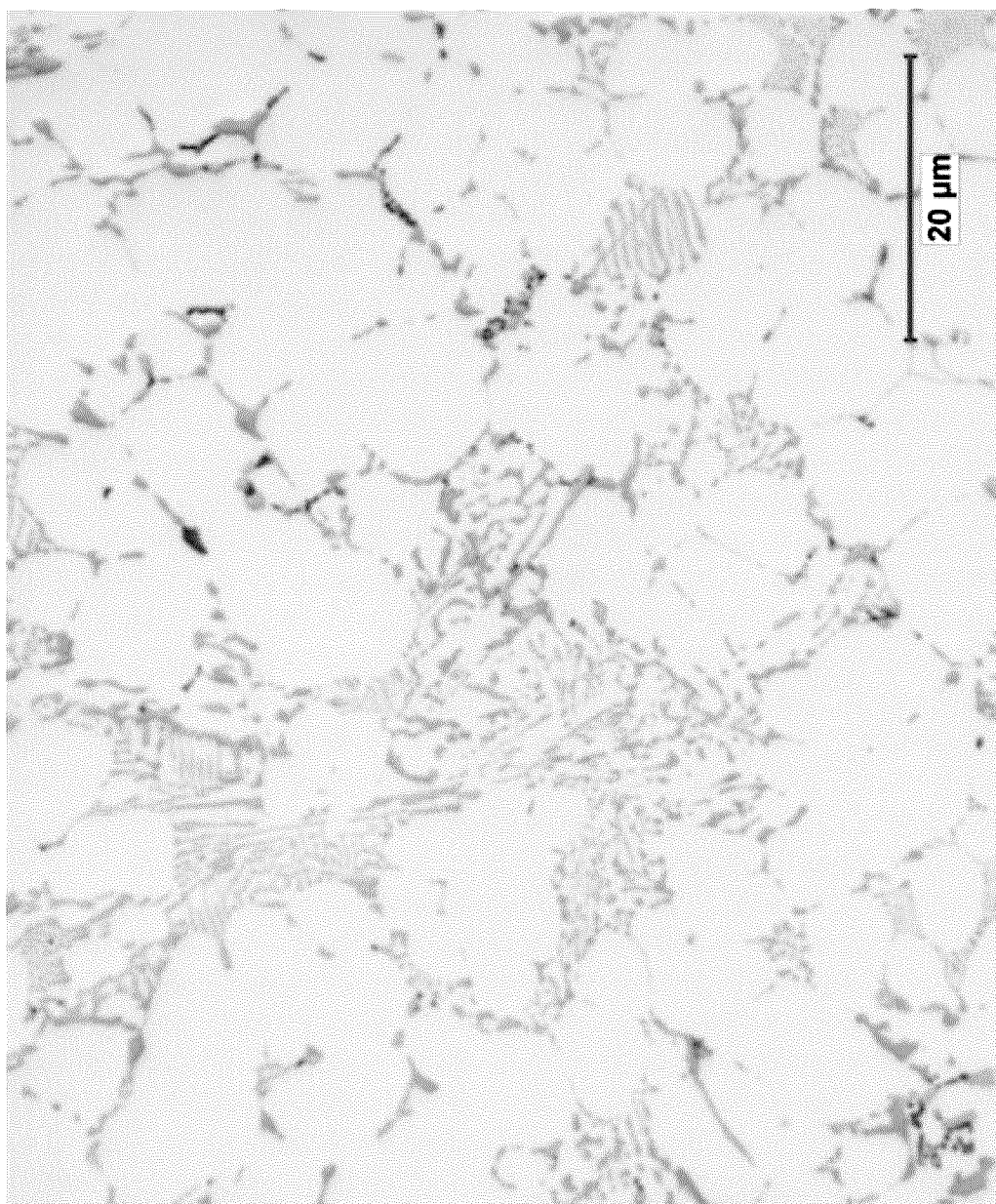


FIG. 24

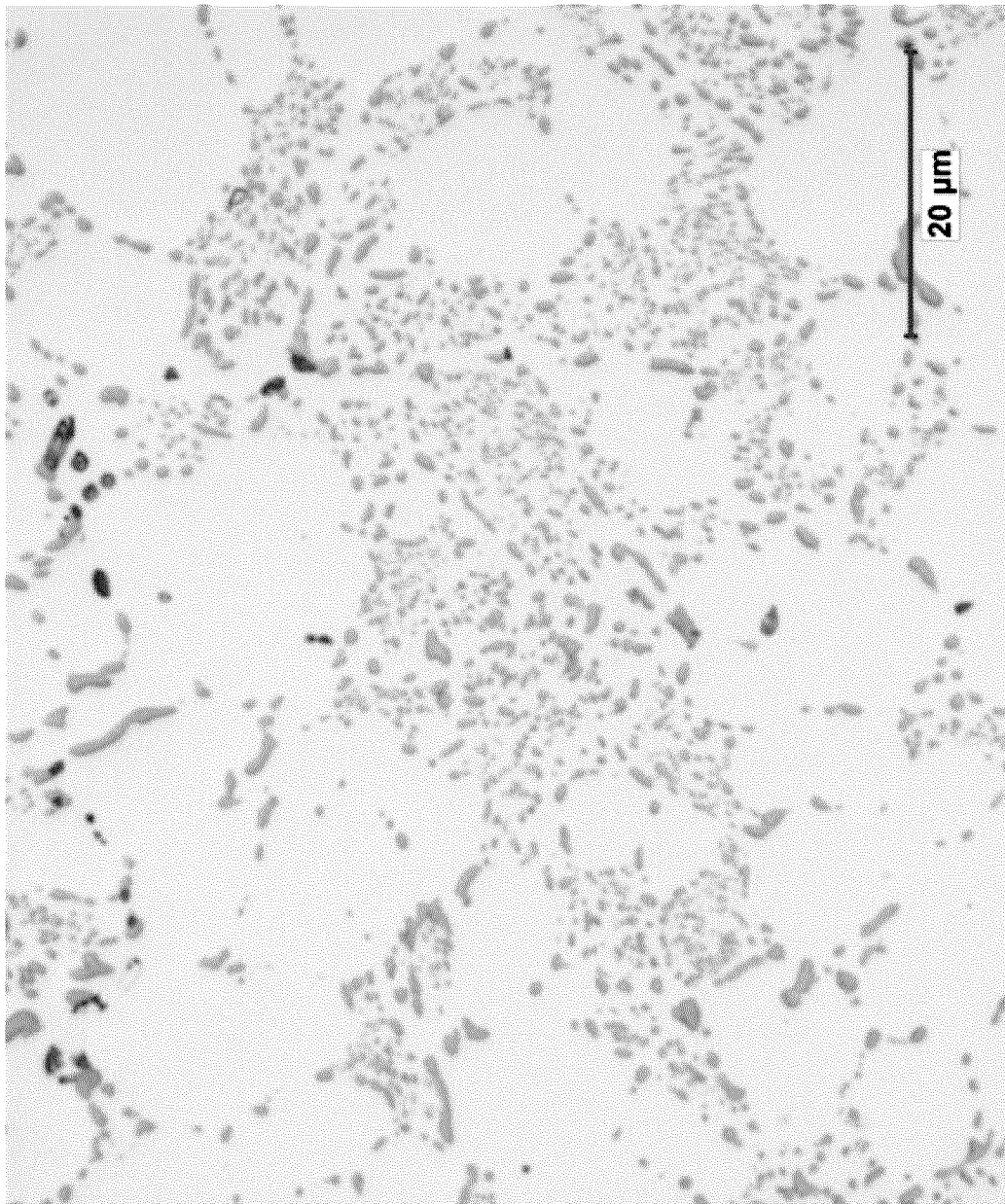


FIG. 25

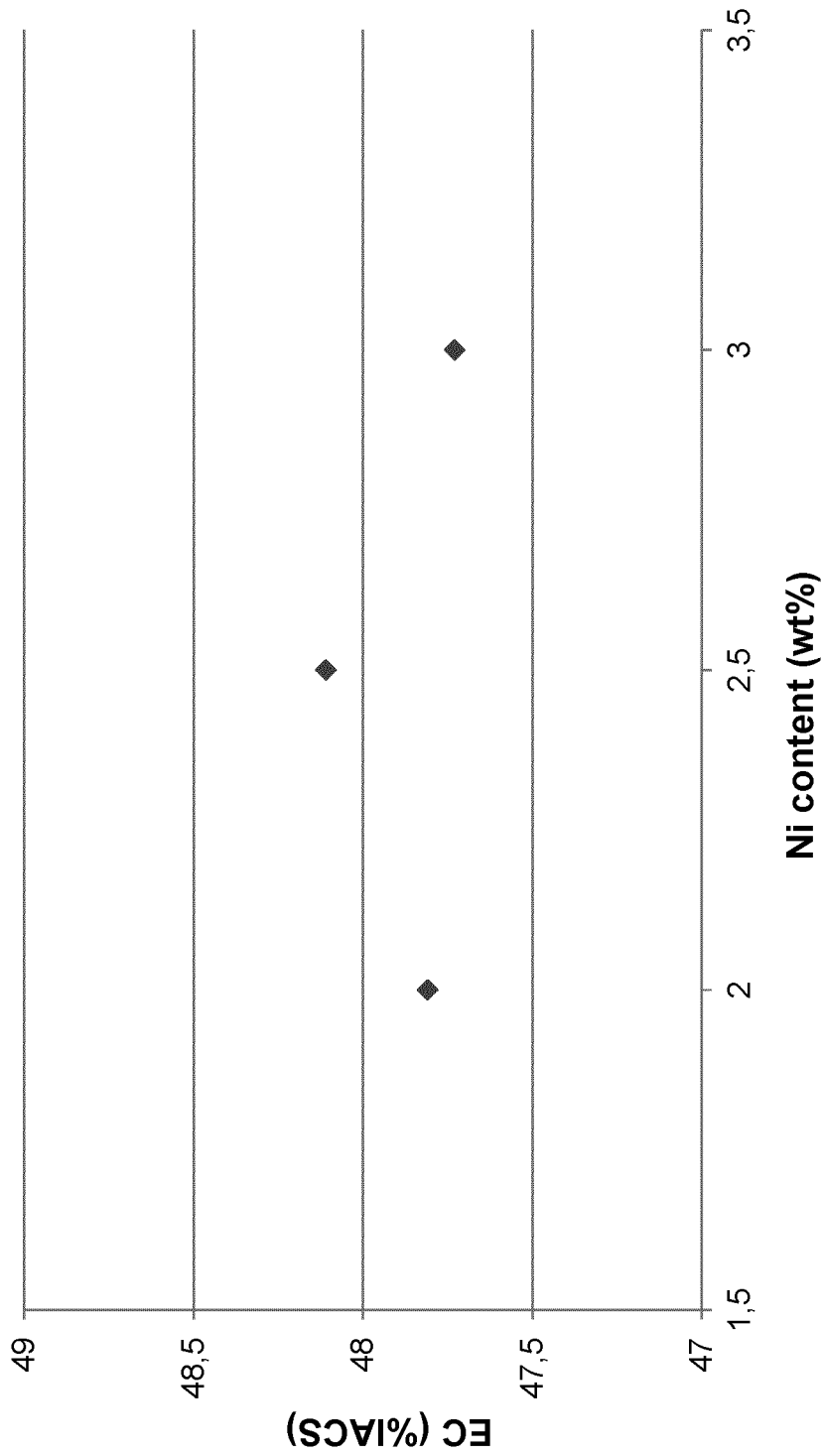


FIG. 26

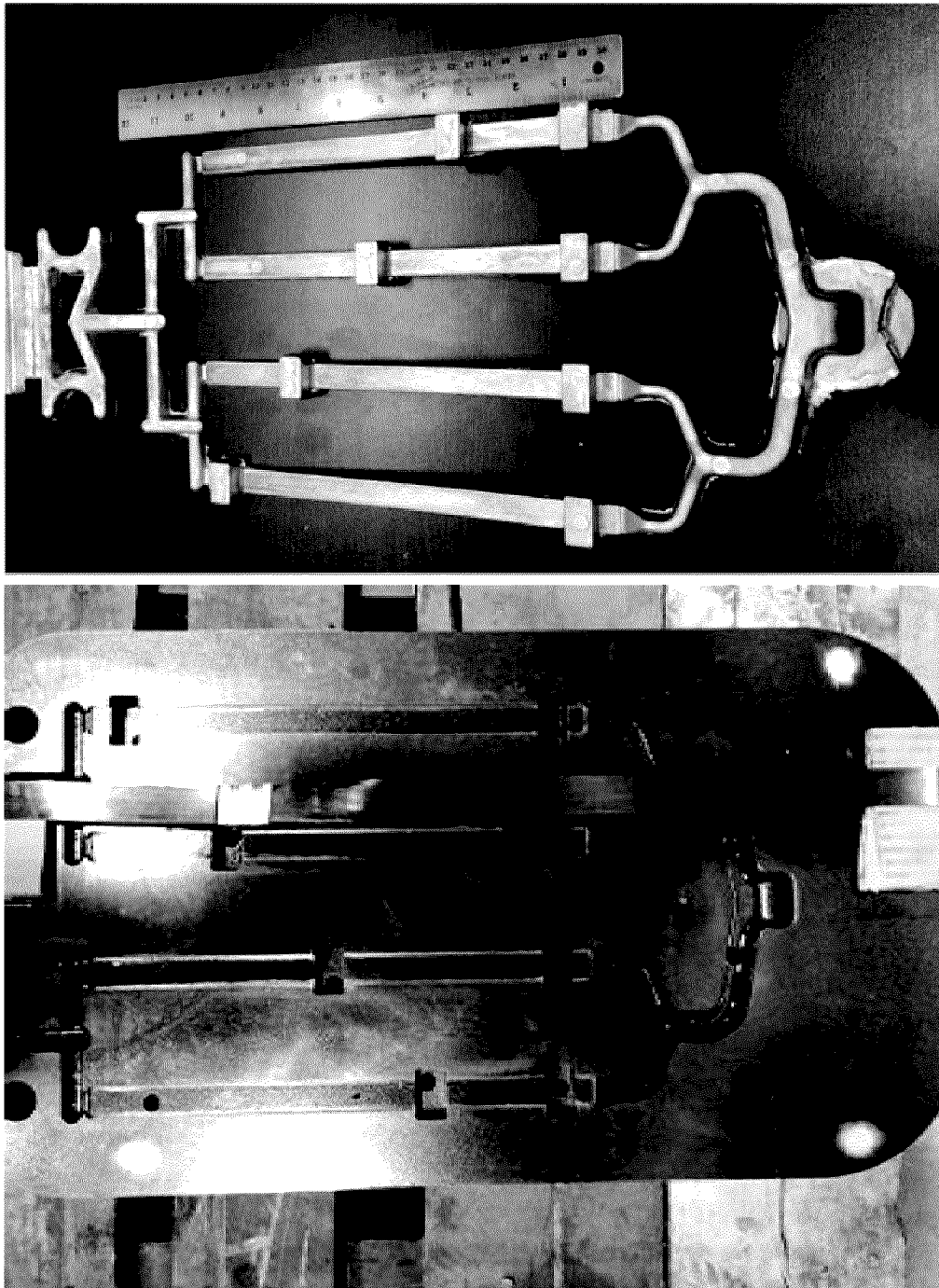


FIG. 27

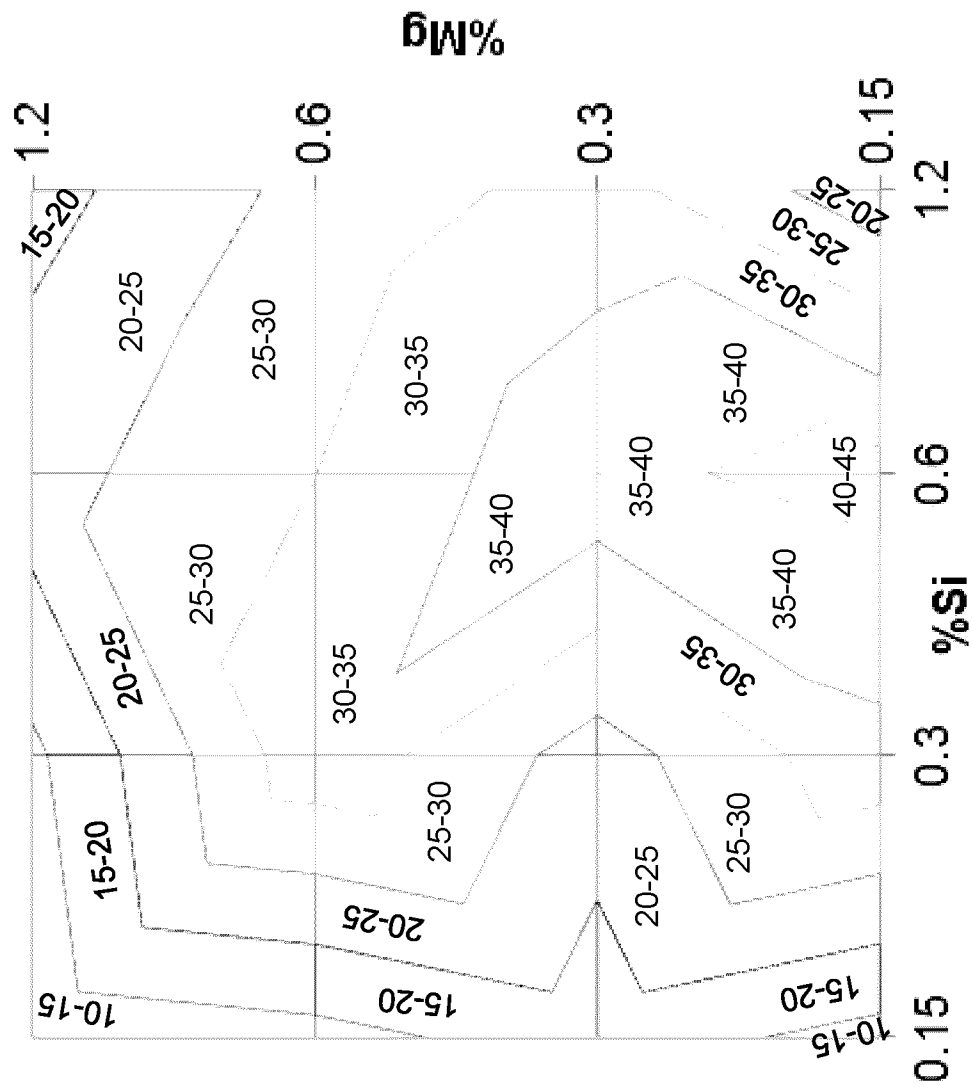


FIG. 28

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2020/050082

A. CLASSIFICATION OF SUBJECT MATTER

IPC: *C22C 21/00* (2006.01), *C22C 21/02* (2006.01), *C22C 21/04* (2006.01), *C22C 21/08* (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: *C22C 21/00* (2006.01), *C22C 21/02* (2006.01), *C22C 21/04* (2006.01), *C22C 21/08* (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Databases: Questel Orbit; Espacenet; Canadian Patents Database; Google

Keywords: Ni; nickel; Si; silicon; Mg; magnesium; Fe; iron; Mn; manganese; Ti; titanium; V; vanadium; Zr; zirconium; Mo; molybdenum; Cr; chromium; Sr; strontium; foundry

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2 155 920 A TONN ET AL. 24 February 2010 (24-02-2010) the whole document	1-58

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

* "A" "D" "E" "L" "O" "P"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance document cited by the applicant in the international application earlier application or patent but published on or after the international filing date 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) document referring to an oral disclosure, use, exhibition or other means document published prior to the international filing date but later than the priority date claimed	"T" "X" "Y" "&"	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 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 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
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Date of the actual completion of the international search
25 March 2020 (25-03-2020)Date of mailing of the international search report
08 April 2020 (08-04-2020)Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer

Charles Greenough (819) 639-8479

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CA2020/050082

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
EP2155920A1	24 February 2010 (24-02-2010)	EP2155920A1	24 February 2010 (24-02-2010)
		DE102007023323A1	20 November 2008 (20-11-2008)
		DE102007023323B4	28 October 2010 (28-10-2010)
		WO2008138614A1	20 November 2008 (20-11-2008)