

3,406,058

NICKEL BASE ALLOYS AND ELECTRICAL RESISTANCE WIRE MADE THEREFROM

Stephen Poch, Wyckoff, Edward E. Edmunds, Shrewsbury, and Arthur S. Lichter, Allenwood, N.J., assignors to Molecu-Wire Corporation, a corporation of New Jersey
No Drawing. Filed July 11, 1966, Ser. No. 564,020
7 Claims. (Cl. 75-171)

ABSTRACT OF THE DISCLOSURE

A nickel base alloy with a flat temperature coefficient of resistivity and the manufacture of wire products from said alloy.

This invention relates to nickel-chromium alloys particularly suitable for use as electrical resistance elements, to methods of processing wire made from such alloys to produce products with exceptionally low temperature coefficients of resistivity and to the novel products resulting therefrom.

More particularly, it relates to alloys having the following nominal compositions (percent by weight):

	Minimum	Maximum	Preferred
Chromium.....	17.5	22.5	19.5-21
Manganese.....	4.5	5.5	About 5
Aluminum.....	4	4.5	About 4.3
Silicon.....	0.90	1.25	About 1.1
Nickel.....	¹ Balance	¹ Balance	¹ Balance

¹ Except for minor amounts of trace elements, deoxidizers, degasifiers, and impurities incidental to the normal commercial production of this type of 80/20 Ni-Cr alloy.

It also relates to an extremely rapid heat treatment of such alloys at temperatures in the range of 1200° F. to 1900° F. for unusually short time intervals, usually less than five seconds. This heat treatment being effected preferably immediately after the alloys have been fabricated into wire by combinations of hot working and cold working and prior to incorporation into a finished article of manufacture, such as a potentiometer, wire wound resistor, or other electrical and electronic apparatus.

One object of the invention is the production of alloys from which wire with desirably low coefficients of resistivity and desirably high electrical resistances is reproducibly obtained.

A principal object of the invention is the production of a wire product having an unusually flat temperature-resistance curve over the range of minus 55° C. to plus 150° C.

Another object is to provide a wire product having a controlled temperature coefficient of resistance which may be positive, or negative, or zero according to the specific processing to which the wire is subjected.

Still a further object is to provide an alloy which may be formed into wire having a combination of high resistance, low temperature coefficient of resistance, improved stability and uniformity of the relation between resistance and temperature.

A further object of the invention is to provide an unusually brief heat treatment for the improvement of wire produced from said alloys.

These and other objects will be apparent from the more complete disclosure of preferred aspects of this invention which follows.

As noted in United States Patent 2,996,378, issued Aug. 15, 1961, nickel-chromium alloys of the 80/20 type, modified by the addition of Al and other specific elements, are well known and have been extensively investigated.

The present invention consists in the use of the above noted combination of alloying elements within the very narrow ranges of proportions specified, to produce stable products with specific resistances of at least as high as 860 ohms per circular mil foot and temperature coefficients of resistance of less than about one part per million over a temperature range of minus 55° C. to plus 125° C. are readily and reproducibly obtained.

In the alloys of this invention the specific range of chromium content is less critical than the ranges specified for the remaining alloying elements and amounts as low as 15 weight percent and as high as 25 weight percent may be tolerated without sacrificing the benefits conferred by the presence of aluminum, manganese and silicon in the proper proportions. However, a chromium content in the range of between about 20% and 21% by weight is preferred.

The manganese content of the alloys of this invention appears to be particularly important, because when the manganese exceeds about 5.5% by weight the alloys are extremely difficult to hot work and tend to edge crack excessively and when the manganese is below about 4.5% the stability and temperature coefficient of resistance are adversely affected and more extensive heat treatment is required to develop the desired properties, than when the manganese is in the range of above about 4.5% and up to about 5.5% by weight.

The presence of aluminum in amounts greater than 4% also appears to permit greatly simplified and shortened heat treatments as compared with the prior art alloys in this field.

One important difference between the alloy of this invention and prior art alloys is in the presence of about 1% silicon which is many times the amount of silicon required for simple deoxidation and degasification of the alloy. The presence of this increased amount of silicon also appears to permit processing by greatly accelerated heat treatments without loss of the desired properties.

Preferred alloys in accordance with this invention are those containing between about 19.5% and 21% Cr; from about 4% to 4.5% Al; from about 4.5% to 5.5% Mn; from about 0.9 to 1.25% silicon; not more than 0.5% Cu; not more than 0.9% Fe; a maximum of about 0.03% C; less than 0.005% of P or S; the balance nickel except for minor amounts of deoxidizers and degasifiers, such as Zr, Ti and the like, totalling less than about 0.3%.

The following alloys will further illustrate the present invention (percent by weight):

	#1	#2	#3	#4	#5
Carbon.....	.01	.01	.01	.01	.02
Manganese.....	3.26	4.89	5.17	5.0	10.38
Silicon.....	1.16	1.10	1.22	1.10	1.16
Chromium.....	20.40	20.61	20.34	20.61	20.28
Aluminum.....	3.97	4.14	4.53	4.1	4.07
Nickel.....	Balance	Balance	Balance	Balance	Balance

After working and heat treatment alloys 2, 3 and 4 exhibited a temperature coefficient of resistance of less than one part per million over the temperature range of minus 55° C. to plus 125° C. as well as a nominal resistivity of at least 860 ohms per circular mil foot, whereas alloy No. 5 with the higher manganese disintegrated during hot working and alloy No. 1 with a manganese content below the desire range exhibited a temperature coefficient of resistance of between 3 and 5 parts per million (with 25° C. as the reference temperature) over the range minus 55° C. to plus 125° C. which is very little improvement over the prior art.

The following is a description of one manner in which

3

alloy No. 3 (above), containing .004% S, .001% P and 0.77% Fe as impurities, has been worked, omitting conventional coating, cleaning, pickling, incidental to wire-drawing.

- (1) Hot work to 1/4" rod.
- (2) Anneal at 2100° F.
- (3) Rapidly quench.
- (4) Draw successively to the following diameters, annealing the continuous strand at 2100° F. after each draw: .140"; 0.080" and 0.032".
- (5) Draw to .0142" diameter; .004" diameter and then .001" diameter or other desired final diameter.
- (6) Anneal in gradient furnace with nonoxidizing atmosphere such as cracked ammonia.

The final annealing temperature depends in part on the size of the wire being processed, the speed at which it passes through the furnace and the temperature coefficient desired. Annealing temperatures between 1200° F. and 2100° F. are usually employed at this stage of the process, for times of between two and fifteen seconds.

Having now described the invention it is not intended that it be limited except as may be required by the appended claims.

We claim:

1. A nickel base alloy consisting essentially of between about 15 and 25% Cr, between about 4.5 and 5.5% Mn, between about 4 and 4.5% Al, between about 0.90 and 1.25% Si, balance nickel except for incidental impurities.
2. An electrical resistance wire formed of the alloy of claim 1.
3. An electrical resistance wire alloy having a flat temperature coefficient of resistance characteristic and consisting essentially of the alloy of claim 1.

4

4. A nickel base alloy consisting essentially of the following in percent by weight:

Cr	17.5-22.5
Mn	4.5-5.5
Al	4-4.5
Si	0.9-1.25

balance nickel except for incidental impurities.

5. The alloy of claim 4 wherein the chromium content is between 20 and 21% by weight.

6. The alloy of claim 5 wherein the manganese is about 5%, the aluminum is about 4.3% and the silicon is about 1.1%.

7. In a method of processing a nickel base alloy consisting essentially of between about 15 and 25% Cr, between about 4.5 and 5.5% Mn, between about 4 and 4.5% Al, between about 0.90 and 1.25% Si, balance nickel except for incidental impurities, according to claim 1, to produce a wire product having a desired temperature coefficient of resistivity, which alloy has been worked and heat treated to produce a wire of the desired final dimensions, the improvement in combination therewith which comprises final annealing said alloy between 2 and 15 seconds at a temperature of between 1200° F. and 2100° F.

References Cited

UNITED STATES PATENTS

2,460,590	2/1949	Lohr	75-171
2,533,735	12/1950	Lohr	75-171
2,533,736	12/1950	Lohr	75-171
2,996,378	8/1961	Edmunds et al.	75-171

RICHARD O. DEAN, *Primary Examiner.*