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ALUMINUM BASE ALLOY ARTICLE

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This invention relates to aluminum base alloy articles which have unique softening characteristics in response to annealing.

As is well known, aluminum in common with many other metals becomes harder and stronger at the expense of ductility when it is rolled, pressed, or otherwise deformed within a temperature range that does not permit the formation of new grains. It is also well recognized that the strain created by such deformation can be relieved by heating the worked product to a temperature between 640° and 670° F. Such a thermal treatment is commonly referred to as annealing and the change brought about in the internal structure of the metal is known as recrystallization, i. e., the formation of new crystals from the grain fragments created by the deformation. The occurrence of recrystallization, as recognized by those skilled in the art, is detected by microscopic examination of a properly etched specimen and observing whether new grains or crystals have been formed from the grain fragments. The presence of new grains in substantial numbers may also be detected by the X-ray diffraction method. Further, a marked change in strength and elongation accompanies the formation of new grains. Tensile tests to determine these properties therefore provide a practical and rapid means of learning wether recrystallization has taken place. Although recrystallization of aluminum occurs within the foregoing temperature range it is possible to obtain this result at a lower temperature depending upon the duration of the treatment, the purity of the metal and the extent to which the metal has been deformed or cold worked. The lowest temperature at which a new strain-free grain srtucture replaces the distorted grain structure of the cold worked metal is known as the recrystallization temperature. Even though the recrystallization temperature of very high purity aluminum may be below 640° F. it has generally been considered impractical, from a manufacturing standpoint, to employ such low temperatures or a range close to them for effecting recrystallization because of the length of time required, the danger of obtaining non-uniform results, and the attendant increase in cost.

As has been mentioned above, the purity of aluminum influences its temperature of recrystallization. For example, metal of a purity of 99.998% has been reported to recrystallize at 212° F. within a period of 6 to 10 minutes following a reduction in thickness of about 91% by cold rolling. The commercial exploitation of such super purity metal is of course limited by its cost and the amount which is available. Hence, even if such high purity metal were otherwise satisfactory, it would not be a competitor of low purity material when large quantities are required. Also, the advantage of a low recrystallization temperature found in high purity metal is lost as the impurity content reaches the level found in metal of ordinary purity.

Although a low recrystallization temperature is of small importance in some cases, in others it may be the

determining factor. An example of this is found in the sheathing of insulated telephone cable. According to one process of making such sheathed cable a cold worked aluminum tube is drawn down upon the core of insulated wires. However, in order to provide the necessary ductility in the aluminum sheath the whole cable must be subjected to an annealing operation. A conventional annealing treatment cannot be employed for this purpose because it would destroy or greatly injure the insulation on the wires comprising the cable. It therefore becomes necessary to employ a sheathing which can be softened and made more ductile without damage to the insulation.

It is an object of this invention to provide a wrought aluminum alloy article that has a lower recrystallization temperature than aluminum containing the same impurities in the same amounts as the alloy. Another object is to provide a wrought aluminum alloy article which recrystallizes at a faster rate than aluminum containing the same impurities in the same amount under the same conditions of work and thermal treatment. A further object is to provide a means for lowering the recrystallization temperature of cold worked aluminum alloy articles containing up to 0.8% total of iron and silicon impurities. Another object is to utilize aluminum of a purity commonly produced to form alloy articles having a lower recrystallization temperature than the aluminum without the alloy addition. Still another object is to provide an aluminum cable sheathing which can be annealed without damage to the insulation.

I have discovered that a lower recrystallization temperature and a higher rate of recrystallization can be obtained in a wrought aluminous article by forming the article of an aluminum alloy consisting essentially of aluminum, at least 0.01% each of iron and silicon, the total of the two elements not exceeding 0.8%, the amount of iron not exceeding the proportion of 4 parts of iron to 3 parts of silicon, a maximum of 0.05% each of copper and magnesium as impurities, 0.005 to 0.25% beryllium and 0.04 to 1.0% nickel than by using aluminum containing the same impurities in the same quantity, and worked to the same extent but with no beryllium and nickel addition. By observing the foregoing iron and silicon ratio together with making the beryllium and nickel additions it has been possible to obtain a recrystallization temperature in a cold worked article which is as much as 200° F. lower than that of aluminum of the same purity without the addition of beryllium and nickel and which has received the same amount of cold work. To state the matter differently, the cold worked aluminum-beryllium-nickel alloy product can be annealed at a lower temperature or in a shorter time at a higher temperature than the same article made of aluminum containing the same kind and amount of impurities as those occurring in the alloy. Moreover, the results of annealing the cold worked alloy articles have been found to be uniform which is of considerable importance from the standpoint of manufacturing operations.

Control of the iron and silicon impurities within the specified limits is essential to the production of a wrought article having the low recrystallization characteristic. While the minimum amount of iron and silicon should be 0.01% of each, the total should not exceed 0.8% of the weight of the alloy and preferably the total amount should be within the range of 0.1 to 0.5%. In an alloy having less than 0.01% each of iron and silicon nothing is gained by adding beryllium and nickel as far as reducing the recrystallization temperature is concerned. On the other hand, if more than a total of 0.8% of these impurities is present, the beryllium and nickel additions have no substantial effect on the temperature of recrystallization. To secure the best result the minimum amount

of iron and silicon should be 0.03% of each. Within the foregoing ranges for iron and silicon, the iron content should not be more than ⅔ of the silicon content and to obtain the best results it should not exceed ¾ of the amount of silicon. In the latter case, the minimum amount of silicon would be proportionately higher than 0.01% and in preferred practice the minimum iron content should be 0.03% while the lowest silicon content should be 0.04%. Unless the ratio of iron to silicon is observed the benefit from the beryllium and nickel additions is greatly reduced.

In regard to other impurities any copper and magnesium should be kept at a minimum, the maximum amount of each not exceeding 0.05%, as mentioned above. Still other impurities, such as manganese, titanium, zirconium, molybdenum, chromium and vanadium may be present but in very small amounts, usually less than 0.01% each, and the total should not exceed 0.02%. In these amounts they do not offset the beneficial effect of beryllium and nickel upon the recrystallization temperature.

The addition of 0.005 to 0.25% beryllium and 0.04 to 1.0% nickel to aluminum of the purity defined above and having the proper ratio of iron to silicon has the surprising effect of producing an alloy having a lower temperature of recrystallization and a higher rate of recrystallization when used in the form of a worked article than prevails in the absence of beryllium and nickel. Although the individual addition of beryllium or nickel to aluminum lowers the recrystallization temperature, as described and claimed in my co-pending applications Serial Nos. 367,094 and 367,095, respectively, I have found that an even greater effect is produced by the simultaneous use of these elements. The effect is greater than would be expected from the sum of the individual elements.

The addition of alloying elements to aluminum has always been found to raise the recrystallization temperature and hence the discovery of the opposite effect of beryllium and nickel is indeed surprising. No explanation of this result is offered. To obtain the optimum benefit from the additions of 0.01 to 0.1% beryllium and 0.15 to 0.5% nickel should be used, especially where the iron impurity is less than ¾ of the silicon content. The beryllium and nickel additions can be made in any one of the conventional ways of introducing the metals.

As stated above, the amount of cold work influences the temperature at which recrystallization will occur. In order to obtain the lowest recrystallization temperature, the alloy articles should receive a reduction in thickness of not less than 20% or be given an equivalent minimum amount of cold work. A reduction in thickness of at least 40% or an equivalent amount of cold work is usually desired while reductions or cold work exceeding 90% are preferred. Such reductions are not difficult to obtain in commercial practice for the alloy is easily fabricated, and in some instances no intermediate annealing may be required in producing the final shape from an ingot.

One of the advantages of my invention rests in the increase in rate of recrystallization which can be obtained at temperatures where aluminum without beryllium and nickel is annealed. Thus, if one does not wish to take advantage of the lowest possible annealing temperature permitted by the addition of beryllium and nickel, a higher temperature can be used and obtain a considerable reduction in the length of time required to effect complete recrystallization. It is well known in annealing aluminum, for example, that with but slight cold working a very long period of time may be required to bring about complete recrystallization. Also, even where the cold working is severe the rate of recrystallization may be low if the annealing temperature is very close to the temperature of recrystallization. Under either condition the addition of beryllium and nickel and control of the ratio of iron to silicon will accelerate recrystallization. For example, it has been found that with an aluminum alloy sheet composed of aluminum, .016% beryllium, 0.18% nickel, 0.03% iron and 0.04% silicon, which had been cold rolled 90% and annealed at a temperature of 400° F., it was possible to obtain complete recrystallization within a period of 15 minutes, whereas, aluminum sheet of the same purity and with the same amount of cold work must be heated at 600° F. to produce complete recrystallization in the same length of time.

The rate of recrystallization is determined by noting when new grains first form and the time elapsed until substantially all of the grain fragments have formed new grains. Such a determination is most conveniently carried out by testing a series of samples cut from the same sheet or other article, heating them to a given temperature and removing the samples at specified time intervals and observing the extent to which recrystallization has occurred. Although the presence of new grains can be microscopically detected upon a proper etching of the metal, it is advisable to supplement the examination with an X-ray determination.

The effect of beryllium and nickel upon the recrystallization temperature of cold rolled sheets of the alloy, especially the combined effect of these elements, is illustrated in the following examples.

Aluminum of 99.9% purity containing 0.03% iron and 0.04% silicon was employed as the base melt. Nine melts of this metal were prepared and different amounts of beryllium and nickel added to each melt except the one serving as the blank or control sample. The alloyed and non-alloyed melts were cast and the ingots rolled to 0.050" thick sheet so that the final product had a reduction in thickness of 90% after the intermediate anneal. Samples of sheet of each composition were heated to and held at a selected temperature for ½ hour. The beryllium and nickel contents of the sheet samples and the lowest temperatures at which recrystallization was complete appear in the table below.

Recrystallization temperatures of Al-Be, Al-Ni *and* Al-Be-Ni *alloys*

Percent Be or Ni	Recrystallization Temperature, ° F.
0	600
0.017 Be	475
0.20 Ni	500
0.19 Ni+0.007 Be	450
0.18 Ni+0.012 Be	400
0.18 Ni+0.016 Be	400
0.17 Ni+0.022 Be	400
0.30 Ni+0.015 Be	400
0.41 Ni+0.015 Be	400

One of the applications for the aluminum-beryllium product made in accordance with my invention is that of forming a sheath for insulated power and telephone cable. As has been mentioned, the sheathing of such cable has presented a difficult problem because of the necessity for softening the sheath after it has been drawn down upon the insulated wires. It has been found that the aluminum-beryllium-nickel product, as defined above, provides a very satisfactory sheath from the standpoints of application to the cable, of being annealed on the cable, and the flexibility of the final cable product. Such advantages, it can be readily appreciated, are of particular importance in providing a seamless sheath on a cable.

This application is a continuation-in-part of my co-pending application Serial No. 172,003, filed July 3, 1950.

Having thus described my invention and certain embodiments thereof, I claim:

1. An aluminum base alloy article which has received at least 20% cold work, said alloy consisting of 0.005 to 0.25% beryllium, 0.04 to 1.0% nickel, a maximum of 0.05% each of copper and magnesium impurities, at

least 0.01% each of iron and silicon, the total quantity of iron and silicon not exceeding 0.8% and the amount of iron not exceeding ⅓ of the silicon content, and the balance aluminum except for other impurities than those named hereinbefore, said cold worked alloy article being characterized by a lower temperature of recrystallization when annealed than aluminum containing only impurities including not less than 0.01% each of iron and silicon and not more than a total of 0.8% of iron and silicon, but the ratio of said iron to silicon exceeding 4 to 3, where said aluminum has received the same amount of cold work as said cold worked article.

2. An aluminum base alloy article which has received at least 20% cold work, said alloy consisting of 0.005% to 0.25% beryllium, 0.04 to 1.0% nickel, a maximum of 0.05% each of copper and magnesium impurities, at least 0.01% each of iron and silicon, the total quantity of iron and silicon not exceeding 0.8% and the amount of iron not exceeding ¾ of the silicon content, and the balance aluminum except for other impurities than those named hereinbefore, said cold worked alloy article being characterized by a lower temperature of recrystallization when annealed than aluminum containing only impurities including not less than 0.01% each of iron and silicon and not more than a total of 0.8% of iron and silicon, but the ratio of said iron to silicon exceeding 3 to 4, where said aluminum has received the same amount of cold work as said cold worked article.

3. An aluminum base alloy article which has received at least 20% cold work, said alloy consisting of 0.01 to 0.1% beryllium, 0.15 to 0.5% nickel, a maximum of 0.05% each of copper and magnesium impurities, at least 0.03% of iron and 0.04% of silicon, the total quantity of iron and silicon not exceeding 0.5% and the amount of iron not exceeding ¾ of the silicon content, and the balance aluminum except for other impurities than those named hereinbefore, said cold worked alloy article being characterized by a lower temperature of recrystallization when annealed than aluminum containing only impurities including not less than 0.01% each of iron and silicon and not more than a total of 0.8% of iron and silicon, but the ratio of said iron to silicon exceeding 3 to 4, where said aluminum has received the same amount of cold work as said cold worked article.

4. An aluminum base alloy article which has received at least 40% cold work, said alloy consisting of 0.005 to 0.25% beryllium, 0.04 to 1.0% nickel, a maximum of 0.05% each of copper and magnesium impurities, at least 0.01% each of iron and silicon, the total quantity of iron and silicon not exceeding 0.8% and the amount of iron not exceeding ⅓ of the silicon content, and the balance aluminum except for other impurities than those named hereinbefore, said cold worked alloy article being characterized by a lower temperature of recrystallization when annealed than aluminum containing only impurities including not less than 0.01% each of iron and silicon and not more than a total of 0.8% of iron and silicon, but the ratio of said iron to silicon exceeding 4 to 3, where said aluminum has received the same amount of cold work as said cold worked article.

5. An aluminum base alloy article which has received at least 90% cold work, said alloy consisting of 0.01% to 0.1% beryllium, 0.15 to 0.5% nickel, a maximum of 0.05% each of copper and magnesium impurities, at least 0.03% of iron and 0.04% of silicon, the total quantity of iron and silicon not exceeding 0.5% and the amount of iron not exceeding ¾ of the silicon content, and the balance aluminum except for other impurities than those named hereinbefore, said cold worked alloy article being characterized by a lower temperature of recrystallization when annealed than aluminum containing only impurities including at least 0.03% iron and 0.04% silicon and not more than a total of 0.5% of iron and silicon, but the ratio of said iron to silicon exceeding 3 to 4, where said aluminum has received the same amount of cold work as said cold worked article.

6. An annealed aluminum base alloy cable sheath which prior to annealing received at least 20% cold work, said alloy consisting of 0.005 to 0.25% beryllium, 0.04 to 1.0% nickel, a maximum of 0.05% each of copper and magnesium impurities, at least 0.01% each of iron and silicon, the total quantity of iron and silicon not exceeding 0.8% and the amount of iron not exceeding ⅓ of the silicon content, and the balance aluminum except for other impurities than those named hereinbefore, said cable sheath being characterized by having undergone recrystallization at a lower temperature than aluminum containing only impurities including not less than 0.01% each of iron and silicon and not more than a total of 0.8% of iron and silicon, but the ratio of said iron to silicon exceeding 4 to 3, where said aluminum has received the same amount of cold work as said aluminum base alloy cable sheath.

7. An annealed aluminum base alloy cable sheath which prior to annealing received at least 90% cold work, said alloy consisting of 0.01 to 0.1% beryllium, 0.15 to 0.5% nickel, a maximum of 0.05% each of copper and magnesium impurities, at least 0.01% each of iron and silicon, the total quantity of iron and silicon not exceeding 0.5% and the amount of iron not exceeding ¾ of the silicon content, and the balance aluminum except for other impurities than those named hereinbefore, said cable sheath being characterized by having undergone recrystallization at a lower temperature than aluminum containing only impurities including not less than 0.01% each of iron and silicon and not more than a total of 0.5% iron and silicon, but the ratio of said iron to silicon exceeding 3 to 4, where said aluminum has received the same amount of cold work as said aluminum base alloy cable sheath.

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