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(54) **ALUMINIUM ALLOY HAVING VISIBLE GRAINS AND ALUMINIUM ALLOY COLORED BY DOUBLE ANODIZATION**

(57) Embodiments relate to a type of aluminum alloy with grains visible to naked eyes. The aluminum alloy may have an average grain size of at least 100 μm . The aluminum alloy can be produced by a process such as casting, extrusion, solutionizing, aging, and etching. The solutionizing causes recrystallization of aluminum and

causes grains of the aluminum to grow. Compared with the solutionizing, the aging is performed at lower temperature but enhances strength of the aluminum alloy. The etching makes grain boundaries of the aluminum alloy more prominent, rendering the grains of the aluminum alloy visible to a naked human eye.

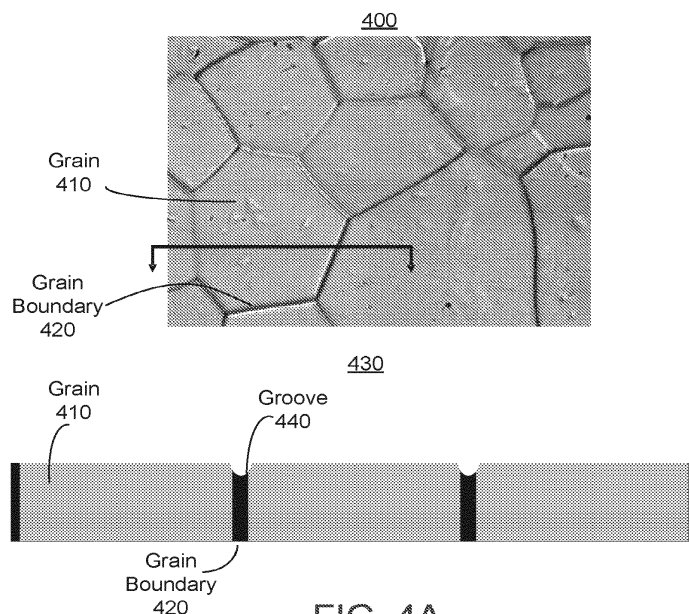


FIG. 4A

Description**BACKGROUND**

[0001] The present disclosure generally relates to aluminum alloy, and specifically relates to aluminum alloy having visible grains and aluminum alloy colored by double anodization.

[0002] Aluminum alloy are widely used. However, most metallurgical features of currently available aluminum alloy are not visible to a human eye. For example, grain boundaries of currently available aluminum alloy are microscopic in size and they cannot be seen or analyzed without optical magnification. Also, currently available aluminum alloy barely have any cosmetic appearance by themselves, which limits their use in products.

SUMMARY

[0003] Embodiments relate to processing an aluminum alloy to render grain boundaries visible to a human eye. The iron concentration in the aluminum alloy is reduced to obtain a concentration of iron below a threshold value. The aluminum alloy is then heated at a first temperature for a period of time to cause recrystallization of aluminum. The aluminum alloy is aged at a second temperature for another period of time to enhance the strength of the aluminum alloy. The second temperature is lower than the first temperature.

[0004] In one or more embodiments, the average grain size of the aluminum alloy is grown to at least 100 μm .

[0005] In one or more embodiments, the growing of the average grain size is performed during a solutionizing process.

[0006] In one or more embodiments, the solutionizing temperature is higher than 480 °C.

[0007] In one or more embodiments, the aging is performed at a temperature lower than a temperature at which the solutionizing process is performed.

[0008] In one or more embodiments, the iron concentration is reduced during a casting process.

[0009] In one or more embodiments, the method may comprise reducing one or more of zirconium, scandium, titanium and carbide.

[0010] In one or more embodiments, rendering of the grain boundaries visible comprises etching grain boundaries of the aluminum alloy.

[0011] In one or more embodiments, the etching is performed using one selected from a group comprising Caustic Soda (NaOH), Hydrofluoric Acid (HF), and Iron III Chloride (FeCl₃), or any combination thereof.

[0012] In one or more embodiments, the rendering of the grain boundaries visible comprises precipitating anodic phases on the grain boundaries.

[0013] In one or more embodiments, the method may comprise:

casting the aluminum alloy using a direct chill cast

process; and

extruding the casted aluminum alloy to a predetermined shape.

[0014] In one or more embodiments, a method for anodizing an aluminum alloy may comprise:

etching grain boundaries of the aluminum alloy;
anodizing the aluminum alloy with a first color, wherein the anodizing causes grain boundaries and grains of the aluminum alloy to be coated with an anodic oxide layer of the first color;
removing the anodic oxide layer of the first color from the grains of the aluminum alloy; and
anodizing the aluminum alloy with a second color, wherein the anodizing causes the grains of the aluminum alloy to be coated with an anodic oxide layer of the second color.

[0015] In one or more embodiments, a method may comprise performing sand blasting after etching the grain boundaries.

[0016] In one or more embodiments, the removing of the anodic oxide layer is performed by lapping.

[0017] In one or more embodiments, an aluminum alloy may be produced by a process, the process may comprise:

reducing iron concentration in the aluminum alloy to obtain a concentration of iron below a threshold value;
heating the aluminum alloy at a first temperature for a first period of time, wherein the heating causes recrystallization of aluminum;
aging the aluminum alloy at a second temperature for a second period of time, the second temperature lower than the first temperature, wherein the aging enhances strength of the aluminum alloy; and
rendering grain boundaries of the aluminum alloy visible to a human eye.

[0018] In one or more embodiments, the aluminum alloy may comprise:

growing average grain size of the aluminum alloy to at least 100 μm .

[0019] In one or more embodiments, the growing of the average grain size is performed during a solutionizing process.

[0020] In one or more embodiments, the solutionizing temperature is higher than 480 °C.

[0021] In one or more embodiments, the aging is performed at a temperature lower than a temperature at which the solutionizing process is performed.

[0022] In one or more embodiments, an aluminum alloy may be anodized by a process comprising:

etching grain boundaries of the aluminum alloy;
anodizing the aluminum alloy with a first color,

wherein the anodizing causes grain boundaries and grains of the aluminum alloy to be coated with an anodic oxide layer of the first color; removing the anodic oxide layer of the first color from the grains of the aluminum alloy; and anodizing the aluminum alloy with a second color, wherein the anodizing causes the grains of the aluminum alloy to be coated with an anodic oxide layer of the second color.

[0023] Embodiments also relate to anodizing an aluminum alloy. The grain boundaries of the aluminum alloy is etched. Then the aluminum alloy is etched with a first color. The anodizing causes grain boundaries and grains of the aluminum alloy to be coated with an anodic oxide layer of the first color. The anodic oxide layer of the first color is removed from the grains of the aluminum alloy. The aluminum alloy is anodized with a second color. The anodizing causes the grains of the aluminum alloy to be coated with an anodic oxide layer of the second color.

[0024] Embodiments according to the invention are in particular disclosed in the attached claims directed to a method for processing an aluminum alloy, a method for anodizing an aluminum alloy, a process for processing an aluminum alloy and a process for anodizing an aluminum alloy, wherein any feature mentioned in one claim category, e.g. method, can be claimed in another claim category, e.g. process, aluminum alloy, system, storage medium, and computer program product as well. The dependencies or references back in the attached claims are chosen for formal reasons only. However any subject matter resulting from a deliberate reference back to any previous claims (in particular multiple dependencies) can be claimed as well, so that any combination of claims and the features thereof is disclosed and can be claimed regardless of the dependencies chosen in the attached claims. The subject-matter which can be claimed comprises not only the combinations of features as set out in the attached claims but also any other combination of features in the claims, wherein each feature mentioned in the claims can be combined with any other feature or combination of other features in the claims. Furthermore, any of the embodiments and features described or depicted herein can be claimed in a separate claim and/or in any combination with any embodiment or feature described or depicted herein or with any of the features of the attached claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

Figure (FIG.) 1 is a diagram illustrating a process for producing aluminum alloy having visible grains by heat treatment, in accordance with an embodiment.

FIG. 2 illustrates effect of iron concentra-

tion on average grain size of solutionized aluminum alloy, in accordance with an embodiment.

5 FIG. 3 illustrates effect of solutionizing temperature on average grain size of solutionized aluminum alloy, in accordance with an embodiment.

10 FIGs. 4A and 4B illustrate etched grain boundaries of aluminum alloy, in accordance with an embodiment.

FIG. 5 illustrates differences in appearances among aluminum alloy etched by three different types of etchant, in accordance with an embodiment.

FIG. 6 illustrates effect of etching time on groove depth of grain boundaries, in accordance with an embodiment.

FIG. 7 illustrates precipitating anodic phase on grain boundaries of aluminum alloy, in accordance with an embodiment.

FIG. 8 is a flowchart illustrating a process of double anodization of an aluminum alloy sample, in accordance with an embodiment.

FIG. 9 are diagrams illustrating double anodization of aluminum alloy, in accordance with an embodiment.

FIG. 10 is an image of aluminum alloy colored by double anodization, in accordance with an embodiment.

[0026] The figures depict embodiments of the present disclosure for purposes of illustration only.

DETAILED DESCRIPTION

[0027] Embodiments relate to a type of aluminum alloy with grains visible to naked eyes. The aluminum alloy may have an average grain size of at least 100 μm . The aluminum alloy can be produced by a process such as casting, extrusion, solutionizing, aging, and etching. The solutionizing causes recrystallization of aluminum and causes grains of the aluminum to grow. Compared with the solutionizing, the aging is performed at lower temperature but enhances strength of the aluminum alloy. The etching makes grain boundaries of the aluminum alloy more prominent, rendering the grains of the aluminum alloy visible to a naked human eye.

[0028] Embodiments also relate to a type of aluminum

alloy colored by double anodization. Grain boundary of the aluminum alloy are etched so that there are grooves at the grain boundaries. The double anodization includes a first anodizing and a second anodizing. The first anodizing creates a first anodizing layer coating the grain boundaries and the grains. The first anodizing layer is then removed from the grains but remains in the grooves. The second anodizing creates a second anodizing layer coating the grains, but not coating the grain boundaries because the grain boundaries are still coated with the first anodizing layer. The first and second anodizing layers have different colors, and therefore, the grain boundaries are distinct from the grains.

Visible Grain

[0029] Figure (FIG.) 1 is a diagram illustrating a process 100 for producing aluminum alloy having visible grains by heat treatment, in accordance with an embodiment. The process 110 includes casting 110, extrusion 120, solutionizing 130, aging 140, and etching 150. In some embodiments, the process 100 may include different or additional steps than those described below in conjunction with FIG. 1. For example, the process 100 may further include polishing before the etching 150. Additionally, steps of the process 100 may be performed in different orders than the order described in conjunction with FIG. 1.

[0030] The casting 110 solidifies liquid aluminum alloy in a mold. In some embodiments, the casting 110 is direct chill casting that produces cylindrical or rectangular solid ingots of aluminum alloy. A cooling process of the direct chill casting includes two cycles of cooling of the aluminum alloy. The first cycle of cooling is through heat expansion through the mold, and the second cycle of cooling is through application of a coolant (e.g., water) on the ingots. The second cycle of cooling contribute majority of the cooling process.

[0031] During the casting 110, iron (Fe) concentration in the aluminum alloy is reduced. Iron is a grain inhibitor, meaning that it can inhibit grain growth. Accordingly, high concentration of iron can cause small grain size. FIG. 2 illustrates the effect of iron concentration on average grain size of solutionized aluminum alloy, in accordance with an embodiment. FIG. 2 includes two images 210 and 220 showing grains of solutionized aluminum alloy having different iron concentrations. The image 210 shows grains of solutionized aluminum alloy having an iron concentration of approximately 0.2 wt%, while the image 210 shows grains of solutionized aluminum alloy having an iron concentration of approximately 0.05 wt%.

[0032] Compared with the grains in the image 210, the grains in the image 220 has a larger average grain size. The average grain size in the image 210 is approximately 20 μm whereas the average grain size in the image 220 is approximately 60 μm to 80 μm . Thus, FIG. 2 illustrates that average grain size of solutionized aluminum alloy increases as iron concentration decreases.

[0033] In some embodiments, iron concentration in the aluminum alloy is reduced to below 0.12 wt%. For example, iron concentration in the aluminum alloy after the casting 110 is approximately 0.01 wt% or 0.03 wt%. Iron can be removed from the aluminum alloy through various methods, including reducing amount of recycled aluminum that carries high amount of iron, adding filter to the aluminum alloy during the casting 110 to remove phases containing iron, cleaning furnaces/molds that are made of iron based material to reduce iron contamination, melting aluminum in Graphite or Molybdenum based crucible to reduce iron contamination, adding alloying elements that react with iron during the casting 110, other similar methods to remove iron, or any combination thereof. Other appropriate methods for removing iron from aluminum alloy can be used. For example, iron is removed from the aluminum alloy by precipitation and separation of inter-metallic phases (e.g., Fe-rich phases) from the liquid aluminum alloys. The separation can be performed through several techniques, such as filtration, centrifugal and electromagnetic separation, or any combination thereof. As another example, iron can be removed through electroslag refining (ESR). In addition to iron, other types of grain inhibitors, such as zirconium, scandium, titanium, carbide, etc, can also be removed from the aluminum alloy.

[0034] Turning back to FIG. 1, the extrusion 120 forces the solid aluminum alloy through a die to form a predetermined shape, e.g., a predetermined cross-section. In some embodiments, the extrusion 120 forms a final shape of the aluminum alloy. Alternatively, the extrusion 120 forms an intermediate shape of the aluminum alloy and the aluminum alloy is re-shaped after the process 100. In some embodiments, the process 100 includes a different step to form the aluminum alloy into the predetermined shape, in addition to or instead of the extrusion 120. For example, examples of the different step includes three-dimensional printing, stamping, cold rolling, cold forging, or any combination thereof. In some embodiments, the aluminum alloy is preheated before the solutionizing 130, e.g., in instances of large scale manufacturing. For example, the aluminum alloy can be preheated at approximately 400 °C.

[0035] The solutionizing 130 is a heat treatment process that causes grain growth. In some embodiments, the solutionizing 130 is conducted at a temperature (i.e., solutionizing temperature) that is at least as high as a recrystallization temperature of the aluminum alloy. Thus, the solutionizing 130 is accompanied with recrystallization. Recrystallization is a process where original grains are replaced by a set of new grains and the new grains grow until the original grains have been entirely consumed. Also, because iron and other types of grain inhibitors are reduced from the aluminum alloy during the casting 110, the new grains of the aluminum alloy can grow into bigger sizes, compared with aluminum alloy having a higher concentration of iron or other types of grain inhibitors. Consequently, average grain size of the

aluminum alloy is increased after the solutionizing 130.

[0036] In some embodiments, grain growth of aluminum alloy occurs in a different heat treatment process than the solutionizing 130. For example, grain growth of aluminum alloy (e.g., AA5XXX, AA3XXX and AA1XXX alloys) occurs during an annealing treatment that causes recrystallization. The annealing treatment can either be full annealing or partial annealing. As another example, grain growth can occur during pre-heating prior to processes, such as hot stamping or hot forging.

[0037] In some embodiments, the average grain size after the solutionizing 130 is greater than 100 μm , so that the new grains are visible to a naked human eye. In one embodiment, the average grain size can fall into millimeter scale, e.g., 1-2 mm. The average grain size is at least partially dependent on solutionizing temperature. Different solutionizing temperatures can result in different grain sizes. FIG. 3 illustrates the effect of solutionizing temperature on average grain size of solutionized aluminum alloy, in accordance with an embodiment. FIG. 3 includes 6 images 310 through 360 that show grains of aluminum alloy solutionized at three different temperatures: 500 °C, 530 °C, and 545 °C. In some embodiments, the time duration of the solutionizing is two hours. Alternatively, the solutionizing time duration can be shorter or longer. Each of the temperatures corresponds to two images: one showing coarse grains on the surface of the solutionized aluminum alloy, i.e., peripheral coarse grains (PCG), and the other showing grains in the cross-section of the solutionized aluminum alloy, i.e., cross-section grains.

[0038] As illustrated by the image 310, PCG and cross-section grain of the aluminum alloy solutionized at 500 °C have different grain sizes. Grain size of the PCG is about 200 μm . But the cross-section grain, as shown in the image 340 is significantly larger than the PCG. The PCG grain sizes of the aluminum alloy solutionized at higher temperatures are larger, shown by the image 330 compared with the image 310. Also, difference between PCG and cross-section grains is lower for the aluminum alloy solutionized at higher temperatures. The grain size in the image 320 is similar to the grain size in the image 350. Difference between the grain sizes in the image 330 and 360 is not apparent. In some embodiment, 545 °C is selected as the solutionizing temperature for the aluminum alloy because it corresponds to larger grains and uniform distribution of grain size. A solutionizing temperature higher than 545 °C can be selected for generating even larger grains. However, because larger grains result in lower strength, in some other embodiments, a solutionizing temperature lower than 545 °C may be selected for consideration of strength. In some embodiments, PCG layers are removed via machining to achieve consistent grain structure.

[0039] In one embodiment, the solutionizing temperature is higher than 480 °C. For example, for 6000 series aluminum alloy, the solutionizing 130 can be conducted at 530 °C for 1 hour. The increased grain size can result in

lower strength of the aluminum alloy. The lower strength can be improved by the aging 140.

[0040] Turning back to FIG. 1, the aging 140 is another heat treatment process that increases strength of the solutionized aluminum alloy. For example, the aging 140 allows alloying elements (e.g., Fe, Mg, Si, etc.) in the aluminum alloy to diffuse through the microstructure and form intermetallic particles. The formed intermetallic particles function as a reinforcing phase, and thereby increase the strength of the solutionized aluminum alloy. Aging temperatures are lower than solutionizing temperatures. But time durations of the aging 140 can be longer than time durations of the solutionizing 130. In some embodiments, the aging 140 of 6000 series aluminum alloy is conducted at approximately 180 °C for about six hours. In other embodiments, the temperature and duration of time of the aging 140 can be different.

[0041] In some embodiments, a hardness test is conducted on the aged aluminum alloy to determine whether the aluminum alloy has sufficient strength. Also, grains size of surface coarse grains (i.e., peripheral coarse grains) can be measured for estimating strength of the aluminum alloy. If the tests show that the strength of the aluminum alloy is lower than required or preferred, one or more additional aging processes are conducted on the aluminum alloy to improve strength. In some embodiments, after the aging 140, the aluminum alloy is machined and/or polished for a smooth surface, e.g., a mirror-like finish, in order to facilitate the etching 150.

[0042] The etching 150 enhances contrast between grains boundaries and grains by creating grooves at the grain boundaries so that the grain boundaries are distinct from the grains. For example, an etchant is applied on the aged aluminum alloy for a predetermined amount of time (i.e., etching time). Atoms located on the grain boundaries dissolve in the etchant, resulting in the grooves. The grain boundaries appear as black lines and the grains become more visible.

[0043] FIG. 4A illustrates etched grain boundaries of aluminum alloy, in accordance with an embodiment, and FIG. 4B is a height map 450 of the aluminum alloy, in accordance with an embodiment. FIG. 4A includes two diagrams 400 and 430. The diagram 400 in FIG. 4A includes a plurality of grains 410 and each grain is surrounded by a plurality of grain boundaries 420. The grain boundaries 420 in the image 400 are darker than the grains 410. By zooming in a portion of the image 400, the diagram 430 shows grooves 440 of the grain boundaries 420. In one embodiment, the grooves have depth of approximately 10-50 μm . In alternative embodiments, the grooves can have a different depth. Image 450 shows cosmetic appearance of the aluminum alloy. The height map 450 shows height of the grains 410 and the grain boundaries 420. For most of the aluminum alloy, the grain boundaries 420 is at least approximately 10 μm lower than the grains 410. The differences in height enhance distinction of the grain boundaries 420 from the grains 410.

[0044] Different etchants or different etching times can result in grooves having different depth or different surface finish, causing different appearance of the aged aluminum alloy. In some embodiments, etchant is selected from a group including Caustic Soda (NaOH), Hydrofluoric Acid (HF), and Iron III Chloride (FeCl_3), or any combination thereof. Other types of etchants can also be used for the etching 150. FIG. 5 illustrates differences in appearances among aluminum alloy etched by three different types of etchant, in accordance with an embodiment. Image 510 corresponds to NaOH, image 520 corresponds to FeCl_3 , and image 530 corresponds to HF. The three images show advantages and disadvantages of the three types of etchant. NaOH gives improved appearance in general. However, in some instances, significant pitting is observed after etching at high concentration or longer time interval. The pitting may be hidden or removed with blasting or polish. Etching with FeCl_3 creates distinct grain colors, but also creates excess pitting that lead to flaking and etches grain line direction. No pitting is observed in the image 530. Also, etching by HF creates a surface having good appearance.

[0045] Different appearances can also be created by changing etching time. Turning now to FIG. 6, FIG. 6 illustrates effect of etching time on groove depth of grain boundaries, in accordance with an embodiment. FIG. 6 includes three images 610, 620, and 630, showing grain boundaries of aluminum alloy etched for three different etching times. The aluminum alloy for the three images are etched with the same type of etchant (e.g., NaOH) having the same solution concentration (e.g., 40 g/L). The image 610 corresponds to an etching time of 5 minutes, versus 10 minutes for the image 620 and 20 minutes for the image 630. As shown in FIG. 6, grain boundaries in the image 630 is more distinct than those in the image 620, and grain boundaries in the image 620 is more distinct than those in the image 610. In other words, longer etching time makes the grain boundaries in the aluminum alloy more distinct. Accordingly, different distinctions of grain boundaries can be created by changing etching time and an appropriate etching time can be determined based on requirement of distinction of grain boundaries (or requirement of groove depth).

[0046] Alternative to the etching 150, grain boundaries can be highlighted by precipitating anodic phases on the grain boundaries. In some embodiments, the grain boundaries are cathodic and grains are anodic. Precipitation of cathodic phases in the grain boundaries and subsequent exposure to a corrosive environment (e.g., 3.5 wt% NaCl solution) can result in preferential corrosion of the grains and cause the grain boundaries higher than the grains. Time of the exposure to the corrosive environment and corrosivity of the corrosive environment can be adjusted to achieve a desired height difference. Taking Al-Cu-Li system as an example, cathodic phases deposited at the grain boundaries can be non-Li containing phase. Consequently, the grains have more Li. Li is highly reactive and can make the grains more anodic. In some

other embodiments, the grain boundaries are anodic and the grains are cathodic, causing the grains higher than the grain boundaries.

[0047] FIG. 7 illustrates precipitating anodic phase on grain boundaries 720 of aluminum alloy, in accordance with an embodiment. In some embodiments, salt solution is used to anodize the grain boundaries 710. Grains 710 acts as cathode and grain boundaries 720 act as anode. The anodization causes the anodic grain boundaries to grow and have different height from the cathodic grains 710, and therefore, results in a texture different between the grains 710 and grain boundaries 720. Consequently, the grain boundaries 720 are distinct from the grains 710.

[0048] The etched aluminum alloy can be further processed. For example, the etched aluminum alloy can be colored by double anodization, which coated an anodic layer of one color on the grains and another anodic layer of a different color on the grain boundaries. More details about double anodization are provided below in conjunction with FIGs. 8 through 10.

Double Anodization

[0049] FIG. 8 is a flowchart illustrating a process 800 for double anodization of an aluminum alloy sample, in accordance with an embodiment. The process 800 creates different colors for grains and grain boundaries of the aluminum alloy sample, so that the grain boundaries are distinct from the grains. The process 800 includes lapping 810, etching 820, first anodizing 830, removing anodization layer 840, and second anodizing 850. In some embodiments, the process 800 may include different or additional steps than those described below in conjunction with FIG. 8. For example, alternatively or additionally, step 810 includes polishing. Also, steps of the process 800 may be performed in different orders than the order described in conjunction with FIG. 8.

[0050] The lapping 810 creates a smooth surface of the aluminum alloy sample. The etching 820 can be similar to the etching 160 described in conjunction with FIG. 1. The etching removes 10-50 μm between grains, i.e., creates 10-50 μm deep grooves at grain boundaries. In some embodiments, the depth of the grooves can be different. Grains of the aluminum alloy sample can be visible to a naked human eye. For example, the grains have an average grain size of at least 100 μm . Alternatively, the grains of the aluminum alloy sample are smaller and may not be visible to a human eye. In some embodiments, the process 800 includes sand blasting after the etching 820. The sand blasting smooths surface of the etched aluminum alloy sample.

[0051] The first anodizing 830 coats the aluminum alloy sample (both the grains and grain boundaries) with a first anodization layer. The first anodization layer has a first color. Accordingly, both the grains and the grain boundaries have the first color. In some embodiments, the first anodization layer is an anodic oxide layer.

[0052] The first anodization layer is removed 840, e.g.,

by lapping. For example, a layer having a depth of 10-50 μm is removed. After the removing 840, the first anodization layer coating the grains is removed. But because of the grooves at the grain boundaries, the grain boundaries are still coated with the first anodization layer.

[0053] The second anodizing 850 coats the grains of the aluminum alloy sample with another anodization layer, e.g., another anodic oxide layer. The other anodic oxide layer has a second color. The second color can be different from the first color. Because the grain boundaries are coated with the first anodization layer, the grain boundaries are not coated with the second anodization layer by the second anodizing 850. Accordingly, the grains are coated with the second color while the grain boundaries are coated with the first color. The color difference enhances contrast between the grains and the grain boundaries.

[0054] The steps in the process 100 and the process 800 can be combined, reordered, or selected in order to create a predetermined cosmetic appearance of an aluminum alloy piece. Also, different portions of an aluminum alloy piece can be processed differently for creating distinctive cosmetic appearances among those portions. For example, a predetermined pattern can be made on the aluminum alloy piece.

[0055] FIG. 9 are diagrams illustrating double anodization of aluminum alloy, in accordance with an embodiment. In the embodiments illustrated in FIG. 9, the diagrams 900, 950, and 960 each has three grains 910 and four grain boundaries 920. But in other embodiments, the aluminum alloy sample includes a different number of grains or grain boundaries. The diagram 900 illustrates the aluminum alloy sample after the first anodizing 830. As shown in the diagram 900, there are grooves 930 at the grain boundaries 920. The grooves 930 and the grains 910 are coated by a first anodization layer 940. The diagram 950 shows the aluminum alloy sample after removing 840 the first anodization layer 940. As shown in the diagram 950, the first anodization layer 940 coating the grains 910 are removed. However, some of the first anodization layer 940 coating the grooves 930 are remained in the grooves 930.

[0056] The diagram 950 shows the aluminum alloy sample after the second anodizing 850. The grains 910 are coated with the second anodizing layer 970, which can be, e.g., an anodic oxide layer. But because the grooves 930 are coated with the first anodization layer 940 before the second anodizing 850, there is no second anodizing layer 970 on top of the grooves 930. Accordingly, the grains 910 and the grain boundaries 920 are coated with two different anodization layers. In embodiments where the first anodization layer 940 has a different color from the second anodization layer 970, the grain boundaries 920 are distinct from the grains 910.

[0057] FIG. 10 is an image of aluminum alloy colored by double anodization, in accordance with an embodiment. Grain boundaries of the aluminum alloy is pink while the grains are dark blue. In one embodiment, the

grains have an average grain size of at least 100 μm . The grain boundaries and/or the grain can have different colors. Additionally, a portion of the aluminum alloy can have one color and a different portion of the aluminum alloy can have another color, e.g., for creating patterns on the aluminum alloy.

[0058] The language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the patent rights be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments is intended to be illustrative, but not limiting, of the scope of the patent rights, which is set forth in the following claims.

Claims

1. A method for processing an aluminum alloy, the method comprising:
 - reducing iron concentration in the aluminum alloy to obtain a concentration of iron below a threshold value;
 - heating the aluminum alloy at a first temperature for a first period of time, wherein the heating causes recrystallization of aluminum;
 - aging the aluminum alloy at a second temperature for a second period of time, the second temperature lower than the first temperature, wherein the aging enhances strength of the aluminum alloy; and
 - rendering grain boundaries of the aluminum alloy visible to a human eye.
2. The method of claim 1, further comprising: growing average grain size of the aluminum alloy to at least 100 μm .
3. The method of claim 2, wherein the growing of the average grain size is performed during a solutionizing process;
 - optionally, wherein the solutionizing temperature is higher than 480 °C; and/or
 - optionally, wherein the aging is performed at a temperature lower than a temperature at which the solutionizing process is performed.
4. The method of any of claims 1 to 3, wherein the iron concentration is reduced during a casting process.
5. The method of any of claims 1 to 4, further comprising reducing one or more of zirconium, scandium, titanium and carbide.
6. The method of any of claims 1 to 5, wherein rendering

- of the grain boundaries visible comprises etching grain boundaries of the aluminum alloy; optionally, wherein the etching is performed using one selected from a group comprising Caustic Soda (NaOH), Hydrofluoric Acid (HF), and Iron III Chloride (FeCl₃), or any combination thereof. 5
7. The method of any of claims 1 to 6, wherein the rendering of the grain boundaries visible comprises precipitating anodic phases on the grain boundaries. 10
8. The method of any of claims 1 to 7, further comprising:
 casting the aluminum alloy using a direct chill cast process; and
 extruding the casted aluminum alloy to a predetermined shape. 15
9. A method for anodizing an aluminum alloy, in particular an aluminum alloy processed according to the method of any of claims 1 to 8, the method comprising:
 etching grain boundaries of the aluminum alloy; 25
 anodizing the aluminum alloy with a first color, wherein the anodizing causes grain boundaries and grains of the aluminum alloy to be coated with an anodic oxide layer of the first color; removing the anodic oxide layer of the first color from the grains of the aluminum alloy; and 30
 anodizing the aluminum alloy with a second color, wherein the anodizing causes the grains of the aluminum alloy to be coated with an anodic oxide layer of the second color. 35
10. The method of claim 9, further comprising performing sand blasting after etching the grain boundaries.
11. The method of claim 9 or 10, wherein the removing of the anodic oxide layer is performed by lapping. 40
12. An aluminum alloy is produced by a process, the process comprising:
 reducing iron concentration in the aluminum alloy to obtain a concentration of iron below a threshold value; 45
 heating the aluminum alloy at a first temperature for a first period of time, wherein the heating causes recrystallization of aluminum; 50
 aging the aluminum alloy at a second temperature for a second period of time, the second temperature lower than the first temperature, wherein the aging enhances strength of the aluminum alloy; and 55
 rendering grain boundaries of the aluminum alloy visible to a human eye.
13. The aluminum alloy of claim 12, further comprising:
 growing average grain size of the aluminum alloy to at least 100 μm;
 optionally, wherein the growing of the average grain size is performed during a solutionizing process;
 optionally, wherein the solutionizing temperature is higher than 480 °C.
14. The aluminum alloy of claim 12 or 13, wherein the aging is performed at a temperature lower than a temperature at which the solutionizing process is performed.
15. An aluminum alloy, in particular an aluminum alloy produced by a process according to any of claims 12 to 14, is anodized by a process, the process comprising:
 etching grain boundaries of the aluminum alloy;
 anodizing the aluminum alloy with a first color, wherein the anodizing causes grain boundaries and grains of the aluminum alloy to be coated with an anodic oxide layer of the first color;
 removing the anodic oxide layer of the first color from the grains of the aluminum alloy; and
 anodizing the aluminum alloy with a second color, wherein the anodizing causes the grains of the aluminum alloy to be coated with an anodic oxide layer of the second color.

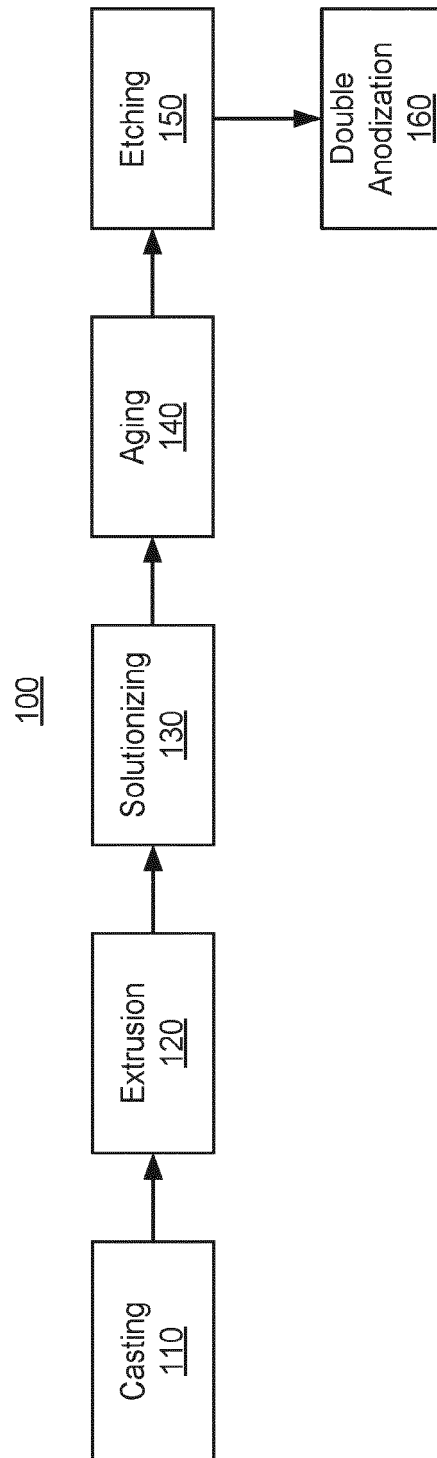
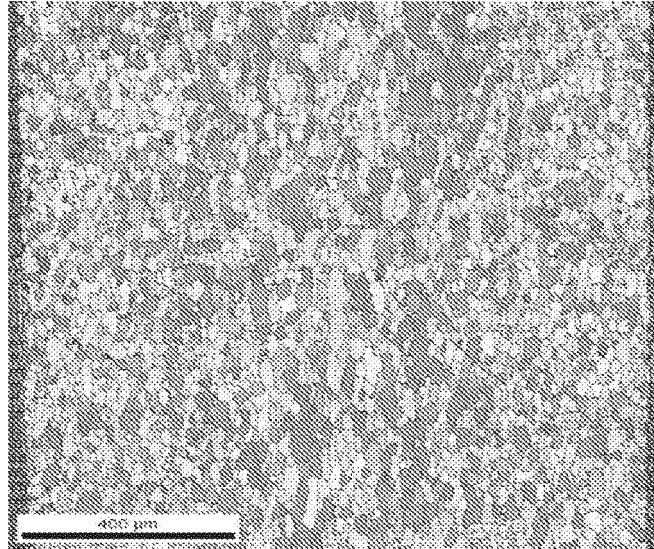


FIG. 1

Fe ~0.2wt% 210



Fe ~0.05wt% 220

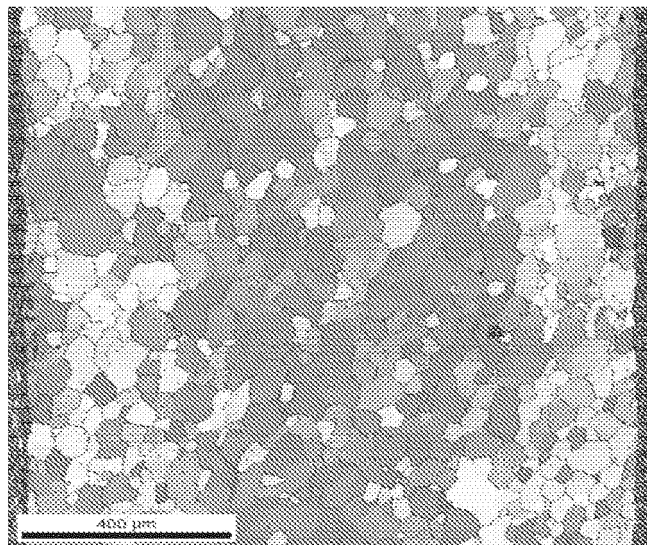


FIG. 2

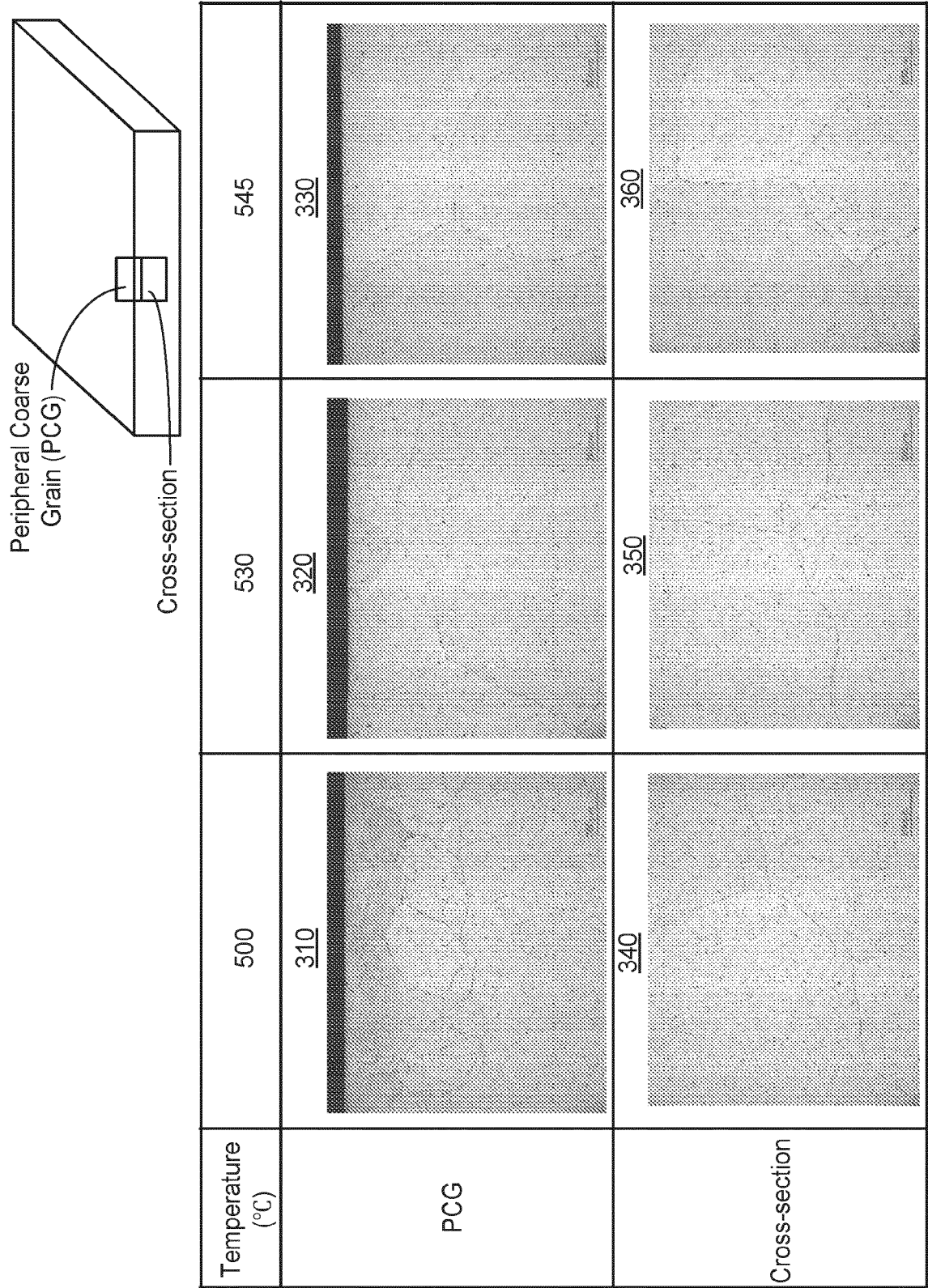


FIG. 3

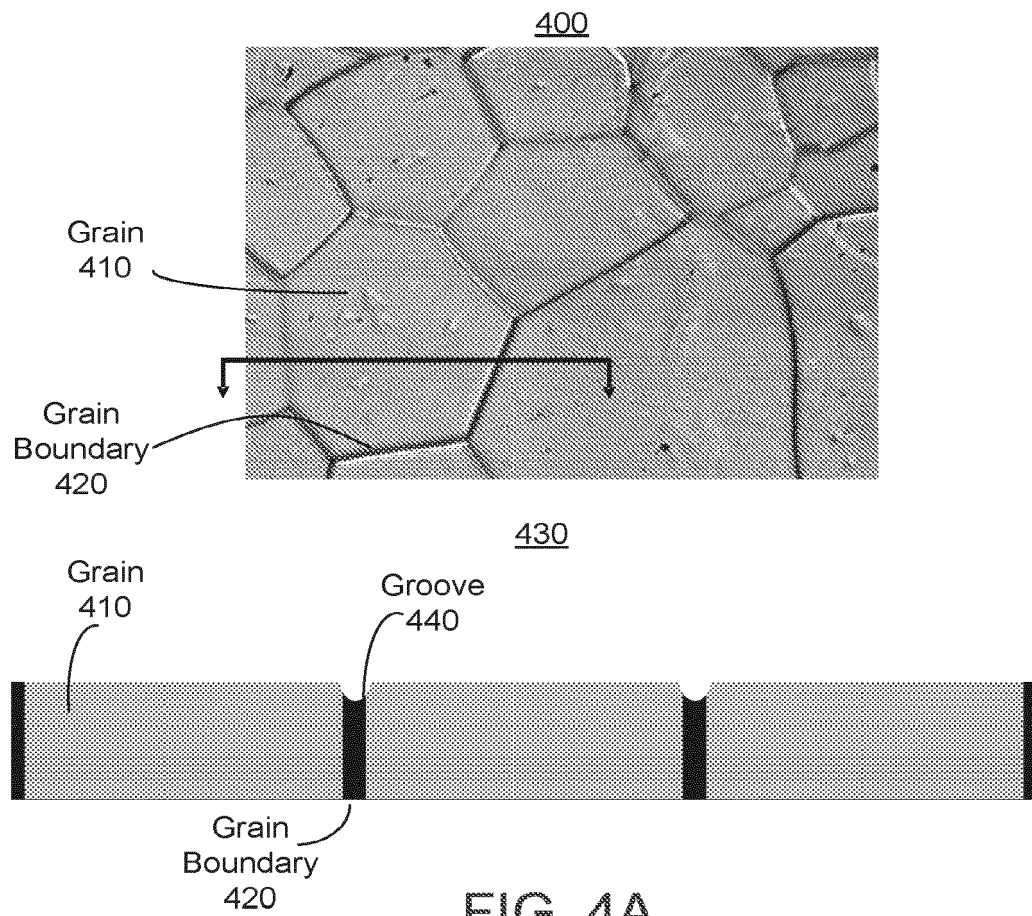


FIG. 4A

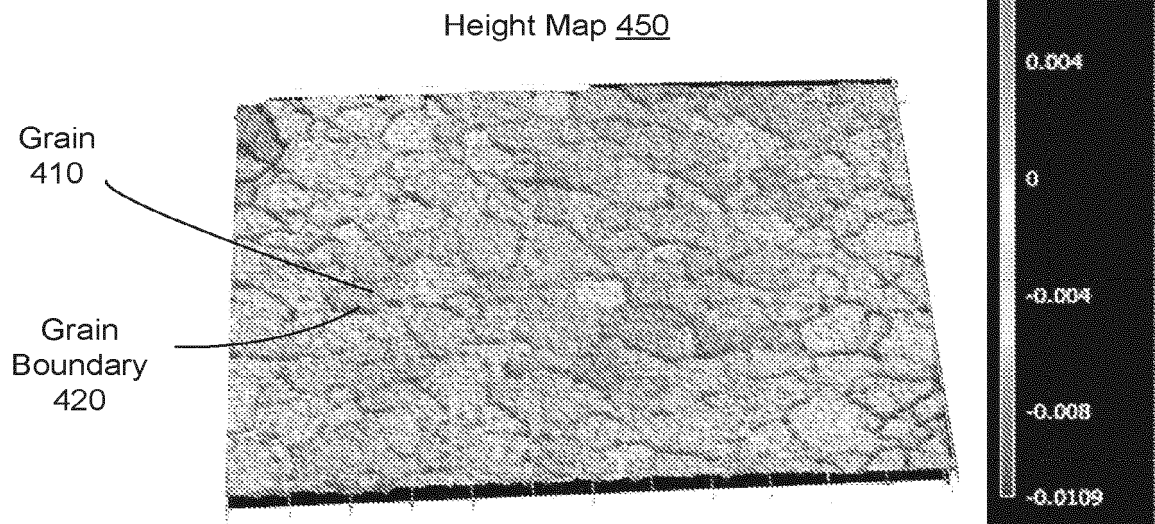
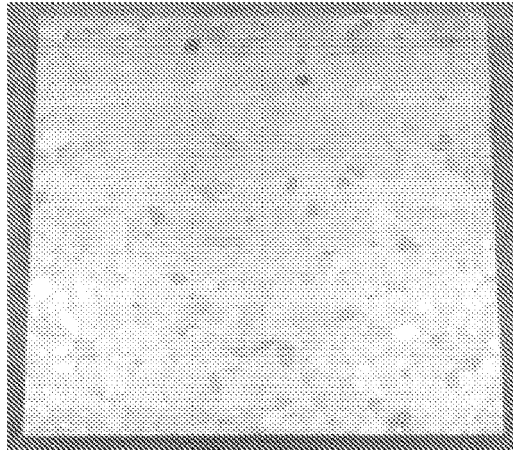


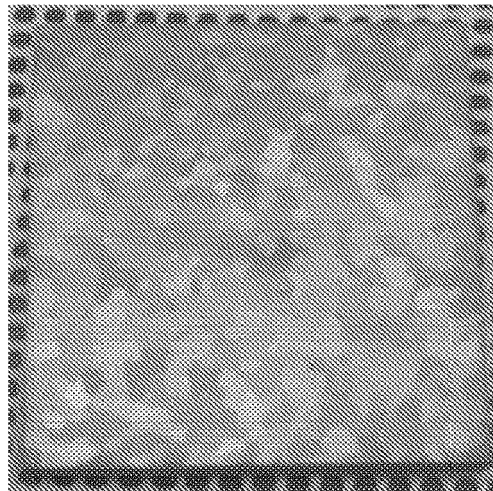
FIG. 4B

510



520

FeCl_3



530

HF

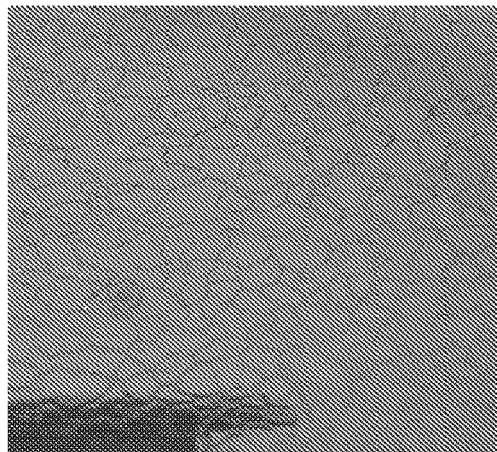
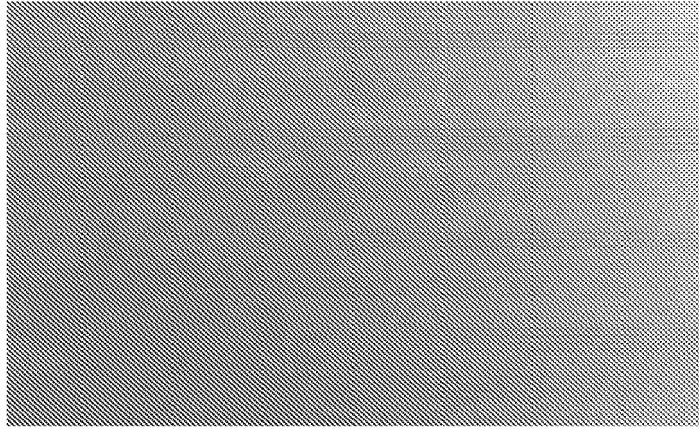
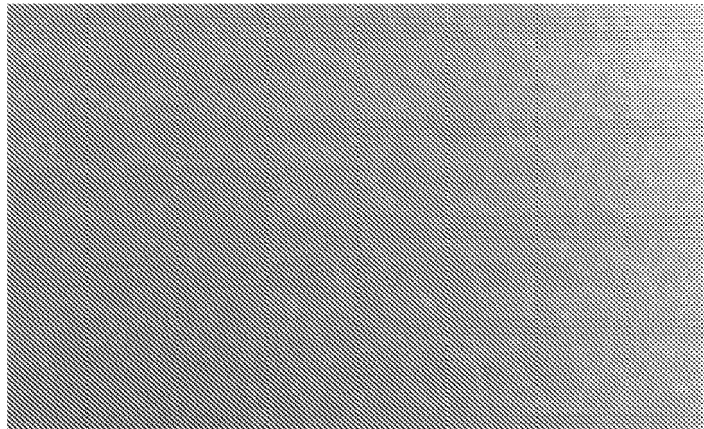


FIG. 5

610



620



630

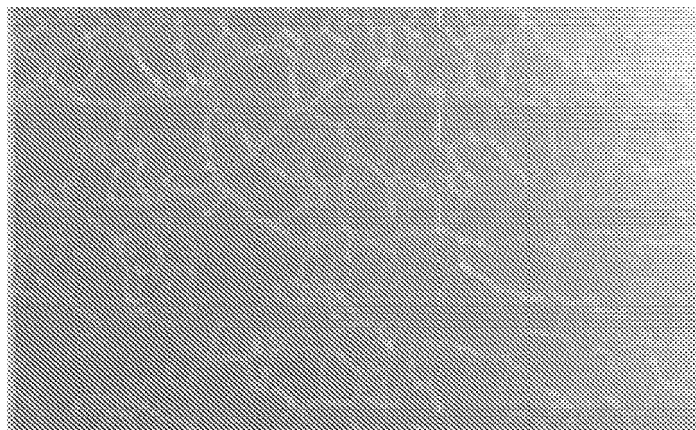


FIG. 6

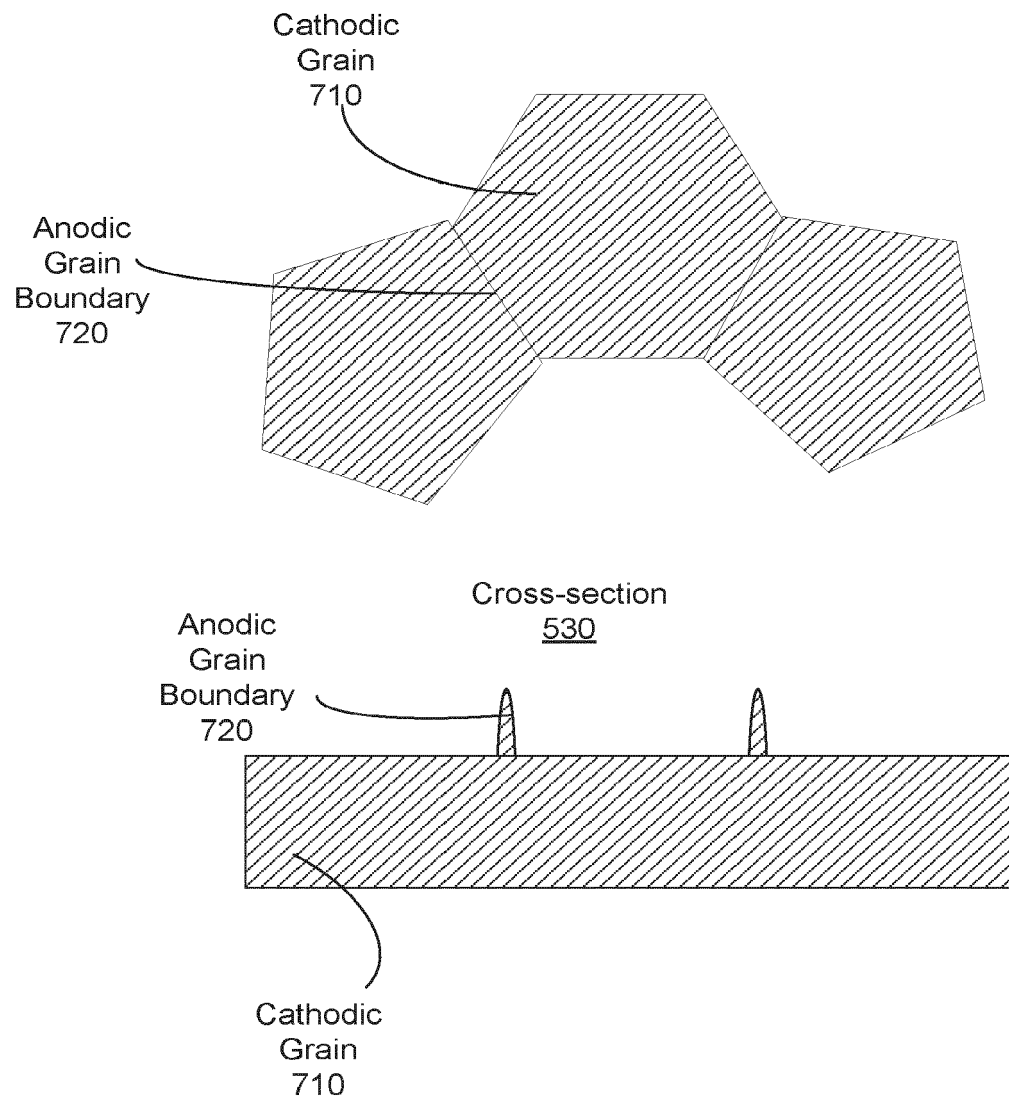


FIG. 7

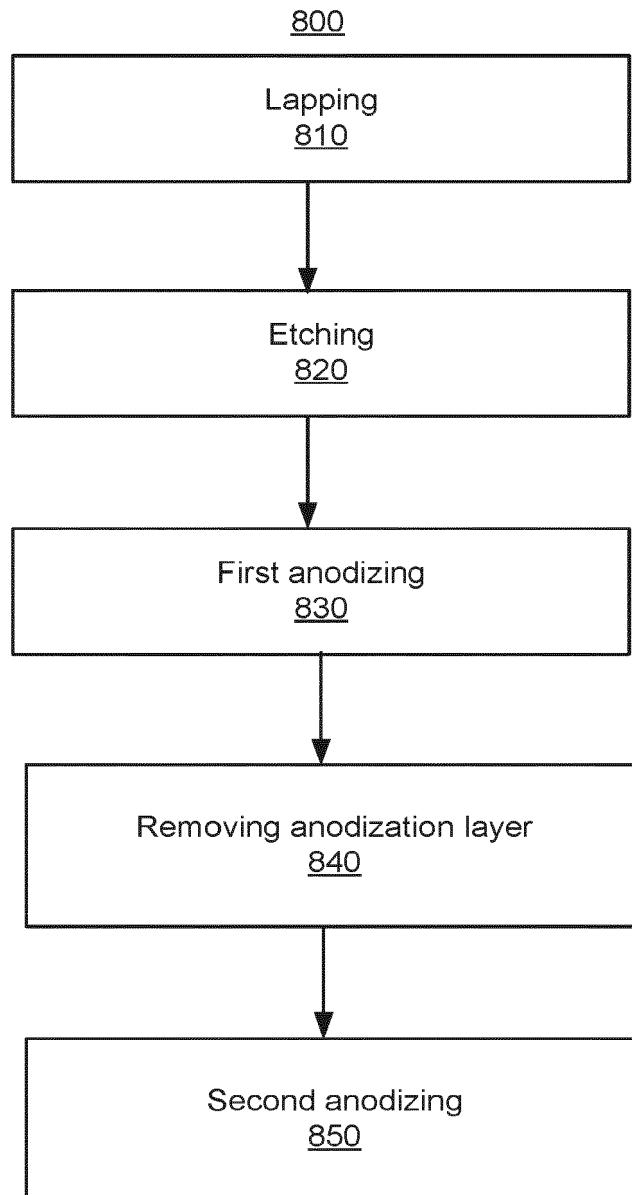


FIG. 8

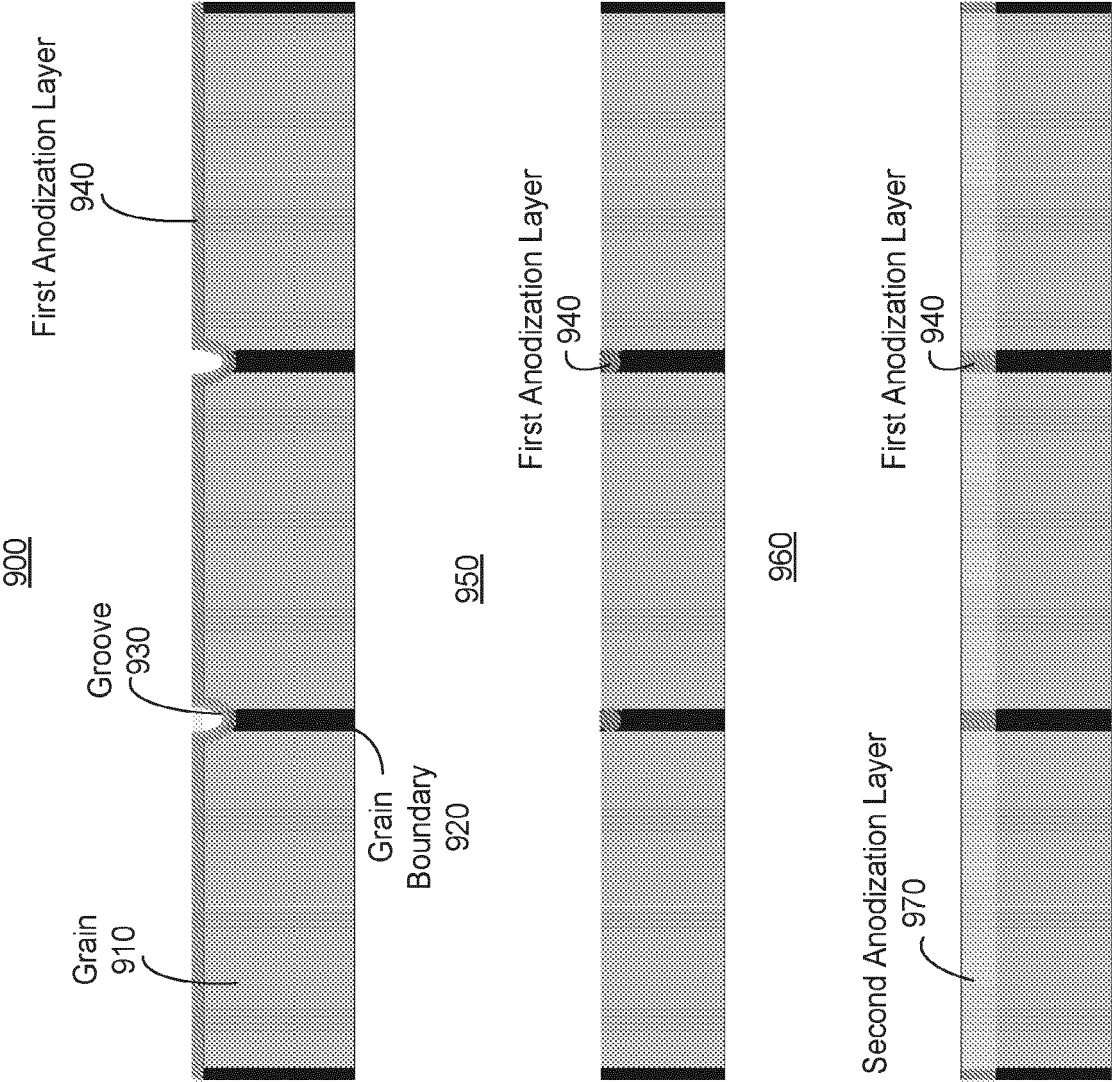


FIG. 9

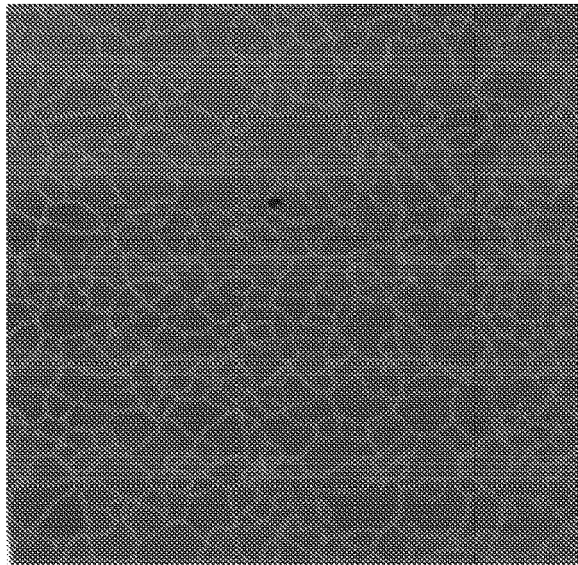


FIG. 10



EUROPEAN SEARCH REPORT

Application Number
EP 18 19 1190

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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X A	US 2 941 930 A (NICHOLAS MOSTOVYCH ET AL) 21 June 1960 (1960-06-21) * column 1, lines 12-14 * * column 2, line 44 - line 47 * * column 2, line 63 - line 64 * * column 3, line 7 - line 57 * * column 4, line 58 - column 5, line 42 * * examples 1,3 *	1-8, 12-15 9-11	INV. C22C21/00 C22F1/04 C23F1/00 C23F1/20 C23F1/36
X A	WO 2017/093304 A1 (NORSK HYDRO AS [NO]) 8 June 2017 (2017-06-08) * pages 5,8,9; example 1 *	1-8, 12-15 9-11	
X A	CA 2 251 337 A1 (ALCAN INT LTD [CA]) 23 October 1997 (1997-10-23) * pages 1-3 * * page 4, line 15 - page 5, line 23 * * example 2 *	1-8, 12-15 9-11	
			TECHNICAL FIELDS SEARCHED (IPC)
			C22C C22F C23F
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 22 October 2018	Examiner Brown, Andrew
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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The members are as contained in the European Patent Office EDP file on
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22-10-2018

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82