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(54) **ALUMINUM ALLOYS WITH HIGH STRENGTH AND COSMETIC APPEAL**

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

CPC ***C22C 21/10*** (2013.01); ***C22C 1/02*** (2013.01); ***C22F 1/053*** (2013.01)

(57) **ABSTRACT**

The disclosure provides aluminum alloys having varying ranges of alloying elements and properties.

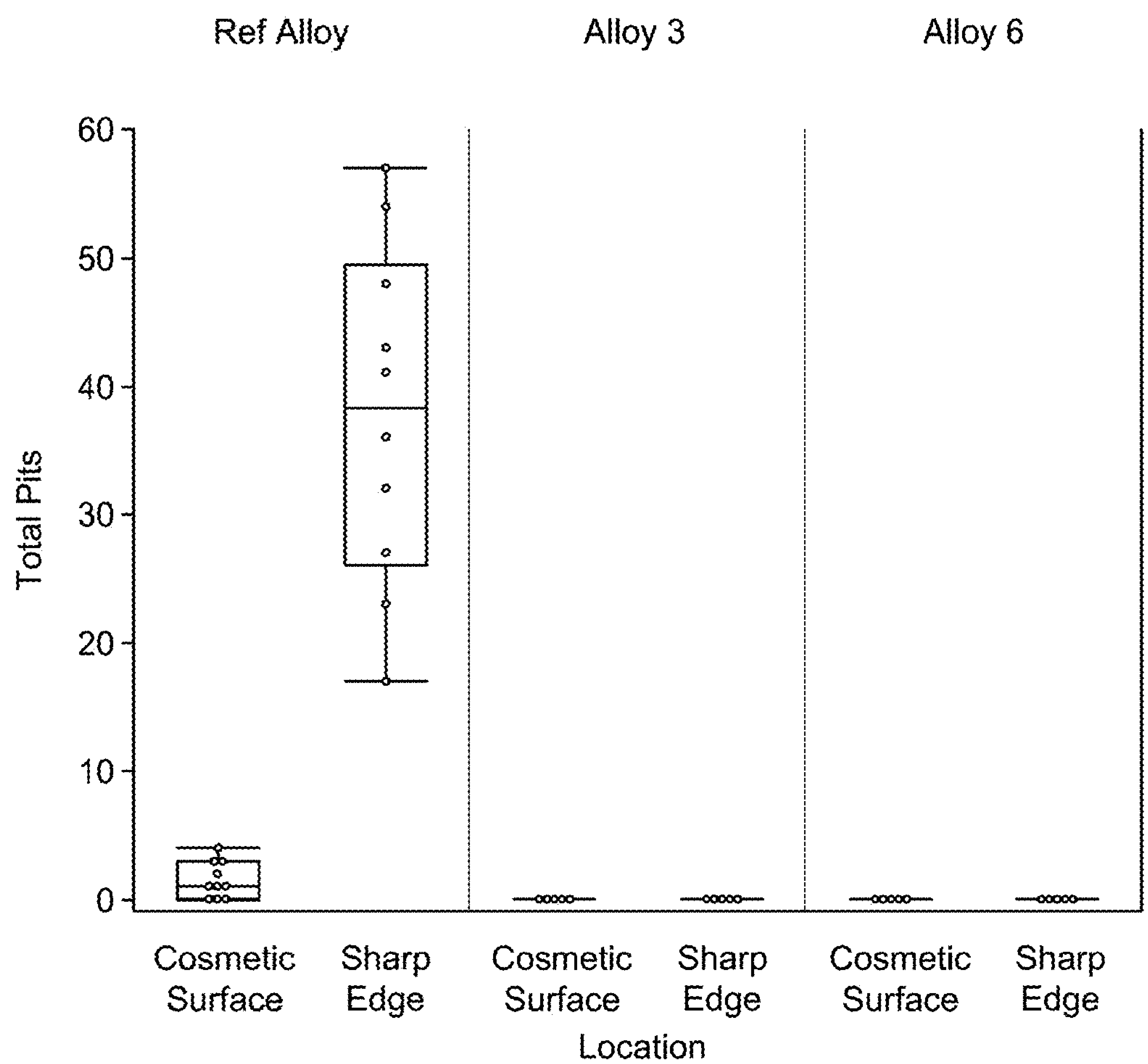

Ref Alloy
Alloy 3
Alloy 6
60
50
40
30
20
10
0
Total Pits
Cosmetic Surface
Sharp Edge
Cosmetic Surface
Sharp Edge
Cosmetic Surface
Sharp Edge
Location

Figure 1

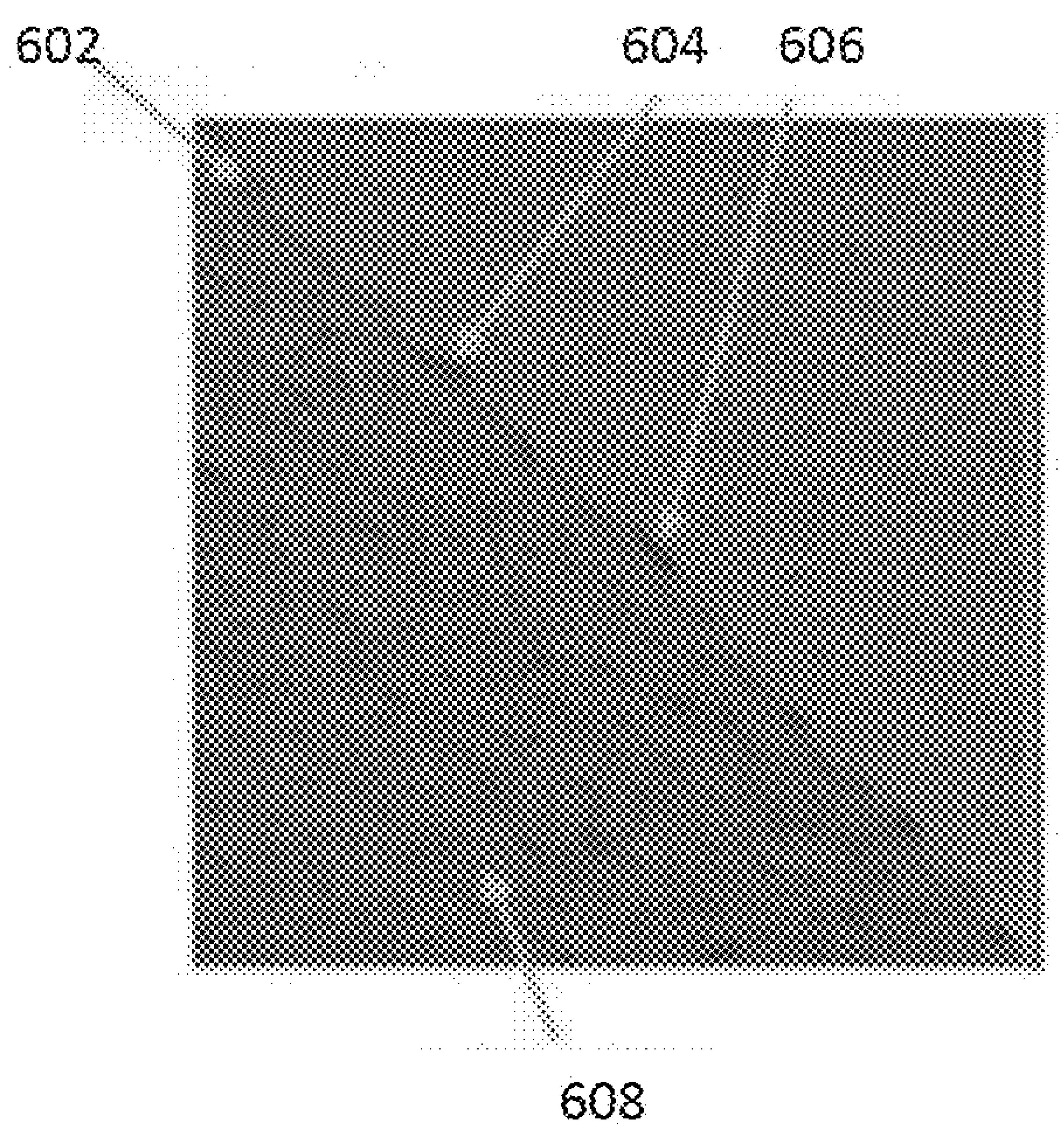


Figure 2A

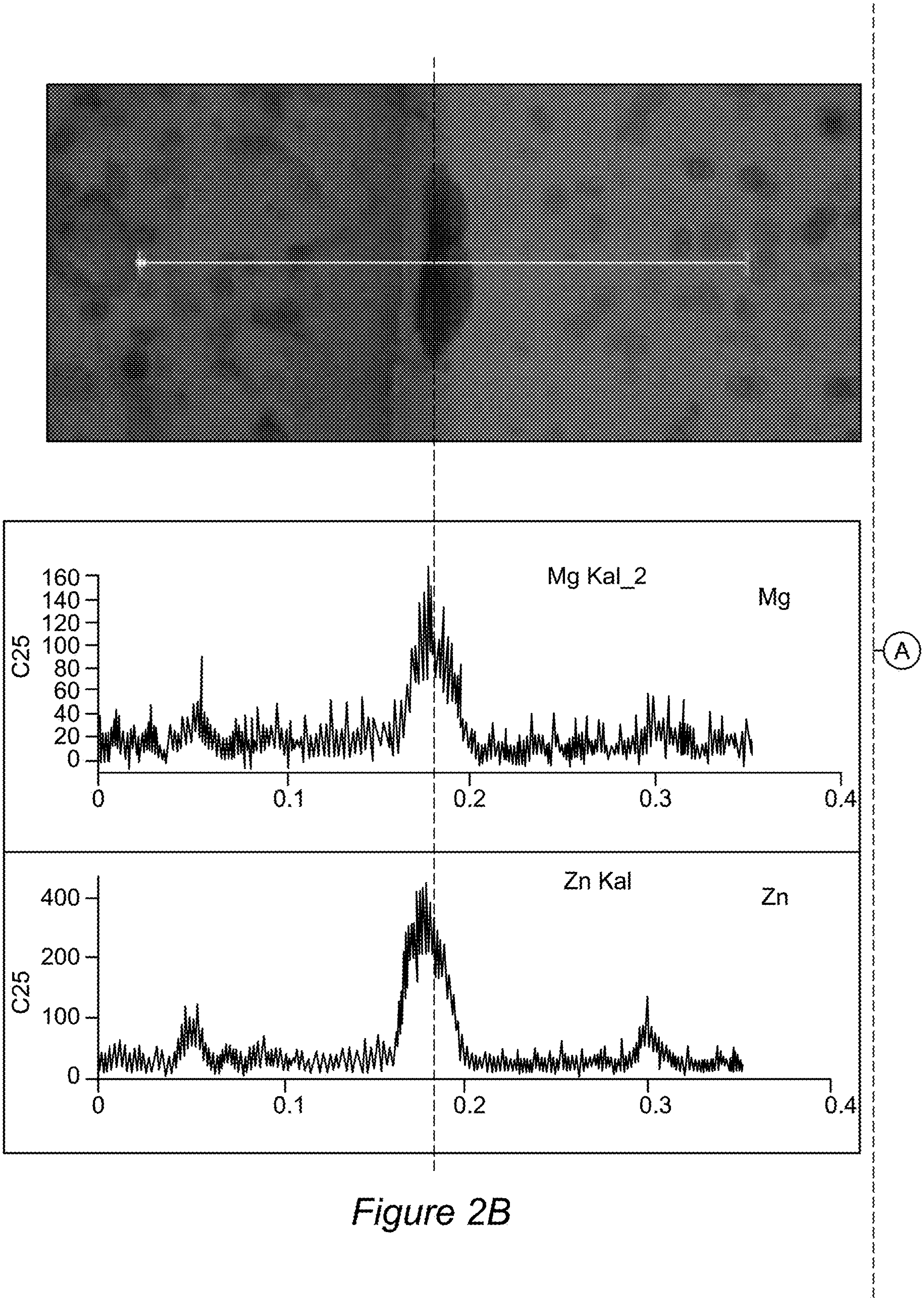

Mg Kal_2
Mg
C25
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
A
Zn Kal
Zn
C25
400
200
100
0
0
0.1
0.2
0.3
0.4

Figure 2B

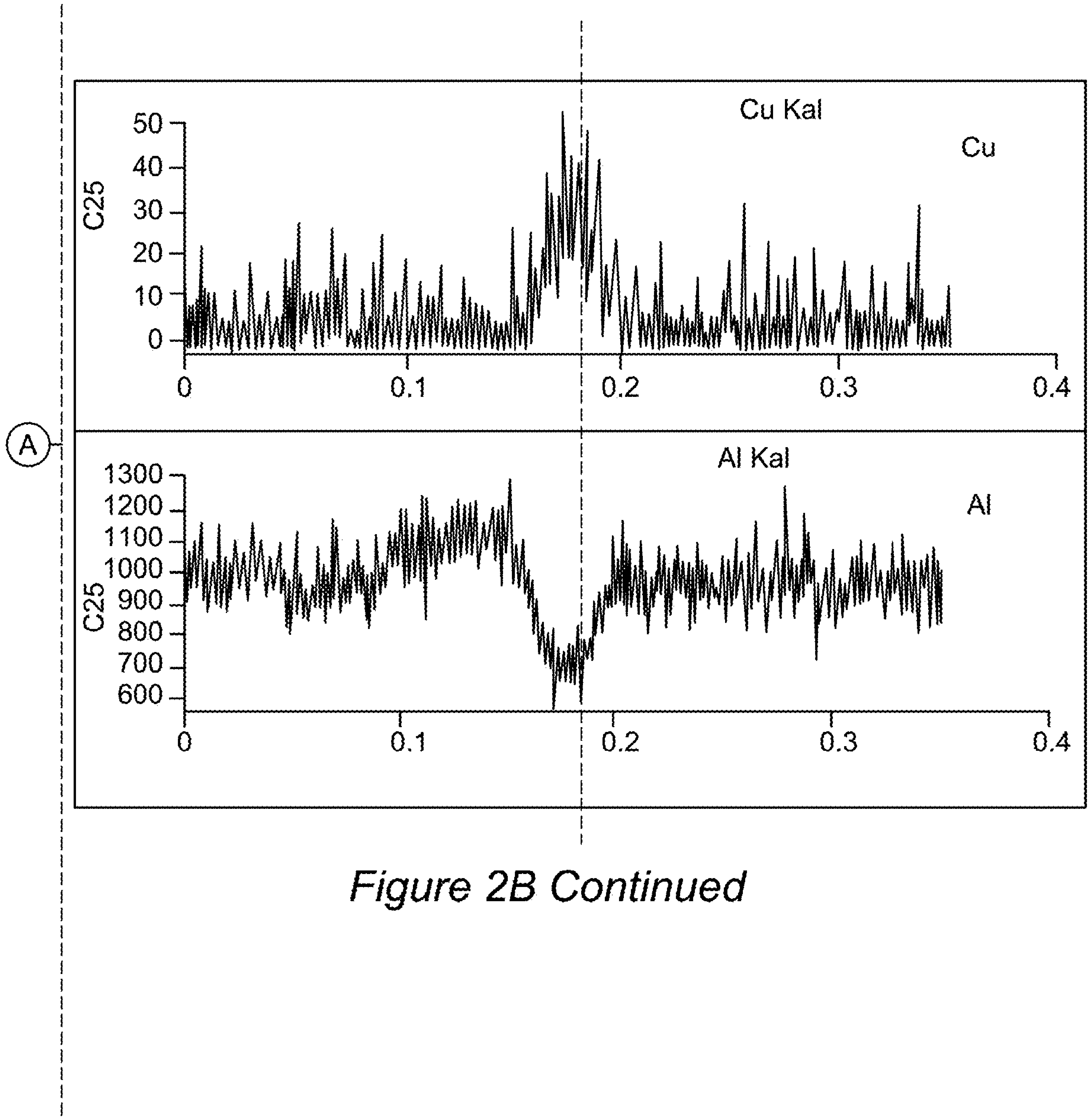


Figure 2B Continued

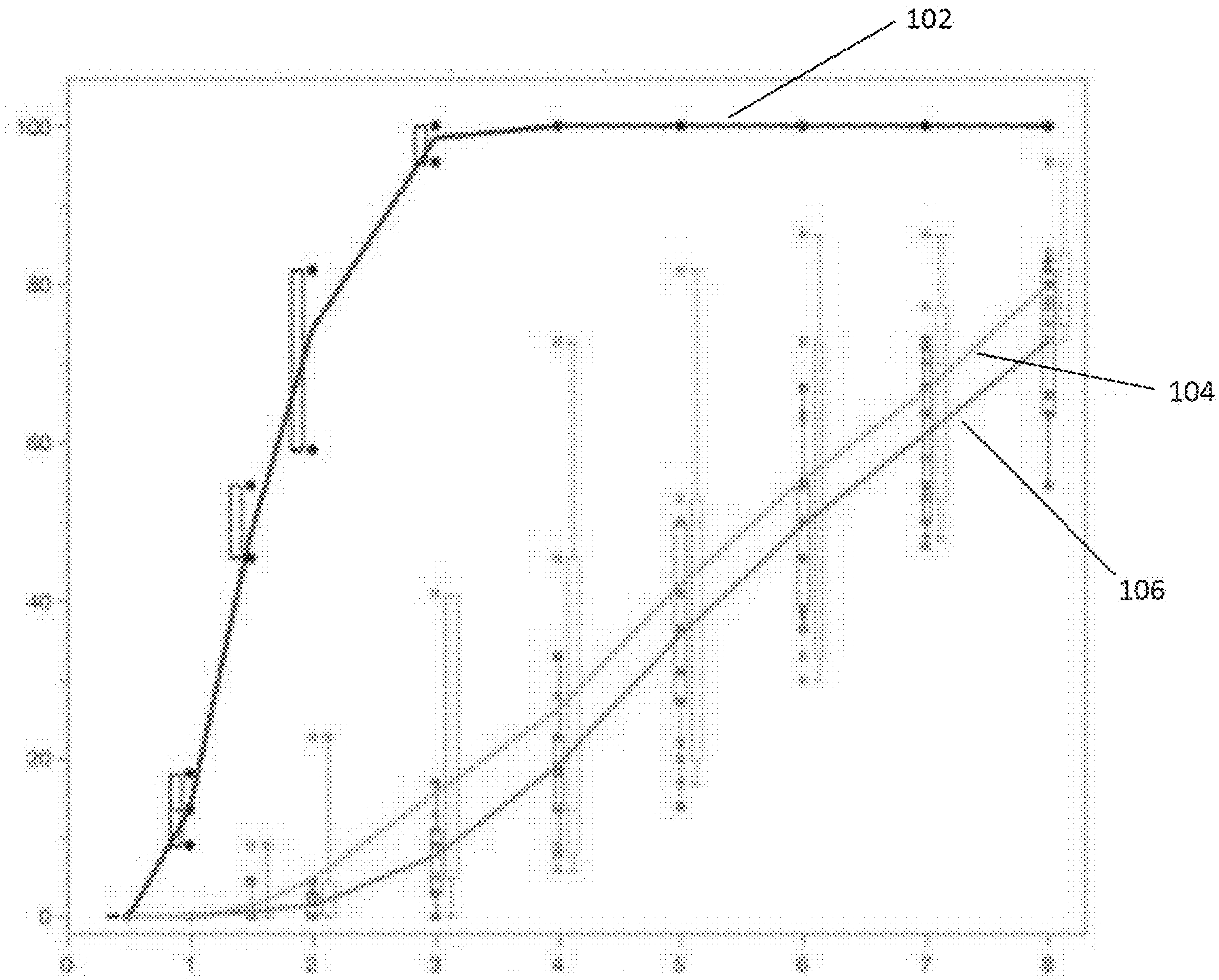


Figure 3

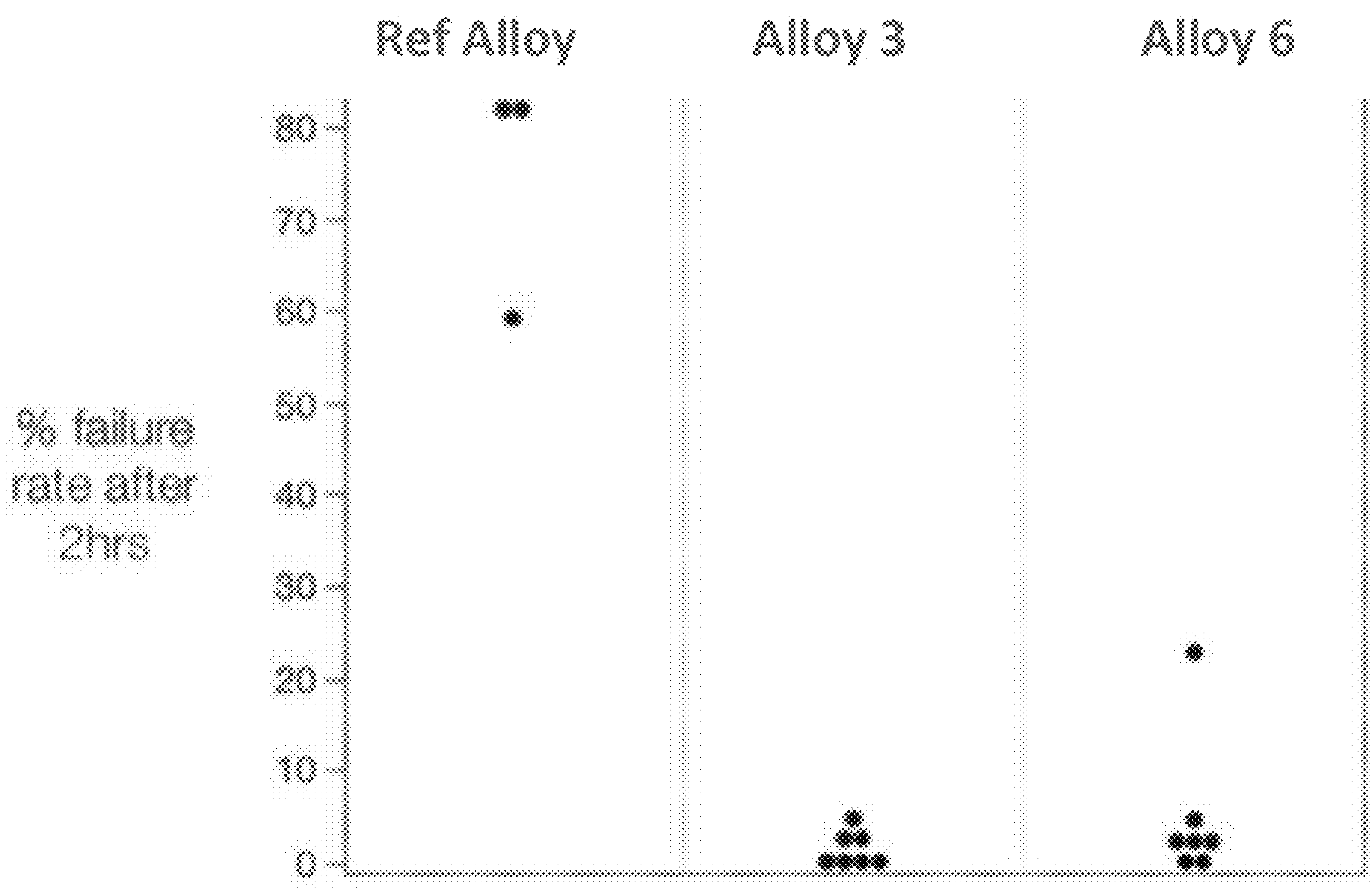

Ref Alloy
Alloy 3
Alloy 6
% failure rate after 2hrs
80
70
60
50
40
30
20
10
0

Figure 4

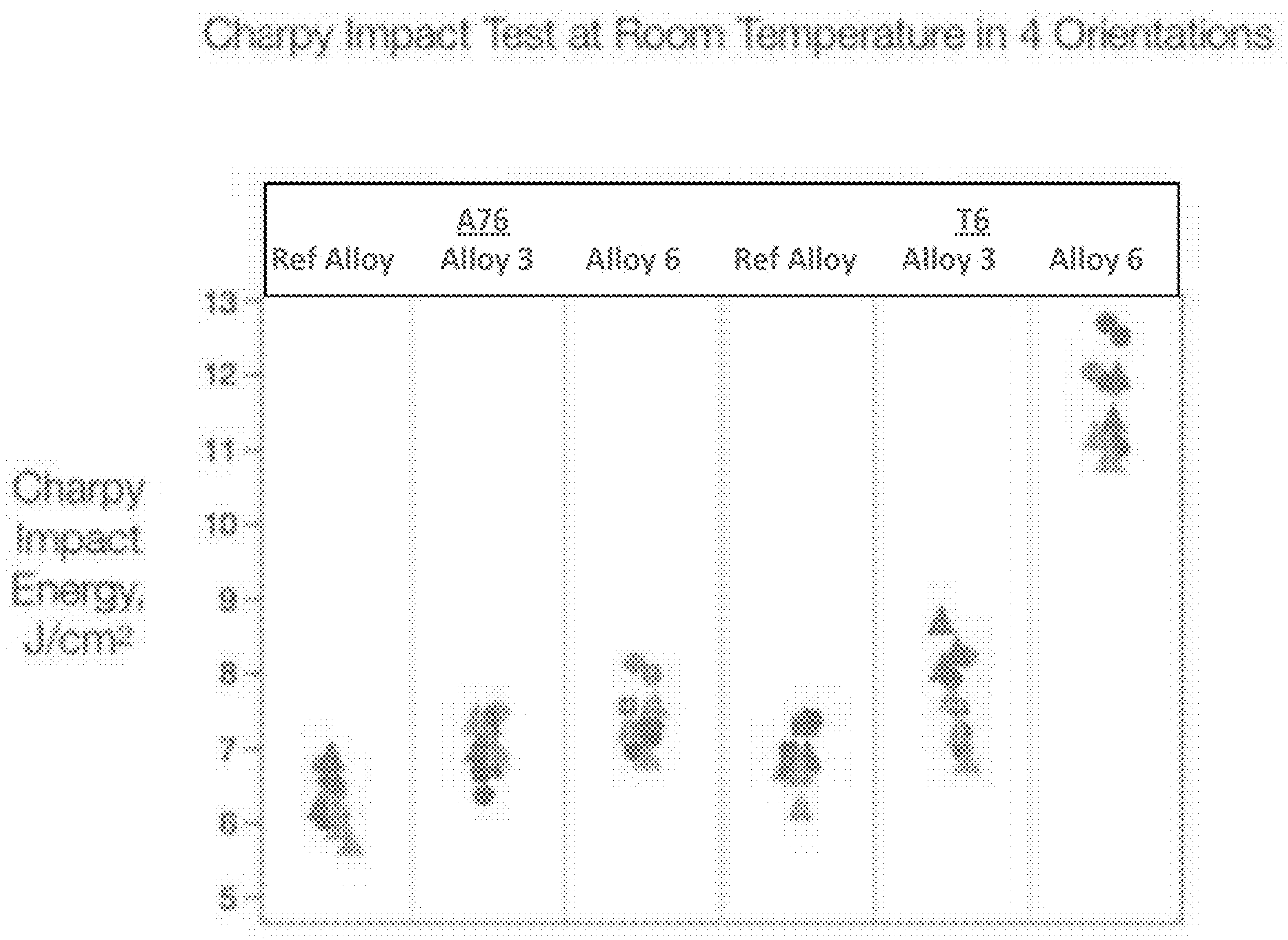

Charpy Impact Test at Room Temperature in 4 Orientations
A76
T6
Ref Alloy
Alloy 3
Alloy 6
Ref Alloy
Alloy 3
Alloy 6
Charpy Impact Energy, J/cm²
13
12
11
10
9
8
7
6
5

Figure 5

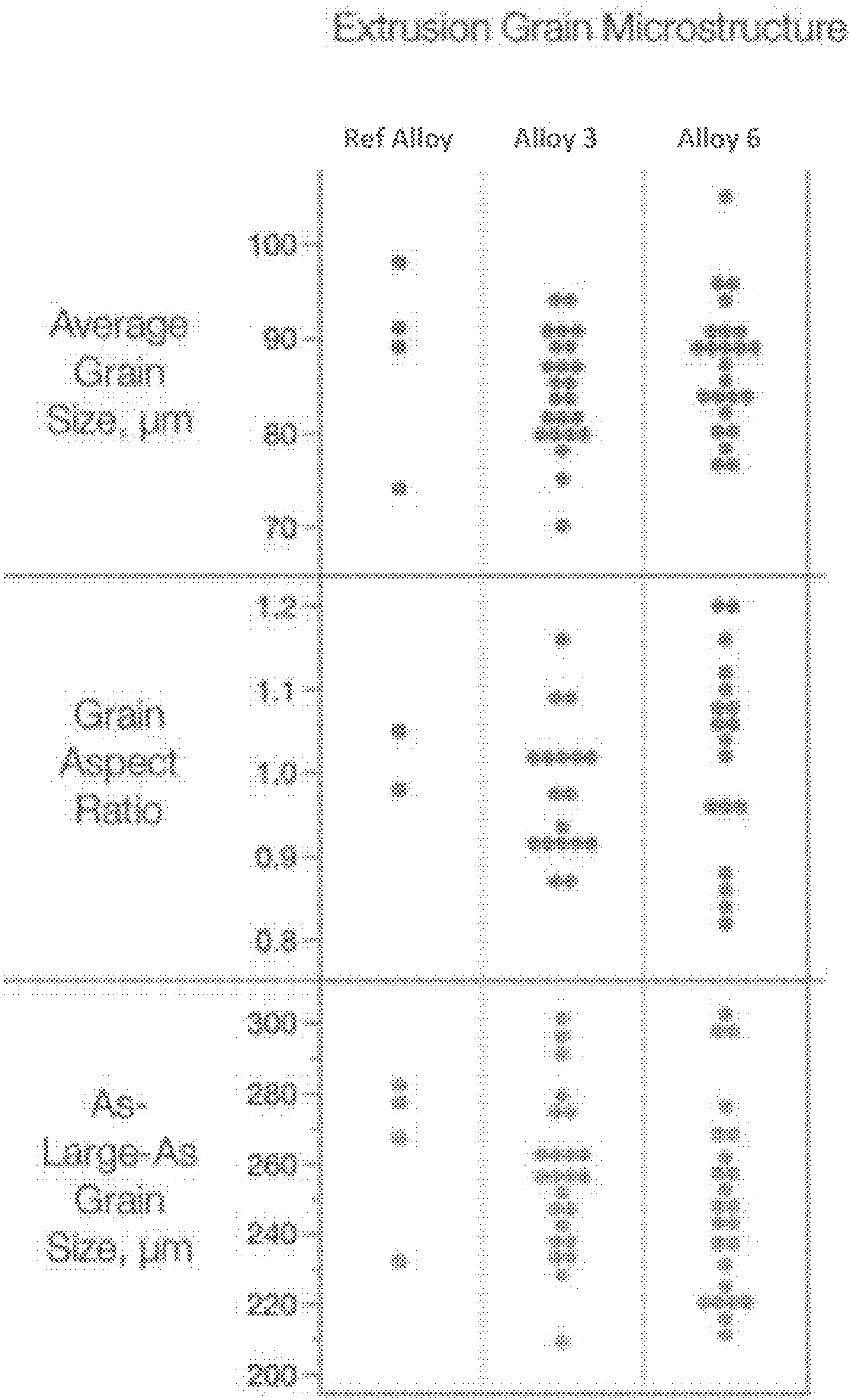

Extrusion Grain Microstructure
Ref Alloy
Alloy 3
Alloy 6
Average Grain Size, µm
100
90
80
70
Grain Aspect Ratio
1.2
1.1
1.0
0.9
0.8
As-Large-As Grain Size, µm
300
280
260
240
220
200

Figure 6

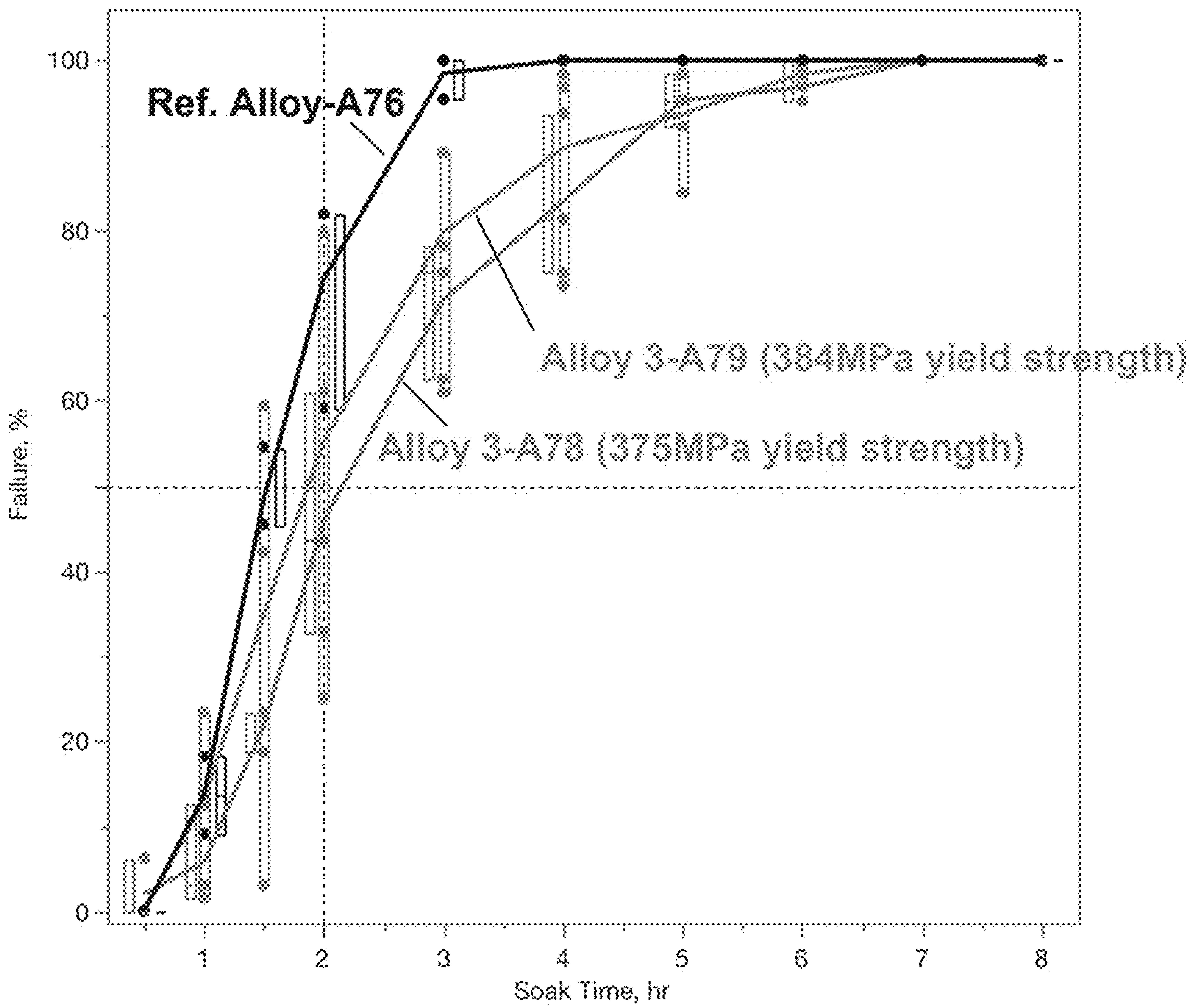

Ref. Alloy-A76
Alloy 3-A79 (384MPa yield strength)
Alloy 3-A78 (375MPa yield strength)
Failure, %
0
20
40
60
80
100
1
2
3
4
5
6
7
8
Soak Time, hr

Figure 7

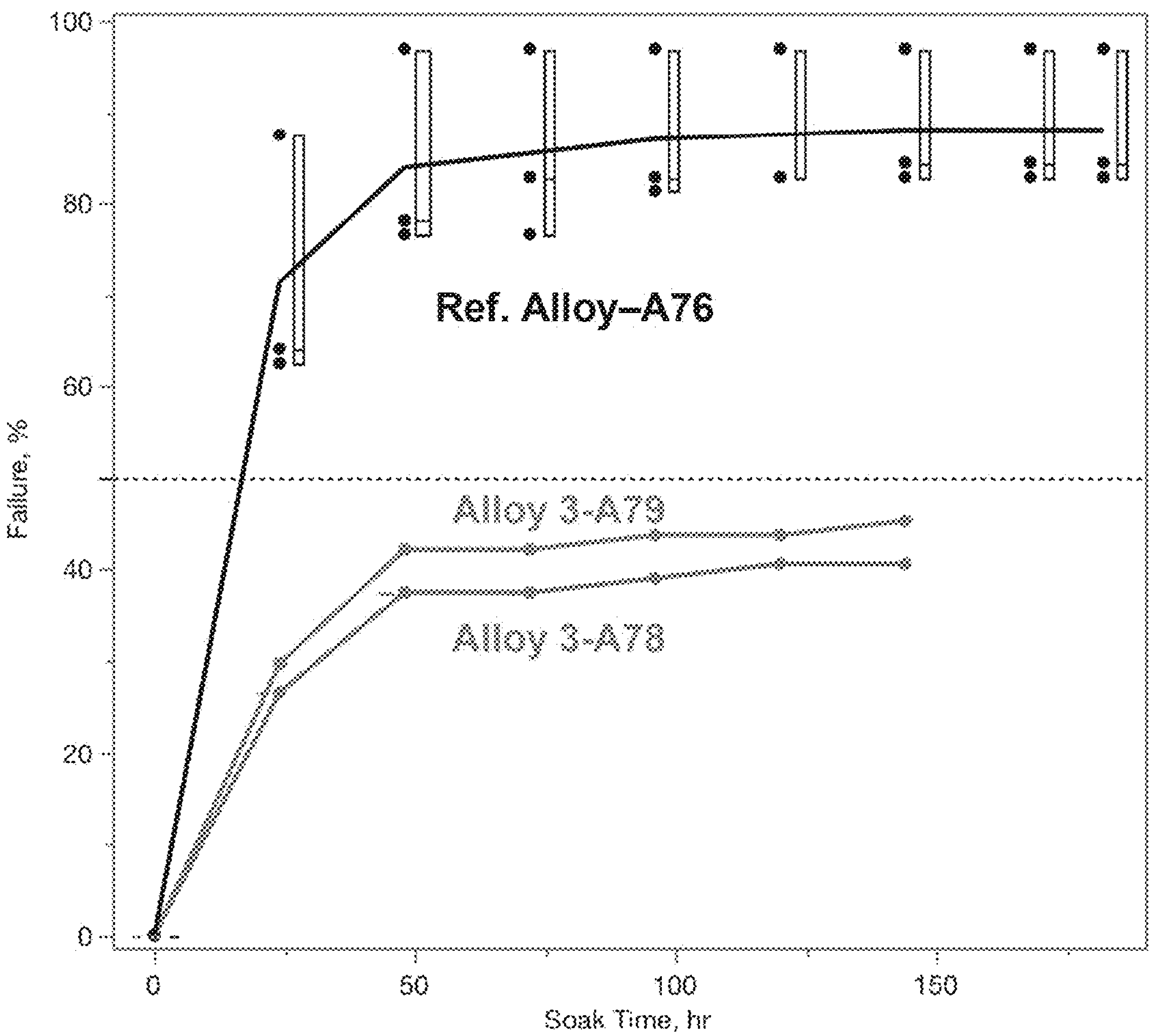

100
80
60
40
20
0
Failure, %
Ref. Alloy–A76
Alloy 3-A79
Alloy 3-A78
0
50
100
150
Soak Time, hr

Figure 8

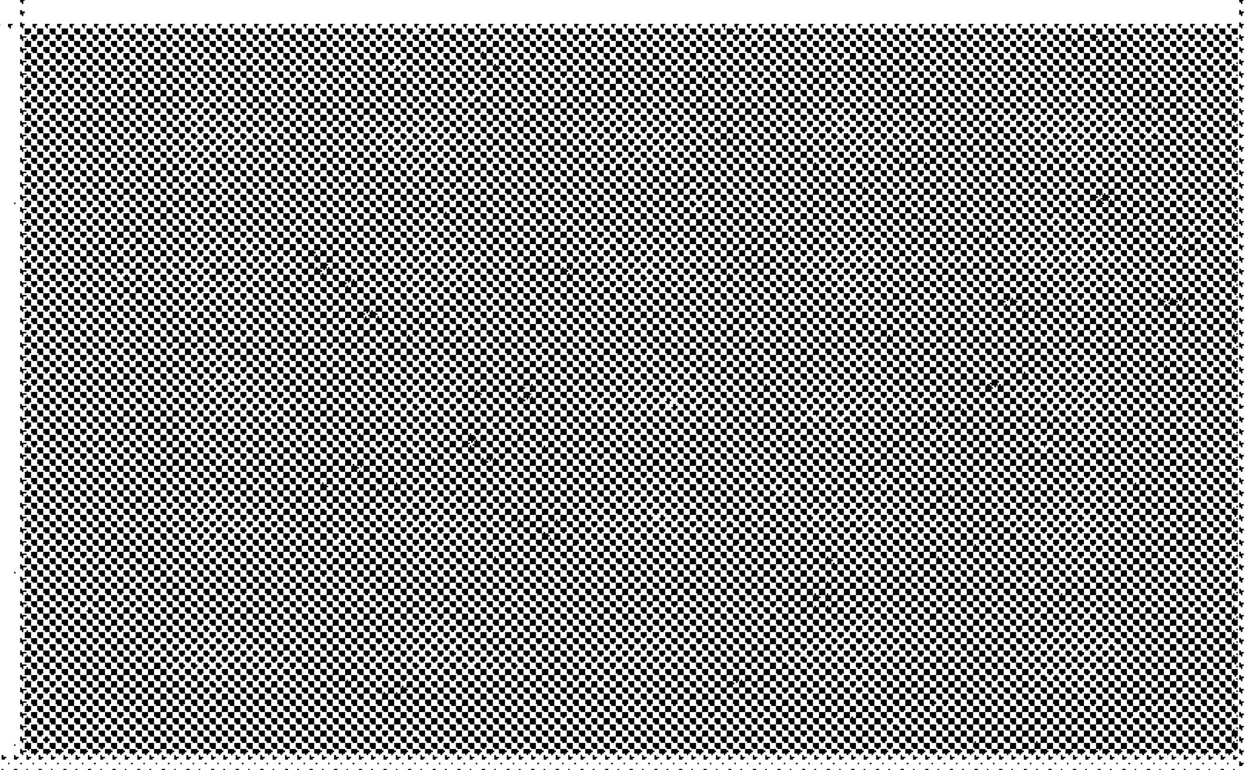
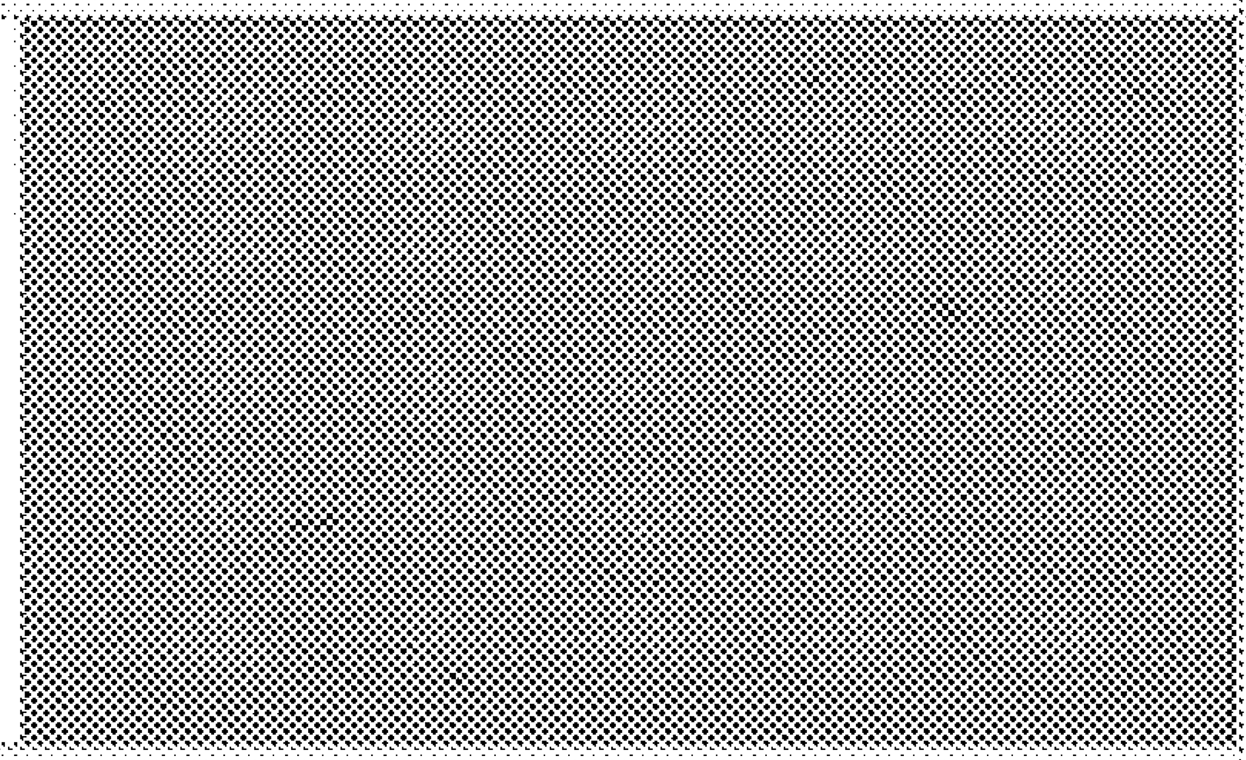
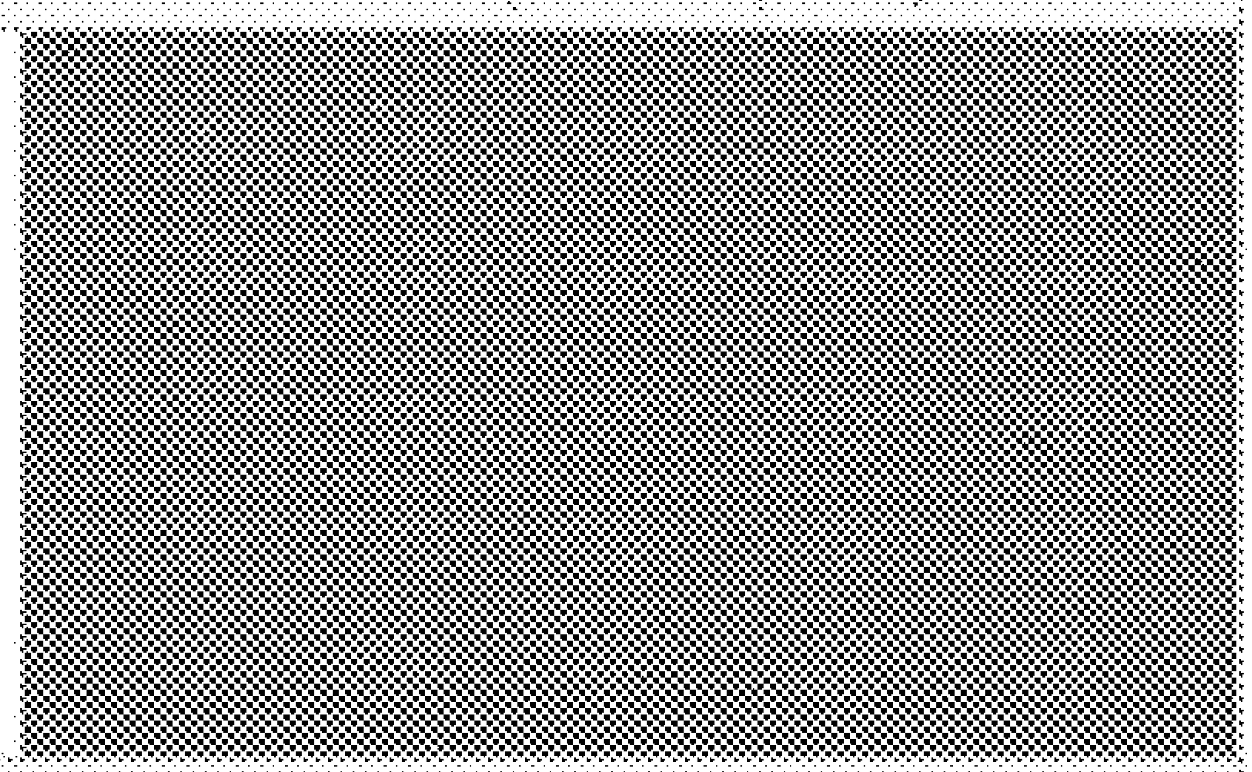
Temper	Delam
T6	
0 vertices with delam (2 samples)	
A76	
0 vertices with delam (2 samples)	
A79	
0 vertices with delam (2 samples)	

Figure 9

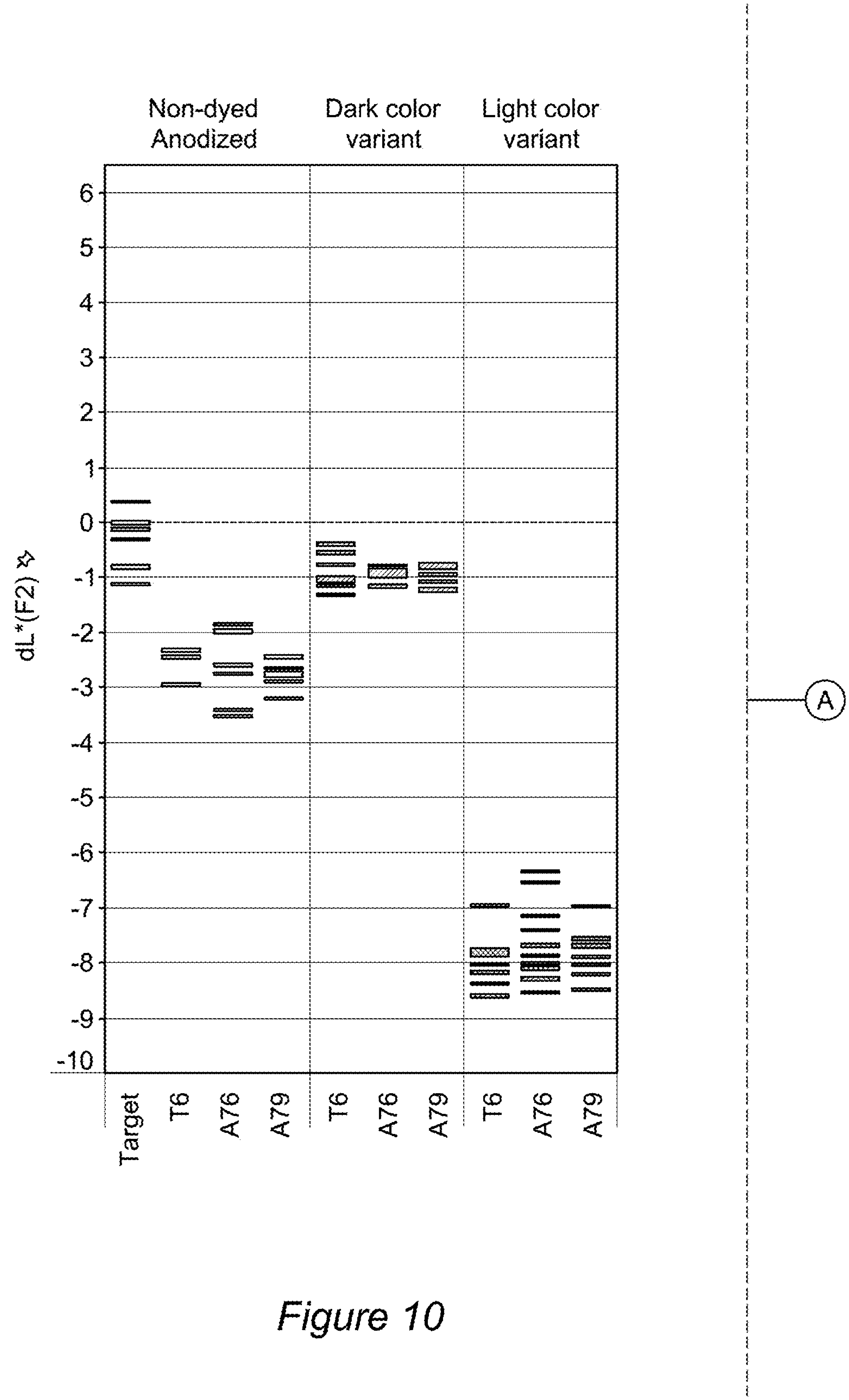
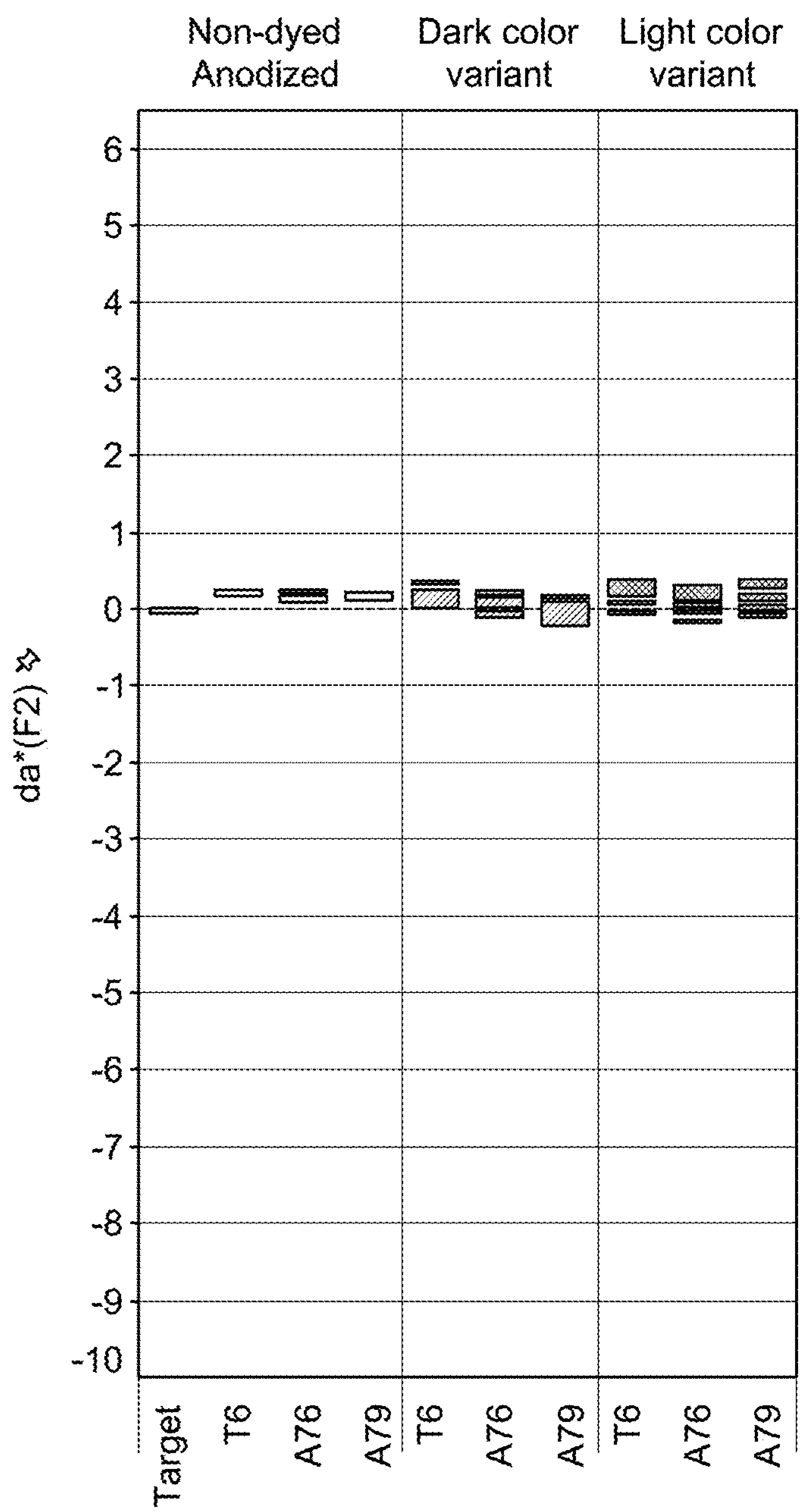

Non-dyed Anodized
Dark color variant
Light color variant
dL*(F2)
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Target
T6
A76
A79
T6
A76
A79
T6
A76
A79
A

Figure 10

A



B

Figure 10 Continued

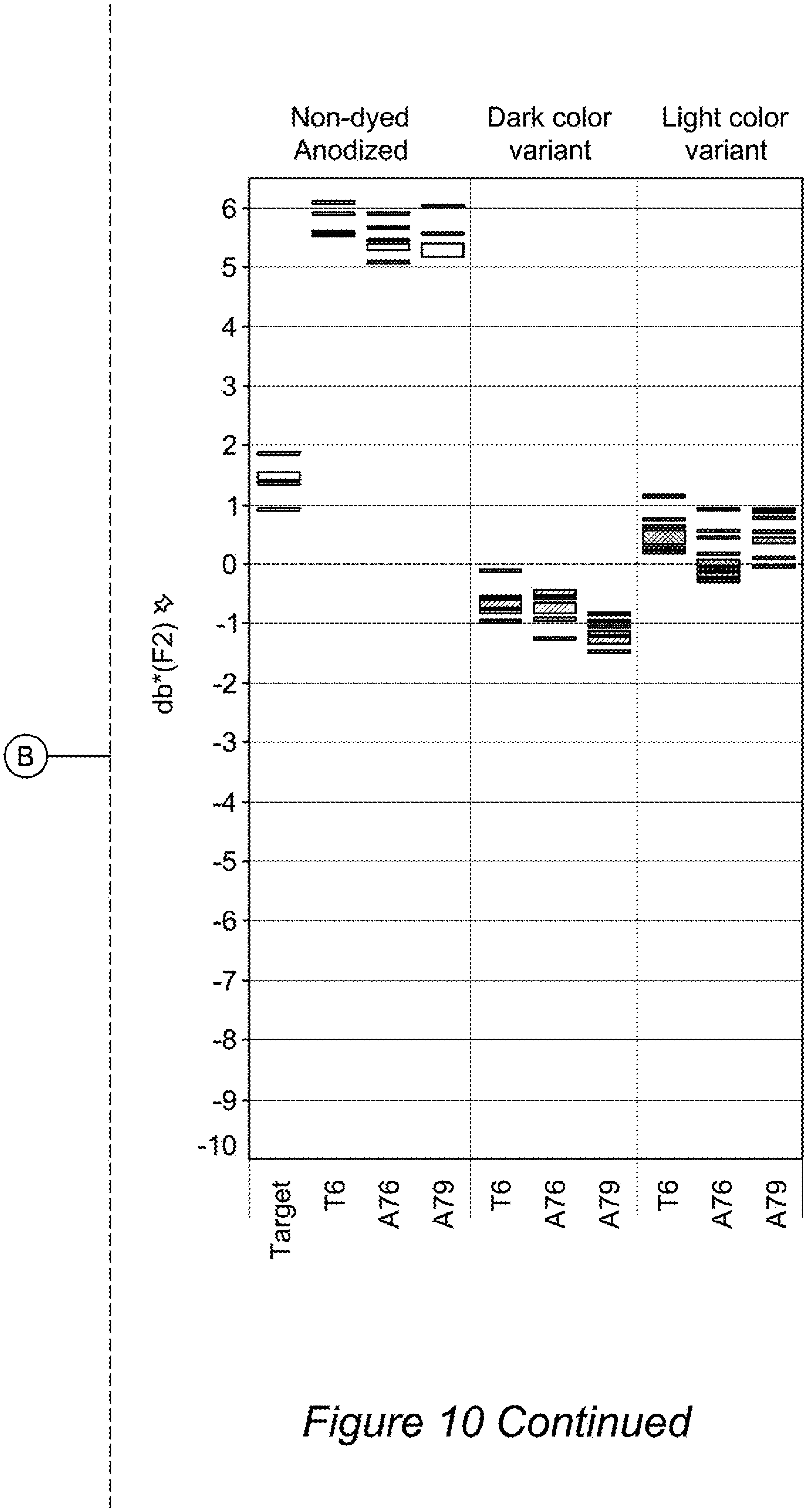


Figure 10 Continued

ALUMINUM ALLOYS WITH HIGH STRENGTH AND COSMETIC APPEAL

PRIORITY

[0001] This patent application claims the benefit of U.S. Provisional Patent Application No. 63/290,956, entitled "ALUMINUM ALLOYS WITH HIGH STRENGTH AND COSMETIC APPEAL," filed on Dec. 17, 2021, and U.S. Provisional Patent Application No. 63/343,443, entitled "ALUMINUM ALLOYS WITH HIGH STRENGTH AND COSMETIC APPEAL," filed on May 18, 2022, both of which are incorporated herein by reference in their entireties.

TECHNICAL FIELD

[0002] The disclosure generally relates to aluminum alloys with improved material properties and cosmetic appeal for applications that include enclosures for electronic devices.

BACKGROUND

[0003] Many commercial 7000 series aluminum alloys have been developed for aerospace applications. Commercial 7000 series aluminum alloys are not cosmetically appealing when in consumer products. Even alloys designed for cosmetic purposes can result in chipping of the anodized surface, stress corrosion cracking (SCC), and mechanical failure.

SUMMARY

[0004] Additional embodiments and features are set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the specification, or may be learned by the practice of the embodiments discussed herein. A further understanding of the nature and advantages of certain embodiments may be realized by reference to the remaining portions of the specification and the drawings, which forms a part of this disclosure.

[0005] In some aspects, the disclosure is directed to and aluminum alloy comprising 3.4 to 5.5 wt % Zn, 1.3 to 2.1 wt % Mg, at least 0.07 wt % Cu, no greater than 0.08 wt % Zr, and 0.04 to 0.20 wt % Fe, wherein the balance is aluminum and incidental impurities. In various aspects, the alloy has no greater than 0.05 wt % Si, Mn, Cr, Ti, Ga, Sn, V, B, Li, Cd, Pb, Ni, P, Na, and Ca. The alloy can have no greater than 0.03 wt % total of Mn and Cr. The alloy can include no greater than 0.02 wt % of any one additional element, and no greater than 0.10 wt % total of additional elements.

[0006] In another aspect, the aluminum alloy includes at least 0.12 wt % Cu.

[0007] In another aspect, the aluminum alloy includes at least 0.28 wt % Cu.

[0008] In another aspect, the aluminum alloy includes at least 4.5-5.5 wt % Zn and 1.5-2.1 wt % Mg.

[0009] In another aspect, the aluminum alloy includes at least 4.0-4.8 wt % Zn and 1.2-1.8 wt % Mg.

[0010] In another aspect, the aluminum alloy has a wt % ratio of Zn to Mg from 1.8-3.5.

[0011] In various aspects, the aluminum alloy can be tempered under T6, A79, or A76 conditions.

[0012] In various aspects, the alloy can be tempered under A 78 or A79 conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Further non-limiting aspects of the disclosure are described by reference to the drawings and descriptions.

[0014] FIG. **1** depicts the ano chipping stress test for Alloy 3 and Alloy 6 as compared to the Reference Alloy combined T6 and A76 temper conditions, according to illustrative embodiments;

[0015] FIG. **2**A depicts a TEM showing the grain boundary of Alloy 3 after A76 tempering, according to illustrative embodiments;

[0016] FIG. **2**B depicts EDS line scan and chemical composition of precipitates at a grain boundary of Alloy 3 after A76 tempering, according to illustrative embodiments;

[0017] FIG. **3** depicts the SCC test for Alloy 3 and Alloy 6 as compared to the Reference Alloy for A76 temper in a ASTM G30 U-bend test at 85° C. and in a 15% NaCl solution emersion, according to illustrative embodiments;

[0018] FIG. **4** depicts the percent failure rate after two hours for Alloy 3 and Alloy 6 as compared to the Reference Alloy after A76 tempering, according to illustrative embodiments;

[0019] FIG. **5** depicts the Charpy Impact Energy for Alloy 3 and Alloy 6 as compared to a Reference Alloy in four orientations at T6 and A76 temper conditions, according to illustrative embodiments;

[0020] FIG. **6** depicts the extrusion grain microstructure including average grain size, grain aspect ratio, and as-large-as grain size for Alloy 3 and Alloy 6 as compared to the Reference Alloy, according to illustrative embodiments;

[0021] FIG. **7** depicts the SCC test for Alloy 3 at A78 and A79 temper conditions as compared to the Reference Alloy at the A76 temper condition, according to illustrative embodiments;

[0022] FIG. **8** depicts the percent failure as a function of soak time for Alloy 3 at A78 and A79 temper conditions as compared to the Reference Alloy at A76 temper conditions in a heat soak ASTM G30 U-bend test at 90% relative humidity (RH) at 65° C., according to illustrative embodiments;

[0023] FIG. **9** depicts de-laminization performance for Alloy 3 under T6, A76, and A79 temper conditions, according to illustrative embodiments; and

[0024] FIG. **10** depicts the consistency of a color difference from a target value for L*, a*, and b* for Alloy 3 under temper conditions T6, A76, and A79, according to illustrative embodiments.

DETAILED DESCRIPTION

[0025] The disclosure may be understood by reference to the following detailed description, taken in conjunction with the drawings as described below. It is noted that, for purposes of illustrative clarity, certain elements in various drawings may not be drawn to scale, may be represented schematically or conceptually, or otherwise may not correspond exactly to certain physical configurations of embodiments.

[0026] The disclosure provides for 7xxx series aluminum alloys that have improved abilities over known alloys. In certain variations, the alloys disclosed herein can meet one or more properties and/or processing variables simultaneously. These properties include a surprising reduction in anodized surface chipping, a reduction in SCC, a substantial reduction in time to failure, and/or an equal or improved

Charpy impact energy over other cosmetic alloys. In some variations, these properties can be achieved without changes in grain microstructure (e.g., average grain size, grain aspect ratio, and as-large-as grain size) or substantial loss of extrusion manufacturing capability.

[0027] The Al alloys can be described by various wt % of elements, as well as specific properties. In all descriptions of the alloys described herein, it will be understood that the wt % balance of alloys is Al and incidental impurities. In various embodiments, an incidental impurity can be no greater than 0.05 wt % of any one additional element (i.e., a single impurity), and no greater than 0.10 wt % total of all additional elements (i.e., total impurities).

[0028] In some aspects, an alloy composition can include a small amount of incidental impurities. The impurity elements can be present, for example, as a byproduct of processing and manufacturing.

[0029] Copper

[0030] In various aspects, the amount of Cu ranges is increased as compared to the Reference Alloy. The higher amount of Cu has surprisingly improved reliability of anodization and improvement of SCC resistance.

[0031] In some variations, the alloy has higher copper as compared to the Reference Alloy.

[0032] In some variations, the alloy includes Cu at least 0.08 wt % Cu. In some variations, the alloy includes Cu at least 0.10 wt % Cu. In some variations, the alloy includes Cu at least 0.12 wt % Cu. In some variations, the alloy includes Cu at least 0.14 wt % Cu. In some variations, the alloy includes Cu at least 0.15 wt % Cu. In some variations, the alloy includes Cu at least 0.16 wt % Cu. In some variations, the alloy includes Cu at least 0.18 wt % Cu. In some variations, the alloy includes Cu at least 0.20 wt % Cu. In some variations, the alloy includes Cu at least 0.22 wt % Cu. In some variations, the alloy includes Cu at least 0.24 wt % Cu. In some variations, the alloy includes Cu at least 0.26 wt % Cu. In some variations, the alloy includes Cu at least 0.28 wt % Cu. In some variations, the alloy includes Cu at least 0.30 wt % Cu. In some variations, the alloy includes Cu at least 0.32 wt % Cu. In some variations, the alloy includes Cu at least 0.34 wt % Cu. In some variations, the alloy includes Cu at least 0.36 wt % Cu. In some variations, the alloy includes Cu at least 0.38 wt % Cu. In some variations, the alloy includes Cu at least 0.40 wt % Cu.

[0033] In some variations, the alloy has equal to or less than 0.45 wt % Cu. In some variations, the alloy has equal to or less than 0.44 wt % Cu. In some variations, the alloy has equal to or less than 0.42 wt % Cu. In some variations, the alloy has equal to or less than 0.40 wt % Cu. In some variations, the alloy has equal to or less than 0.38 wt % Cu. In some variations, the alloy has equal to or less than 0.36 wt % Cu. In some variations, the alloy has equal to or less than 0.34 wt % Cu. In some variations, the alloy has equal to or less than 0.32 wt % Cu. In some variations, the alloy has equal to or less than 0.30 wt % Cu. In some variations, the alloy has equal to or less than 0.28 wt % Cu. In some variations, the alloy has equal to or less than 0.26 wt % Cu. In some variations, the alloy has equal to or less than 0.24 wt % Cu. In some variations, the alloy has equal to or less than 0.22 wt % Cu. In some variations, the alloy has equal to or less than 0.20 wt % Cu. In some variations, the alloy has equal to or less than 0.18 wt % Cu. In some variations, the alloy has equal to or less than 0.16 wt % Cu. In some variations, the alloy has equal to or less than 0.14 wt % Cu. In some variations, the alloy has equal to or less than 0.12 wt % Cu. In some variations, the alloy has equal to or less than 0.10 wt % Cu.

[0034] In some variations, the alloy has an amount of copper from 0.06 wt %-0.08 wt %. In some variations, the alloy has an amount of Cu from 0.10 to 0.20 wt %. In some variations, the alloy has an amount of Cu from 0.025 wt % to 0.035 wt %.

[0035] Table 1 depicts the elemental composition of six alloys as compared to a Reference Alloy. The Reference Alloy is similar to a representative alloy of PCT/US2017/041731 to Misra et al. published as WO 2018/013700, which is incorporated herein by reference in its entirety, where Zn is 5.0 wt %. In addition, PCT/US2014/058427 to Gable et al., published as WO 2015/048788, is incorporated herein by reference in its entirety.

TABLE 1

Wt %	Reference Alloy	Alloy 1	Alloy 2	Alloy 3	Alloy 4	Alloy 5	Alloy 6
Zn	5.0	5.0	5.0	5.0	4.4	4.4	4.4
Mg	1.8	1.8	1.8	1.8	1.5	1.5	1.5
Fe	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Cu	0.04	0.08	0.15	0.30	0.08	0.15	0.30
Zr	0.04	0.04	0.04	0.04	0.04	0.04	0.04

[0036] Table 1 shows the elemental composition of six example alloys as compared to a Reference Alloy. Alloys 1-3 have 5.0 wt % Zn and 1.8 wt % Mg, and Alloys 4-6 have 4.4 wt % Zn and 1.5 wt % Mg. Alloys 1-3 and Alloys 4-6, respectively, increase in the amount of Cu from 0.08 wt %, 0.15 wt % Cu, and 0.30 wt % Cu.

TABLE 2

	T6 Temper Properties		A76 Temper Properties		
	Tensile Yield Strength (MPa)	5 × 5 Ano Delam Defects	Tensile Yield Strength (MPa)	5 × 5 Ano Delam Defects	SCC Immersion % crack@2 hour
Reference Alloy	390	13	340	4	80-95
Alloy 1	400	5	340	1	77
Alloy 2	401	4	343	2	94
Alloy 3	406	1	332	0	0
Alloy 4	354	3	319	1	0
Alloy 5	354	0	320	1	0
Alloy 6	364	0	337	0	0

[0037] In some variations, reduced anodized chipping from increased copper as compared to the Reference Alloy. With reference to Table 2, an increased amount of Cu to 0.08, 0.15, and 0.30 results in a dramatic decrease in anodization delamination as compared to the Reference Alloy.

[0038] Table 2 depicts the tensile yield strength and a 5×5 anodization delamination test data Alloys 1-6, as compared to the Reference Alloy, under T6 and A76 tempering conditions. T6 refers to peak aging heat treatment in which the alloy is water quenched following extrusion, and subsequent aging by a two-step heat treatment of first heating at 100° C. for 5 hours, and second heating at 150° C. for 15 hours. A76 refers to an over-aging treatment to an alloy. In particular, the A76 treatment can refer to an aging treatment in which the alloy is forced-air cooled, extruded, and aged by a two-step heat treatment of heating at 100° C. for 5 hours followed by heated at 165° C. for 12 hours. T6 tempering typically improves alloy strength, while A76 tempering typically decreases SCC.

[0039] Increasing the amount of Cu results in surprising improvements in a number of alloy properties under T6 and A76 tempering conditions. Under T6 tempering conditions, the anodization delamination drops precipitously, with a small increase of Cu from 0.04 wt % Cu to 0.08 wt % Cu. The effect is more pronounced at 0.15 wt % Cu and 0.30 wt % Cu, particularly for Alloys 5 and 6 which have lower Mg and Zn.

[0040] Alloy 3 and Alloy 6 each have 0.30 wt % Cu. These alloys have substantially improved post-anodization chipping resistance compared to the Reference Alloy. FIG. **1** depicts the anodized chipping stress test for Alloy 3 and Alloy 6 as compared to the Reference Alloy under combined T6 and A76 temper conditions. Both Alloy 3 and Alloy 6 show a substantial improvement over the Reference Alloy. Reference Alloy tests show large number of pits formed in the cosmetic shipping test, and a substantially larger number of pits in the sharp edge chipping test than Alloy 3 or 6. More convincingly, Alloy 3 and Alloy 6 had no pits under each test under identical conditions. The elimination, or near elimination, of chipping under the tested conditions represents a surprising and dramatic improvement over Reference Alloy.

[0041] During the anodization process of forming aluminum oxide on the alloy substrate, alloying elements can accumulate underneath the coating and affect the adhesion strength between the coating and the alloy. Zn accumulation reduces anodized layer adhesion. Cu accumulation can reduce Zn accumulation, thereby improving anodized layer adhesion.

[0042] FIG. **2**A depicts a transmission electron microscope (TEM) showing the grain boundary **602** of Alloy 3 after A76 tempering. The grain boundary **602** include grain boundary precipitates **602** and **604**. The grain boundary precipitates are separate from intra-grain precipitates **608**. The TEM shows Cu-enriched MgZn precipitates. The Cu enrichment enhances the resistance to SCC. The quantity of each element in the MgZn enriched precipitates is shown in the EDS line scan in FIG. **2**B.

[0043] Stress Corrosion Cracking Resistance

[0044] With further reference to Table 2, a substantial decrease in SCC is observed from Alloy 2, which as 0.15 wt % Cu, to Alloy 3, which has 0.30 wt % Cu. The SCC does not decrease linearly with the increase in Cu. The fall from 0.15 wt % Cu was unexpected. Similarly, the precipitous fall in SCC from 0.15 wt % Cu to 0.30 wt % Cu is substantially greater than expected, and does not fall linearly with Cu. The SCC drops precipitously at lower quantities of Cu for Alloys 4-6. Alloys 4-6 have a lower yield strength.

[0045] FIG. **3** depicts the SCC test for Alloy 3 104 and Alloy 6 106 as compared to the Reference Alloy 102 for A76 temper ASTM G30 U-bend at 85 C and in a 15% NaCl solution emersion. The Reference Alloy showed nearly 100% failure at 3 hours. Neither Alloy 3 nor Alloy 6 showed close to the level of failure of the Reference Alloy at 3 hours. Neither Alloy 3 nor Alloy 6 showed 100% failure at the end of a 12 hour measurement period. As such, both Alloy 3 and Alloy 6 showed substantial improvement in the SCC test as compared to the SCC of Reference Alloy 1.

[0046] Likewise, FIG. **4** depicts the percent failure rate after two hours for Alloy 3 and Alloy 6 as compared to the Reference Alloy after A76 tempering. Both Alloy 3 and Alloy 6 showed substantially reduced failure rate at 2 hours as compared to the Reference Alloy 1.

[0047] In some variations, improved SCC resistance results from increased copper. During the manufacturing process, a grain boundary develops $MgZn_2$ precipitates that is more anodic than the aluminum anodized matrix, resulting in an SCC path through anodic dissolution mechanism. Increased Cu dissolves into the $MgZn_2$ precipitates at the grain boundary, making them less anodic and resulting in reduced SCC.

[0048] In some variations, the alloy can have a less than 50% failure rate after 1.5 hours in an immersion ASTM G30 U-bend test in a 15% NaCl solution at 85° C. In some variations, the alloy can have a less than 50% failure rate after 1.75 hours in an immersion ASTM G30 U-bend test in a 15% NaCl solution at 85° C. In some variations, the alloy can have a less than 50% failure rate after 2.0 hours in an immersion ASTM G30 U-bend test in a 15% NaCl solution at 85° C. In certain variations, the alloy with an above failure rate is tempered under A78 conditions. In certain variations, the alloy with an above failure rate is tempered under A 79 conditions. In certain variations, the alloy is Alloy 3.

[0049] As a non-limiting example, FIG. **7** depicts the percent failure as a function of soak time for Alloy 3 at A78 and A79 temper conditions as compared to the Reference Alloy at A76 temper conditions. Alloy 3 tempered under A78 or 79 conditions showed a lower failure as a function of soak time in an immersion ASTM G30 U-bend test in a 15% NaCl solution at 85° C. Alloy 3 showed lower SCC failure rates than the Reference Alloy. Alloy 3 at both A78 and 79 temper conditions had a yield strength of greater than 370 MPa (A78 temper resulted in a yield strength of 375 MPa, while A79 temper resulted in a yield strength of 384 MPa).

[0050] In some variations, the alloy can have a less than 50% failure rate in a heat soak ASTM G30 U-bend test at 90% relative humidity (RH) at 65° C. at 50 hours. In some variations, the alloy SCC can have a less than 50% failure rate in a heat soak ASTM G30 U-bend test at 90% relative humidity (RH) at 65° C. at 100 hours. In some variations, the alloy SCC can have a less than 50% failure rate in a heat soak ASTM G30 U-bend test at 90% relative humidity (RH) at 65° C. at 150 hours. In certain variations, the alloy with an above failure rate is tempered under A78 conditions. In certain variations, the alloy with an above failure rate is tempered under A 79 conditions. In certain variations, the alloy is Alloy 3. As referred to herein, the heat soak ASTM G30 U-bend test is as of May 1, 2022.

[0051] As a non-limiting example, FIG. **8** depicts the percent failure as a function of soak time for Alloy 3 under both A78 and A79 temper conditions as compared to the Reference Alloy at A76 temper conditions. Alloy 3 under both A78 and A79 temper conditions failed as a function of soak time in less than 50% of instances in a heat soak ASTM G30 U-bend test at 90% relative humidity (RH) at 65° C. Failure reached a plateau, failing in less than 50% of instances at 50 hours, 100 hours, and 150 hours for Alloy 3 tempered under both A78 and A79 conditions. Alloy 3 showed lower SCC failure rates than the Reference Alloy.

[0052] Yield Strength

[0053] In some variations, the yield strength of the alloy is at least 340 MPa. In some variations, the yield strength of the alloy is at least 350 MPa. In some variations, the yield strength of the alloy is at least 360 MPa. In some variations, the yield strength of the alloy is at least 370 MPa. In some variations, the yield strength of the alloy is at least 380 MPa. In some variations, the yield strength of the alloy is at least 390 MPa. In certain variations, the alloy is tempered under A78 conditions. In certain variations, the alloy is tempered under A 79 conditions. In certain variations, the alloy is Alloy 3.

[0054] In some variations, the alloy can have both a yield strength greater than 370 MPa and SCC resistance with a single temper condition. An alloy tempered at a single condition inherently has a color matching the alloy used in other locations.

[0055] In some instances, the alloy can have a yield strength and an SCC resistance above a threshold. If an alloy having different temper conditions at two different locations to have yield strength and SCC resistance, the two tempers may not match in color. An alloy at a single temper with both yield strength and SCC resistance can provide a consistent color in a device.

[0056] Alloys under temper conditions showed no delamination. FIG. **9** depicts de-laminization performance for Alloy 3 under T6, A76, and A79 temper conditions. Alloy 3 showed no delamination under multiple temper conditions. Each of the temper conditions showed zero vertices with delamination for two samples.

[0057] Zinc and Magnesium

[0058] In some variations, the alloy has equal to or greater than 4.0 wt % Zn. In some variations, the alloy has equal to or greater than 4.1 wt % Zn. In some variations, the alloy has equal to or greater than 4.2 wt % Zn. In some variations, the alloy has equal to or greater than 4.3 wt % Zn. In some variations, the alloy has equal to or greater than 4.4 wt % Zn. In some variations, the alloy has equal to or greater than 4.5 wt % Zn. In some variations, the alloy has equal to or greater than 4.6 wt % Zn. In some variations, the alloy has equal to or greater than 4.7 wt % Zn. In some variations, the alloy has equal to or greater than 4.8 wt % Zn. In some variations, the alloy has less than or equal to than 4.9 wt % Zn. In some variations, the alloy has equal to or greater than 5.0 wt % Zn. In some variations, the alloy has equal to or greater than 5.1 wt % Zn. In some variations, the alloy has equal to or greater than 5.2 wt % Zn. In some variations, the alloy has equal to or greater than 5.3 wt % Zn. In some variations, the alloy has equal to or greater than 5.4 wt % Zn.

[0059] In some variations, the alloy has less than or equal to than 5.5 wt % Zn. In some variations, the alloy has less than or equal to than 5.4 wt % Zn. In some variations, the alloy has less than or equal to than 5.3 wt % Zn. In some variations, the alloy has less than or equal to than 5.2 wt % Zn. In some variations, the alloy has less than or equal to than 5.1 wt % Zn. In some variations, the alloy has less than or equal to than 5.0 wt % Zn. In some variations, the alloy has less than or equal to than 4.9 wt % Zn. In some variations, the alloy has less than or equal to than 4.8 wt % Zn. In some variations, the alloy has less than or equal to than 4.7 wt % Zn. In some variations, the alloy has less than or equal to than 4.6 wt % Zn. In some variations, the alloy has less than or equal to than 4.5 wt % Zn. In some variations, the alloy has less than or equal to than 4.4 wt % Zn. In some variations, the alloy has less than or equal to than 4.3 wt % Zn. In some variations, the alloy has less than or equal to than 4.2 wt % Zn. In some variations, the alloy has less than or equal to than 4.1 wt % Zn.

[0060] In some variations, the alloy has 4.0-5.5 wt % Zn. In some variations, the alloy has 4.0-5.0 wt % Zn. In some variations, the alloy has 4.5-5.5 wt % Zn.

[0061] In some variations, the alloy has equal to or greater than 1.0 wt % Mg. In some variations, the alloy has equal to or greater than 1.1 wt % Mg. In some variations, the alloy has equal to or greater than 1.2 wt % Mg. In some variations, the alloy has equal to or greater than 1.3 wt % Mg. In some variations, the alloy has equal to or greater than 1.4 wt % Mg. In some variations, the alloy has equal to or greater than 1.5 wt % Mg. In some variations, the alloy has equal to or greater than 1.6 wt % Mg. In some variations, the alloy has equal to or greater than 1.7 wt % Mg. In some variations, the alloy has equal to or greater than 1.8 wt % Mg. In some variations, the alloy has equal to or greater than 1.9 wt % Mg. In some variations, the alloy has equal to or greater than 2.0 wt % Mg. In some variations, the alloy has equal to or greater than 2.1 wt % Mg. In some variations, the alloy has equal to or greater than 2.2 wt % Mg. In some variations, the alloy has equal to or greater than 2.3 wt % Mg. In some variations, the alloy has equal to or greater than 2.4 wt % Mg.

[0062] In some variations, the alloy has less than or equal to 2.5 wt % Mg. In some variations, the alloy has less than or equal to 2.4 wt % Mg. In some variations, the alloy has less than or equal to 2.3 wt % Mg. In some variations, the alloy has less than or equal to 2.2 wt % Mg. In some variations, the alloy has less than or equal to 2.1 wt % Mg. In some variations, the alloy has less than or equal to 2.0 wt % Mg. In some variations, the alloy has less than or equal to 1.9 wt % Mg. In some variations, the alloy has less than or equal to 1.8 wt % Mg. In some variations, the alloy has less than or equal to 1.7 wt % Mg. In some variations, the alloy has less than or equal to 1.6 wt % Mg. In some variations, the alloy has less than or equal to 1.5 wt % Mg. In some variations, the alloy has less than or equal to 1.4 wt % Mg. In some variations, the alloy has less than or equal to 1.3 wt % Mg. In some variations, the alloy has less than or equal to 1.2 wt % Mg. In some variations, the alloy has less than or equal to 1.1 wt % Mg.

In some variations, the alloy has from 1.0-2.5 wt % Mg. In some variations, the alloy has from 1.0-2.0 wt % Mg. In some variations, the alloy has from 1.3-2.5 wt % Mg.

[0063] In certain variations, the alloy has from 4.9-5.1 wt % Zn and 1.7-1.9 wt % Mg.

[0064] In certain variations, the alloy has from 4.3-4.5 wt % Zn and 1.4-1.6 wt % Mg.

[0065] In some variations, solid solution strengthening can improve the strength of a pure metal. In this alloying technique, atoms of one element, e.g. an alloying element, may be added to the crystalline lattice of another element, e.g. a base metal. The alloying element can be contained with the matrix, forming a solid solution.

[0066] Zn and Mg precipitate as Mg_xZn_y (e.g., $MgZn_2$) to form a second Mg_xZn_y phase in the alloy. This second Mg_xZn_y phase can increase the strength of the alloy by precipitation strengthening. In some variations, Mg_xZn_y precipitates can be produced from processes including rapid quenching and subsequent heat treatment, as described herein.

[0067] In some variations, the Zn/Mg wt % ratio is from 1.7-3.2. In some variations, the Zn/Mg wt % ratio is from 1.7-3.0. In some variations, the Zn/Mg wt % ratio is from 2.5-3.2.

[0068] Mg_xZn_y (e.g., $MgZn_2$) particles or precipitates can be formed and distributed in the Al. In some aspects, the alloys can have a Zn:Mg wt % ratio from 1.7-3.2. In some aspects, the Zn/Mg wt % ratio is from 2.0 to 3.5. In some variations, the Zn/Mg wt % ratio is from 2.5 to 3.5. In some variations, the Zn/Mg wt % ratio is from 2.0 to 3.2. In some variations, the Zn/Mg wt % ratio is from 2.5 to 3.0. In some variations, the alloys can have Zn to Mg (Zn/Mg) weight ratio of 2.5<Zn:Mg<3.2. In some variations, the alloys have improved SCC resistance.

[0069] Iron

[0070] In various aspects, the wt % of Fe in the alloys described herein can be lower than that for conventional 7xxx series aluminum alloys. By controlling the Fe level to be at the disclosed quantities, the alloys can appear less dark, i.e. have a lighter color, after anodization treatment, and possess fewer coarse particle defects. The amount of Fe can reduce the volume fraction of course particles, which can improve cosmetic qualities such as distinctness of image ("DOI") and Haze after anodization.

[0071] The alloys also can have lower impurity levels of Fe than commercial 7000 series aluminum alloys. The reduced Fe content in the alloys can help reduce the number of coarse secondary particles that may compromise the cosmetic appearance, both before and after anodizing. In contrast, commercial alloys have higher impurity of Fe than the alloys of the disclosure. The resulting DOI and Log Haze can be substantially improved in the alloys described herein.

[0072] The wt % of Fe can help the alloy maintain a fine grain structure. In some variations, the alloy has no greater than 0.08 wt % Fe. In some variations, the alloy has no greater than 0.10 wt % Fe. In some variations, the alloy has no greater than 0.15 wt % Fe. In some variations, the alloy has no greater than 0.20 wt % Fe. In some variations, the alloy has at least 0.04 wt %. In some variations, the alloy has at least 0.06 wt %. In some variations, the alloy has from 0.04 wt %-0.20 wt % Fe. In some variations, the alloy has from 0.04 wt %-0.15 wt % Fe. In some variations, the alloy has from 0.06 wt %-0.08 wt % Fe.

[0073] In various aspects, reduced or eliminated Zr can combine with low wt % Fe to allow for grain size control.

[0074] Zirconium

[0075] In the alloys disclosed herein, the reduction in or absence of Zr allows surprising grain structure control at a low average grain aspect ratio from sample-to-sample. In addition, reduction or elimination of Zr in the alloy can reduce elongated grain structures and/or streaky lines in finished products.

[0076] In some variations, Zr additions to the alloys can inhibit recrystallization and produce a long grain structure that can lead to undesirable anodized cosmetics. Absence or low amount of Zr in the alloys can help form equiaxed grains.

[0077] In some variations, the alloy includes no Zr. In some variations, the alloy includes at least 0.02 wt % Zr. In some variations, the alloy includes at least 0.03 wt % Zr. In some variations, the alloy includes 0.04 wt % Zr. In some variations, the alloy includes 0.05 wt % Zr. In some variations, the alloy includes at least 0.05 wt % Zr. In some variations, the alloy includes at least 0.06 wt % Zr. In some variations, the alloy includes at least 0.07 wt % Zr. In some variations, the alloy includes at least 0.08 wt % Zr. In some variations, the alloy includes equal to or less than 0.10 wt % Zr. In some variations, the alloy includes equal to or less than 0.08 wt % Zr. In some variations, the alloy includes equal to or less than 0.07 wt % Zr. In some variations, the alloy includes equal to or less than 0.06 wt % Zr. In some variations, the alloy includes equal to or less than 0.05 wt % Zr. In some variations, the alloy includes equal to or less than 0.04 wt % Zr. In some variations, the alloy includes equal to or less than 0.03 wt % Zr. In some variations, the alloy includes equal to or less than 0.02 wt % Zr. In some variations, the alloy can have 0.02-0.06 wt % Zr. In some embodiments, the alloy can have 0.03-0.05 wt % Zr. In some variations, the alloy can have from 0.04-0.06 wt % Zr. In some embodiments, the alloy can have from 0.03-0.05 wt % Zr. In still further variations the alloy can have about 0.04 wt % Zr. In further variations, the alloy can have about 0.05 wt % Zr.

[0078] In some variations, the alloys include Zr from 0 to 0.01 wt %. In some variations, the alloys include Zr less than 0.001 wt %. In some variations, the alloys include Zr greater than 0 wt %.

[0079] Titanium

[0080] In some variations, the alloy has zero Ti. In some variations, the alloy has at least 0.005 wt % Ti. In some variations, the alloy has at least 0.010 wt % Ti. In some variations, the alloy has at least 0.015 wt % Ti. In some variations, the alloy has at least 0.020 wt % Ti. In some variations, the alloy has at least 0.025 wt % Ti. In some variations, the alloy has less than or equal to 0.030 wt % Ti. In some variations, the alloy has less than or equal to 0.030 wt % Ti. In some variations, the alloy has less than or equal to 0.025 wt % Ti. In some variations, the alloy has less than or equal to 0.020 wt % Ti. In some variations, the alloy has less than or equal to 0.015 wt % Ti. In some variations, the alloy has less than or equal to 0.010 wt % Ti. In some variations, the alloy has less than or equal to 0.005 wt % Ti.

[0081] In some example variations, the alloy has 0.005 wt % Ti to 0.025 wt % Ti. In some example variations, the alloy has 0.010 to 0.020 wt % Ti.

[0082] Additional Elements

[0083] In various additional embodiments, additionally elements can be added to the alloy. In some variations, additional elements that do not exceed 0.05 wt % include Si. Additional elements that do not exceed 0.05 wt % include Si, Mn, Cr, Ga, Sn, V, B, Li, Cd, Pb, Ni, and P. In some variations, additional elements that do not exceed 0.02 include Mn, Cr, Ga, Sn, and V. Additional elements that do not exceed 0.01 include B, Li, Cd, Pb, Ni, and P. Additional elements that do not exceed 0.001 include Na and Ca. In various aspects, the combination of Mn and Cr does not exceed 0.03.

[0084] Specific Alloys

[0085] In some variations, the alloy has 3.4-5.5 wt % Zn, 1.3-2.1 wt % Mg, at least 0.07 wt % Cu, 0-0.08 wt % Zr, 0.04-0.15 wt % Fe. In some variations, the alloy can include no greater than 0.05 wt % Si, no greater than 0.02 wt % Mn, no greater than 0.02 wt % Cr, no greater than 0.02 wt % Ga, no greater than 0.02 wt % Sn, no greater than 0.02 wt % V, no greater than 0.01 wt % B, no greater than 0.01 wt % Li, no greater than 0.01 wt % Cd, no greater than 0.01 wt % Pb, no greater than 0.01 wt % Ni, and no greater than 0.01 wt % P, no greater than 0.001 wt % Na, no greater than 0.001

wt % Ca, no greater than 0.03 wt % total of Mn and Cr, no greater than 0.02 wt % of any single additional element not recited above (i.e., a single impurity), and no greater than 0.10 wt % total of all additional elements not described above (i.e., total impurities), with the balance being aluminum. In some of additional variations, the alloy can have an amount of any element described herein. For example, in some variations, the alloy can have at least 0.12 wt % Cu. In some additional variations, the alloy has at least 0.28 wt % Cu. In some of these variations, the alloy can be T6 tempered. In some variations, the alloy can be A76 tempered.

[0086] In some variations, the alloy has 4.5-5.5 wt % Zn, 1.5-2.1 wt % Mg, at least 0.07 wt % Cu, 0-0.08 wt % Zr, 0.04-0.15 wt % Fe. In some variations, the alloy can include no greater than 0.05 wt % Si, no greater than 0.02 wt % Mn, no greater than 0.02 wt % Cr, no greater than 0.02 wt % Ga, no greater than 0.02 wt % Sn, no greater than 0.02 wt % V, no greater than 0.01 wt % B, no greater than 0.01 wt % Li, no greater than 0.01 wt % Cd, no greater than 0.01 wt % Pb, no greater than 0.01 wt % Ni, and no greater than 0.01 wt % P, no greater than 0.001 wt % Na, no greater than 0.001 wt % Ca, no greater than 0.03 wt % total of Mn and Cr, no greater than 0.02 wt % of any single additional element not recited above (i.e., a single impurity), and no greater than 0.10 wt % total of all additional elements not described above (i.e., total impurities), with the balance being aluminum. In some of additional variations, the alloy can have an amount of any element described herein. For example, in some variations, the alloy can have at least 0.12 wt % Cu. In some additional variations, the alloy has at least 0.28 wt % Cu. In some of these variations, the alloy can be T6 tempered. In some variations, the alloy can be A76 tempered.

[0087] In some variations, the alloy has 4.0-4.8 wt % Zn, 1.2-1.8 wt % Mg, at least 0.07 wt % Cu, 0-0.08 wt % Zr, 0.04-0.15 wt % Fe. In some variations, the alloy can include no greater than 0.05 wt % Si, no greater than 0.02 wt % Mn, no greater than 0.02 wt % Cr, no greater than 0.02 wt % Ga, no greater than 0.02 wt % Sn, no greater than 0.02 wt % V, no greater than 0.01 wt % B, no greater than 0.01 wt % Li, no greater than 0.01 wt % Cd, no greater than 0.01 wt % Pb, no greater than 0.01 wt % Ni, and no greater than 0.01 wt % P, no greater than 0.001 wt % Na, no greater than 0.001 wt % Ca, no greater than 0.03 wt % total of Mn and Cr, no greater than 0.02 wt % of any single additional element not recited above (i.e., a single impurity), and no greater than 0.10 wt % total of all additional elements not described above (i.e., total impurities), with the balance being aluminum. In some of additional variations, the alloy can have an amount of any element described herein. For example, in some variations, the alloy can have at least 0.12 wt % Cu. In some additional variations, the alloy has at least 0.28 wt % Cu. In some of these variations, the alloy can be T6 tempered. In some variations, the alloy can be A76 tempered.

[0088] In further aspects, the toughness of the peak aged alloys remains the same or increases over that of the Reference Alloy. As depicted in FIG. **5**, Alloy 6 shows showed an improved Charpy impact energy over that of the Reference Alloy for peak aged (T6) alloys. Alloy 6 after peak aging absorbed more impact energy per square unit area than the Reference Alloy. This observed effect held for each orientation of Alloy 6. The Charpy Impact Energy is not reduced in over-aged (A76) Alloy 6, and is not diminished in peak aged (T6) or over-aged (A76) Alloy 3.

[0089] Extrusion Properties

[0090] In some variations, the alloys can be extruded over an extrusion temperature range that maintains the temperature and allows the disclosed alloy to be press quenchable. Higher strength alloys (such as 7000 series alloys) are extruded under higher pressure. Surprisingly, the disclosed alloys achieve similar extrudability while at a higher T6 tensile yield strength.

[0091] Grain Morphology Properties

[0092] Surprisingly, the grain morphology of Alloys 1-6 does not deviate from the grain morphology of the Reference Alloy, in spite of the significant improvements in other properties. FIG. **6** depicts the extrusion grain microstructure including average grain size, grain aspect ratio, and as-large-as grain size for Alloy 3 and Alloy 6 as compared to the Reference Alloy. Both Alloy 3 and Alloy 6 achieved similar grain structures to the Reference Alloy.

[0093] Grain Size and Aspect Ratio

[0094] In various aspects, the alloys have equiaxed grains.

[0095] FIG. **6** depicts a comparison of the Reference Alloy to Alloy 3 and Alloy 6. The average grain size, grain aspect ratio, and as-large-as grain size of Alloy 3 and Alloy 6 did not deviate from those of the Reference Alloy.

[0096] In some variations, the average grain size is less than or equal to 120 microns. In some variations, the average grain size is less than or equal to 110 microns. In some variations, the average grain size is less than or equal to 100 microns. In some variations, the average grain size is at least 60 microns. In some variations, the average grain size of the alloy is 65 microns. In some variations, the average grain size of the alloy is 70 microns.

[0097] In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.3. In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.2. In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.1. In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.05. In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.04. In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.03. In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.02. In some variations, the alloy has an average grain aspect ratio less than or equal to 1:1.01. In some variations, the alloy has an average grain aspect ratio equal to 1:1.

[0098] In some variations, the alloy has an average grain aspect ratio at least 0.8:1. In some aspects, the alloy has an average grain aspect ratio at least 0.9:1. In some variations, the alloy has an average grain aspect ratio at least 0.95:1. In some variations, the alloy has an average grain aspect ratio at least 0.96:1. In some variations, the alloy has an average grain aspect ratio at least 0.97:1. In some variations, the alloy has an average grain aspect ratio at least 0.98:1. In some variations, the alloy has an average grain aspect ratio at least 0.99:1.

[0099] In some variations, the as-large-as grain size is less than or equal to 350 microns. In some variations, the as-large-as grain size is less than or equal to 340 microns. In some variations, the as-large-as grain size is less than or equal to 330 microns. In some variations, the as-large-as grain size is less than or equal to 320 microns. In some variations, the as-large-as grain size is less than or equal to

310 microns. In some variations, the as-large-as grain size is less than or equal to 300 microns. In some variations, the as-large-as grain size is at least 150 microns. In some variations, the as-large-as grain size is at least 160 microns. In some variations, the as-large-as grain size is at least 170 microns. In some variations, the as-large-as grain size is at least 180 microns. In some variations, the as-large-as grain size is at least 190 microns. In some variations, the as-large-as grain size is at least 200 microns.

[0100] Cosmetics

[0101] The disclosed alloys provide improved lightness and clarity in combination with increased yield strength and hardness over conventional alloys. In conventional Al alloys, high wt % Fe and/or Si can result in poor anodization and cosmetics. In the alloys disclosed herein, low Fe and Si result in fewer inclusions that disrupt clarity following anodization. As a result, the alloys described herein have improved clarity.

[0102] Standard methods may be used for the evaluation of cosmetics including color, gloss and haze. Gloss describes the perception of a surface appearing "shiny" when light is reflected. The Gloss Unit (GU) is defined in international standards including ISO 2813 and ASTM D523. It is determined by the amount of reflected light from a highly polished black glass standard of known refractive index of 1.567. The standard is assigned with a specular gloss value of 100. Haze describes the milky halo or bloom seen on the surface of high gloss surfaces. Haze is calculated using the angular tolerances described in ASTM E430. The instrument can display the natural haze value (HU) or Log Haze Value (HU_{LOG}). A high gloss surface with zero haze has a deep reflection image with high contrast. DOI (Distinctness Of Image) is, as the name implies, a function of the sharpness of a reflected image in a coating surface, based on ASTM D5767. Orange peel, texture, flow out, and other parameters can be assessed in coating applications where high gloss quality is becoming increasingly important. The measurements of gloss, haze, and DOI may be performed by testing equipment, such as Rhopoint IQ.

[0103] By using the aluminum alloys of the present disclosure, defects viewed through the anodized layer were reduced, while maintaining yield strength and hardness, thereby providing a high gloss and high distinctness of image with surprisingly low haze.

[0104] Processing

[0105] In some embodiments, a melt for an alloy can be prepared by heating the alloy, including the composition. After the melt is cooled to room temperature, the alloys may be subjected to various heat treatments, such homogenization, extruding, forging, aging, and/or other forming or solution heat treatment techniques.

[0106] The Mg_xZn_y phase in the alloys described herein may be both within the grains and at the grain boundary. The Mg_xZn_y phase may constitute about 3 vol % to about 6 vol % of the alloys. Mg_xZn_y may be formed as discrete particles and/or linked particles. Various heat treatments can be used to guide the formation of Mg_xZn_y as discrete particles, rather than linked particles. In various aspects, discrete particles can result in better strengthening than linked particles.

[0107] In some embodiments, the cooled alloy can be homogenized by heating to an elevated temperature, such as 500° C., and held at the elevated temperature for a period of time, such as for about 8 hours. It will be appreciated by those skilled in the art that the heat treatment conditions (e.g. temperature and time) may vary. Homogenization refers to a process in which high-temperature soaking is used at an elevated temperature for a period of time. Homogenization can reduce chemical or metallurgical segregation, which may occur as a natural result of solidification in some alloys. In some embodiments, the high-temperature soaking is conducted for a dwell time, e.g. from about 4 hours to about 48 hours. It will be appreciated by those skilled in the art that the heat treatment condition (e.g. temperature and time) may vary.

[0108] In some embodiments, the homogenized alloy can be hot-worked, e.g., extruded. Extrusion is a process for converting a metal ingot or billet into lengths of uniform cross section by forcing the metal to flow plastically through a die orifice.

[0109] In some embodiments, the hot-worked alloys can be solution heat-treated at elevated temperatures above 450° C. for a period of time, e.g. 2 hours. The solution heat treatments can alter the strength of the alloy.

[0110] After the solution-heat treatment, the alloy can be aged at a first temperature and time, e.g. 100° C. for about 5 hours, then heated to a second temperature for a second period of time, e.g. 150° C. for about 9 hours, and then quenched with water. Aging (or tempering) is a heat treatment at an elevated temperature, and may induce a precipitation reaction to form Mg_xZn_y precipitates. In some embodiments, aging may be conducted at a first temperature for a first period of time and followed at a second temperature for a second period of time. Single temperature heat treatments may also be used, for example, at 120° C. for 24 hours. It will be appreciated by those skilled in the art that the heat treatment condition (e.g. temperature and time) may vary.

[0111] The alloy can be tempered under various tempering conditions known in the art. IN some variations, the alloy can be tempered under an T6, A79, or A76 condition. In other variations, the alloy can be tempered under an A78 condition. In further variations, the alloy can be tempered under an A79 condition.

[0112] In further embodiments, the alloy may be optionally subjected to a stress-relief treatment between the solution heat-treatment and the aging heat-treatment. The stress-relief treatment can include stretching the alloy, compressing the alloy, or combinations thereof.

[0113] Anodizing and Blasting

[0114] In some embodiments, the alloys can be anodized. Anodizing is a surface treatment process for metal, most commonly used to protect aluminum alloys. Anodizing uses electrolytic passivation to increase the thickness of the natural oxide layer on the surface of metal parts. Anodizing may increase corrosion resistance and wear resistance, and may also provide better adhesion for paint primers and glues than bare metal. Anodized films may also be used for cosmetic effects, for example, it may add interference effects to reflected light.

[0115] The alloys described herein can be anodized using solely sulfuric acid at 20° C. and 1.5 ASD.

[0116] Without wishing to be held to a particular mechanism or mode of action, reducing free Zn can reduce anodization delamination. Alternatively, in various embodiments, some excess Zn or Mg may be present.

[0117] In some embodiments, the alloys can form enclosures for the electronic devices. The enclosures may be designed to have a blasted surface finish, or an absence of streaky lines. Blasting is a surface finishing process, for example, smoothing a rough surface or roughening a smooth surface. Blasting may remove surface materials by forcibly propelling a stream of abrasive material against a surface under high pressure.

[0118] Color

[0119] Standard methods may be used for evaluation of cosmetics including color, gloss, and haze. The color of objects may be determined by the wavelength of light that is reflected or transmitted without being absorbed, assuming incident light is white light. The visual appearance of objects may vary with light reflection or transmission. Additional appearance attributes may be based on the directional brightness distribution of reflected light or transmitted light, commonly referred to glossy, shiny, dull, clear, haze, among others. The quantitative evaluation may be performed based on ASTM Standards on Color & Appearance Measurement or ASTM E-430 Standard Test Methods for Measurement of Gloss of High-Gloss Surfaces, including ASTM D523 (Gloss), ASTM D2457 (Gloss on plastics), ASTM E430 (Gloss on high-gloss surfaces, haze), and ASTM D5767 (DOI), among others. The measurements of gloss, haze, and DOI may be performed by testing equipment, such as Rhopoint IQ.

[0120] In some embodiments, color may be quantified by parameters L*, a*, and b*, where L* stands for light brightness, a* stands for color between red and green, and b* stands for color between blue and yellow. For example, high b* values suggest an unappealing yellowish color, not a gold yellow color. Values near zero in a* and b* suggest a neutral color. Low L* values suggest dark brightness, while high L* value suggests great brightness. For color measurement, testing equipment, such as X-Rite Color i7 XTH, X-Rite Coloreye 7000 may be used. These measurements are according to CIE/ISO standards for illuminants, observers, and the L* a* b* color scale. For example, the standards include: (a) ISO 11664-1:2007(E)/CIE S 014-1/E:2006: Joint ISO/CIE Standard: Colorimetry—Part 1: CIE Standard Colorimetric Observers; (b) ISO 11664-2:2007(E)/CIE S 014-2/E:2006: Joint ISO/CIE Standard: Colorimetry—Part 2: CIE Standard Illuminants for Colorimetry, (c) ISO 11664-3:2012(E)/CIE S 014-3/E:2011: Joint ISO/CIE Standard: Colorimetry—Part 3: CIE Tristimulus Values; and (d) ISO 11664-4:2008(E)/CIE S 014-4/E:2007: Joint ISO/CIE Standard: Colorimetry—Part 4: CIE 1976 L* a* b* Colour Space.

[0121] As described herein, reducing or eliminating Cu from the alloys provides the alloy with neutral color. Alloys have the neutral color and low aspect ratios in the range 0.8-1.2 as described herein. The L*a*b* corresponding neutral color resulting at least in part from the alloy composition described herein is described herein.

[0122] In various aspects, the L* of the alloy disclosed herein is at least 85. In some instances, the L* of the alloy is at least 90.

[0123] The alloys disclosed herein can have neutral color. Neutral color refers to a* and b* that does not deviate beyond certain values close to 0. In various aspects, a* is not less than −0.5. In various aspects, a* is not less than −0.25. In various aspects, a* is not greater than 0.25. In various aspects, a* is not greater than 0.5. In further aspects, a* is not less than −0.5 and not greater than 0.5. In further aspects, a* is not less than −0.25 and not greater than 0.25.

[0124] In various aspects, b* is not less than −1.0. In various aspects, b* is not less than −0.5. In various aspects, b* is not less than 0.0. In various aspects, b* is not less than 0.5. In various aspects, b* is not less than 1.0. In various aspects, b* is not less than 1.5. In various aspects, b* is not greater than 0.0. In various aspects, b* is not greater than 0.5. In various aspects, b* is not greater than 1.0. In various aspects, b* is not greater than 1.25. In various aspects, b* is not greater than 1.50. In various aspects, b* is not greater than 1.75. In various aspects, b* is not greater than 2.0. In various aspects, b* is not greater than 2.35. In various aspects, b* is not greater than 2.5. In various aspects, b* is not greater than 2.75. In various aspects, b* is not greater than 3.0.

[0125] FIG. **10** depicts the color difference from a target value for L*, a*, and b* for Alloy 3 under temper conditions T6, A76, and A79. Despite three different tempers, a narrow color range was achieved. There was little temper-to-temper variation for each of L*, a*, and b*. For each of the non-dyed anodized, dark color variant, and light color variant alloys, each of L*, a*, and b* was consistent between tempers. The color was also consistent between samples for each temper within each color variant.

[0126] In various embodiments, the alloys may be used as housings or other parts of an electronic device, such as, for example, a part of the housing or casing of the device. Devices can include any consumer electronic device, such as cell phones, desktop computers, laptop computers, and/or portable music players. The device can be a part of a display, such as a digital display, a monitor, an electronic-book reader, a portable web-browser, and a computer monitor. The device can also be an entertainment device, including a portable DVD player, DVD player, Blue-Ray disk player, video game console, or music player, such as a portable music player. The device can also be a part of a device that provides control, such as controlling the streaming of images, videos, sounds, or it can be a remote control for an electronic device. The alloys can be part of a computer or its accessories, such as the hard driver tower housing or casing, laptop housing, laptop keyboard, laptop track pad, desktop keyboard, mouse, and speaker. The alloys can also be applied to a device such as a watch or a clock.

[0127] In various further embodiments, more than one alloy can be used in a device casing. For example, an alloy having increased SCC resistance can be placed on the edges of a casing, while alloy without this difference is in the middle of the casing.

[0128] Having described several embodiments, it will be recognized by those skilled in the art that various modifications, alternative constructions, and equivalents may be used without departing from the spirit of the disclosure. Additionally, a number of well-known processes and elements have not been described in order to avoid unnecessarily obscuring the embodiments disclosed herein. Accordingly, the above description should not be taken as limiting the scope of the document.

[0129] Those skilled in the art will appreciate that the presently disclosed embodiments teach by way of example and not by limitation. Therefore, the matter contained in the above description or shown in the accompanying drawings should be interpreted as illustrative and not in a limiting sense. The following claims are intended to cover all generic and specific features described herein, as well as all statements of the scope of the method and system, which, as a matter of language, might be said to fall there between.

1. An aluminum alloy comprising:
3.4 to 5.5 wt % Zn;
1.3 to 2.1 wt % Mg;
at least 0.07 wt % Cu;
no greater than 0.08 wt % Zr; and
0.04 to 0.20 wt % Fe;
no greater than 0.05 wt % Ti;
wherein the balance is aluminum and incidental impurities.

2. The aluminum alloy of claim 1, comprising:
no greater than 0.05 wt % Si;
no greater than 0.05 wt % Mn;
no greater than 0.05 wt % Cr;
no greater than 0.05 wt % Ga;
no greater than 0.05 wt % Sn;
no greater than 0.05 wt % V;
no greater than 0.05 wt % B;
no greater than 0.05 wt % Li;
no greater than 0.05 wt % Cd;
no greater than 0.05 wt % Pb;
no greater than 0.05 wt % Ni;
no greater than 0.05 wt % P;
no greater than 0.05 wt % Na;
no greater than 0.05 wt % Ca;
no greater than 0.03 wt % total of Mn and Cr;
no greater than 0.02 wt % of any one additional element; and
no greater than 0.10 wt % total of additional elements.

3. The aluminum alloy according to claim 1, comprising at least 0.24 wt % Cu.

4. The aluminum alloy according to claim 1, comprising at least 0.28 wt % Cu.

5. The aluminum alloy according to claim 1, comprising 4.5-5.5 wt % Zn and 1.5-2.1 wt % Mg.

6. The aluminum alloy according to claim 1, comprising 4.0-4.8 wt % Zn and 1.2-1.8 wt % Mg.

7. The aluminum alloy according to claim 1, wherein the alloy having a wt % ratio of Zn to Mg from 1.8-3.5.

8. The aluminum alloy according to claim 1, wherein the alloy is tempered under a T6, A79, or A76 condition.

9. The aluminum alloy according to claim 1, wherein the alloy is tempered under an A78 or an A79 condition.

10. The aluminum alloy according to claim 1, wherein the alloy has a yield strength of at least 370 MPa.

11. The aluminum alloy according to claim 1, wherein the alloy has less than 50% failure rate at 1.5 hours in an immersion ASTM G30 U-bend test in a 15% NaCl solution at 85° C.

12. The aluminum alloy according to claim 1, wherein the alloy has less than 50% failure rate in a heat soak ASTM G30 U-bend test at 90% relative humidity (RH) at 65° C. at 50 hours.

13. A method for producing an aluminum alloy, the method comprising:
forming a melt that comprises:
3.4 to 5.5 wt % Zn;
1.3 to 2.1 wt % Mg;
at least 0.07 wt % Cu;
no greater than 0.08 wt % Zr;
0.04 to 0.20 wt % Fe;
wherein the balance is aluminum and incidental impurities;
cooling the melt to room temperature to from a cooled melt;
homogenizing the cooled melt by heating to a first elevated temperature to form a homogenized alloy;
hot-working the homogenized alloy to form a hot-worked alloy;
solution-treating the hot-worked alloy at a second elevated temperature to form a solution treated alloy; and
tempering the solution treated alloy at a third elevated temperature for a period of time to produce the aluminum alloy.

14. The method of claim 13, wherein the melt comprises:
no greater than 0.05 wt % Si;
no greater than 0.05 wt % Mn;
no greater than 0.05 wt % Cr;
no greater than 0.05 wt % Ti;
no greater than 0.05 wt % Ga;
no greater than 0.05 wt % Sn;
no greater than 0.05 wt % V;
no greater than 0.05 wt % B;
no greater than 0.05 wt % Li;
no greater than 0.05 wt % Cd;
no greater than 0.05 wt % Pb;
no greater than 0.05 wt % Ni;
no greater than 0.05 wt % P;
no greater than 0.05 wt % Na;
no greater than 0.05 wt % Ca;
no greater than 0.03 wt % total of Mn and Cr;
no greater than 0.02 wt % of any one additional element; and
no greater than 0.10 wt % total of additional elements.

15. The method according to claim 13, comprising at least 0.28 wt % Cu.

16. The method according to claim 13, wherein the tempering is under a T6, A79, or A76 condition.

17. The method according to claim 13, wherein the tempering is under an A78 or an A79 condition.

18. The method according to claim 13, wherein the alloy has a yield strength of at least 370 MPa.

19. The method according to claim 13, wherein the alloy has less than 50% failure rate at 1.5 hours in an immersion ASTM G30 U-bend test in a 15% NaCl solution at 85° C.

20. The method according to claim 13, wherein the alloy has less than 50% failure rate in a heat soak ASTM G30 U-bend test at 90% relative humidity (RH) at 65° C. at 50 hours.

21. An article comprising an alloy comprising:
3.4 to 5.5 wt % Zn;
1.3 to 2.1 wt % Mg;
at least 0.07 wt % Cu;
no greater than 0.08 wt % Zr; and
0.04 to 0.20 wt % Fe;
wherein the balance is aluminum and incidental impurities.

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