United States Patent Office 3,598,578 Patented Aug. 10, 1971

3,598,578

ELECTRICAL RESISTANCE ALLOY AND METHOD OF PRODUCING SAME

Teh Po Wang, Cedar Grove, N.J., assignor to Wilbur B. Driver Company

No Drawing. Filed Mar. 28, 1969, Ser. No. 811,594
Int. Cl. C22c 19/00
U.S. Cl. 75—171 5 Claims

ABSTRACT OF THE DISCLOSURE

An electrical resistance alloy characterized by a temperature coefficient of resistance which maintains an essentially constant fixed value approaching zero over a selected temperature range and comprising, as expressed in percent by weight, the following major constituents:

	Percent
Aluminum	2.75–3.75
Manganese	4.0–5.5
Silicon	0.70–1.25
Chromium	17.5–22.5
Nickel	Balance

To this is added as a minor constituent at least one deoxidizer selected from the class consisting of zirconium, calcium and magnesium in an amount up to 0.1%. The alloy is produced by a process in which it is strand annealed, rapid cooled, heat treated and slow cooled.

BACKGROUND OF THE INVENTION

The temperature coefficient of resistance of a material is defined over any temperature range as follows:

$$TCR = \frac{R_2 - R_1}{R_{REF}(T_2 - T_1)}$$

where:

TCR is the temperature coefficient of resistance between temperature T_1 and T_2, where $T_2 > T_1$;
R_1 is the resistance at temperature T_1;
R_2 is the resistance at temperature T_2; and
R_{REF} is the resistance at a reference temperature, which is usually either 20° or 25° C.

An ideal resistance alloy would, among other parameters, exhibit a constant value of resistance over the entire range of temperatures to which the alloy is to be subjected. Since no alloy is ideal, the objective is to obtain an alloy that approaches one. Therefore, a TCR that approaches zero in the temperature ranges from −55° C. to +25° C. to 105° C., the normal ranges of interest, will also have a low incremental TCR between these two ranges. This can approximate one part per million per degree C. (p.p.m./°). However, commercially available alloys exhibit non zero values of TCR over each of these ranges.

Certain known alloys have exhibited incremental TCR values of one p.p.m./° C. For example, U.S. Pat. 3,406,058 discloses an electrical resistance alloy having a resistivity of 860 ohms per circular mill foot and an incremental TCR of about one p.p.m./° C. over a temperature range of −55° C. to 125° C. The alloy composition, as expressed in percent by weight, is 15%–25% chromium, 4.5%–5.5% manganese, 4%–4.5% aluminum, 0.90%–1.25% silicon, balance nickel.

This known alloy while useful for a variety of applications, has two inherent disadvantages. First, the alloy, during processing, must be formed into wire and heated rapidly and uniformly by strand annealing in order to maintain the incremental TCR at one p.p.m./° C. This process can be applied successfully only to wires of small

diameter as for example .0025 inch or less. When the diameter of the wire is increased appreciably beyond this value, the incremental TCR increases to unacceptable values. Secondly, the alloy is difficult to forge and draw.

I have discovered that both the above disadvantages can be overcome by producing an alloy of the same general type with a substantially reduced aluminum content. More particularly, my alloy is heated slowly whereby wire of any diameter up to about .010 inch can be brought to temperature and cooled at the same rate while the incremental TCR is held at one p.p.m./° C. Moreover, my alloy can be forged and worked more easily than an alloy with higher aluminum content.

SUMMARY OF THE INVENTION

My alloy has the following major constituents, as expressed in percent by weight:

	Percent
Aluminum	2.75–3.75
Manganese	4.0–5.5
Silicon	0.70–1.25
Chromium	17.5–22.5
Nickel	Balance

To this is added up to 0.1% of at least one deoxidizer selected from the group consisting of zirconium, calcium and magnesium.

My alloy exhibits an incremental TCR of one p.p.m./° C. or less over the temperature range of interest, regardless of the diameter of the wire in which it is formed. My alloy can be forged and worked without difficulty.

BRIEF DESCRIPTION OF PREFERRED EMBODIMENTS

A typical alloy in accordance with my invention had the following composition:

	Percent
Aluminum	3.03
Manganese	4.51
Silicon	0.82
Chromium	20.67
Zirconium	.05
Calcium	.05
Magnesium	.05
Nickel	Balance

This alloy was cast, hot rolled, and subsequently drawn to wire and annealed at a selected temperature within the range 1700° F. to 2000° F. as for example 2000° F. for a few seconds and then was rapidly quenched. In this condition, the resistivity of the wire was 767 ohms per circular mil foot. The TCR cold, ie, over the range −55° to 25° C., was +52 p.p.m./° C., and the TCR hot, between +25° to +105° C., was +49 parts p.p.m./° C.

After a subsequent heat treatment for about one hour at 940° F. in a hydrogen atmosphere with the wire wound upon a spool, the resistivity of my alloy increased to about 830 ohms per circular mil foot. Typically, the TCR cold was 0 p.p.m./° C. while the TCR hot was −1 p.p.m./° C.

Unlike strand annealing techniques, this heat treatment is effective regardless of the diameter of the wire being treated. For example, the same results can be obtained for diameters ranging between .0004 inch and .010 inch.

By varying the temperature of the second heating step within the range 900° F. to 1000° F. and by varying the time within the range of approximately thirty minutes to ninety minutes, the TCR hot and the TCR cold values can be varied, while maintaining the overall value of incremental TCR at a value of one p.p.m./° C.

While I have described my invention with respect to preferred embodiments, my invention is to be limited only by the terms of the claims which follow.

What is claimed is:

1. An electrical resistance alloy having a temperature coefficient of resistance which does not vary more than about one part per million per degree centigrade over the temperature ranges of −55° C. to 25° C. and 25° C. to 105° C. and, as expressed in percent by weight, consisting essentially of:

	Percent
Aluminum	2.75–3.75
Manganese	4.0–5.5
Silicon	0.70–1.25
Chromium	17.5–22.5
Nickel	Balance

2. An alloy as set forth in claim 1 further including up to 0.1% of at least one deoxidizer selected from the group consisting of zirconium, calcium and magnesium.

3. A method for producing an electrical resistance alloy with a resistivity of at least 800 ohms per circular mil foot and a temperature coefficient of resistance which does not vary more than one part per million over the temperature range from −55° C. to 25° C. and from 25° C. to 105° C. from a starting alloy comprising, as expressed in percent by weight, 2.75%–3.75% aluminum, 4.0%–5.5% manganese, 0.70%–1.25% silicon, 17.5%–22.5% chromium, balance nickel, which comprises the steps of:

(a) drawing said starting alloy to a wire of desired dimension;
(b) strand annealing said wire to a temperature between 1700° F.–2000° F. for a short period;
(c) rapid cooling said annealed wire;
(d) heat treating said cooled wire at a temperature of 900° F.–1000° F. in a reducing atmosphere for a longer period; and
(e) slow cooling said treated wire to produce said electrical resistance alloy.

4. A method as set forth in claim 3 wherein step (c) is carried out by quenching.

5. A method as set forth in claim 3 wherein step (b) uses a period of several seconds and step (d) uses a period of at least thirty minutes.

References Cited

UNITED STATES PATENTS

2,533,736	12/1950	Lohr	75—171
3,406,058	10/1968	Poch et al.	75—171

RICHARD O. DEAN, Primary Examiner

U.S. Cl. X.R.

148—11.5, 13, 20.3