

NICHROME RESISTIVE ELEMENT AND METHOD OF
MAKING SAME

1 A type of resistor in common use involves an insulating
substrate core to which has been added a metal film. The core is
usually composed of a ceramic or glass substance to which is
5 added a nickel-chromium alloy (nichrome) or nickel-chromium
alloyed with one or more other elements which is evaporated or
sputtered onto the substrate. A nichrome film is used in
resistors because of its stability and near-zero temperature
co-efficient of resistance (TCR) in the resistors.

10 It is common to add aluminum to these nichrome films in
order to achieve a better TCR. Work with superalloys has
indicated that the addition of several percent of aluminum to
nichrome superalloys allows a surface oxide to form which
consists mainly of Al_2O_3 . This oxide scale provides greater
15 protection against impurities and corrosion. However, the Al_2O_3
oxide spalls at high temperatures. It has further been found
that relatively minor additions of rare earth or transitional
metals improve the oxidization resistance of the
nichrome-aluminum superalloys. Other studies have suggested that
20 common impurities which might invade the film pull electrons away
from metal atoms and prevent these electrons from contributing to
the stronger metallic-type bonds across grain boundaries.

These studies have not translated easily to work with
nichrome films as opposed to superalloys. Research connected
25 with superalloys has not involved electrical resistors. For
instance, a patent was issued to NASA in July 1982, involving
work to improve superalloys. In that patent, No. 4,340,425,
zirconium was added to improve the performance of the superalloys
with about .13% weight optimal and a range of .06 to .20% weight
30 effective. Work by this inventor discloses that nichrome films

require much higher percentages in order to obtain the desired effects, with improvements noted for percentages from about 1.0% to 6.0%, with the optimum around 3.0%. Resistor films also differ considerably from superalloys in their basic makeup. For example, resistor films have a chromium content of 30% or higher, whereas the superalloys usually have a chromium content of 10 to 20%. It is necessary to add 1.0% or more of transitional metals or rare earth elements to obtain results with nichrome film, whereas additions of a fraction of a percent seem optimum for superalloys.

The inventor here has discovered that the addition of a transitional or rare earth element or both improves corrosion resistance and stability and prevents permeation of impurities.

The theory has been developed in the discovery of this invention that addition of the elements listed in this patent improve the resistance of the oxide to corrosion and/or enhance Al_2O_3 scale and nickel-chromium-aluminum adherence and stability of the scale. All of the elements are oxygen-active and are also sulfur-active. Elements with a large atomic radius as compared to nickel, which are nearly insoluble with nickel, and which are oxygen-active are also candidates for improving Al_2O_3 adherence and stability and, thus, nichrome film stability.

It is the object of this invention to provide a nichrome film or metal film substitute with improved electrical stability on high temperature storage or high power operation or a combination of the two. It is the further objective of this invention to provide

greater protection from impurities and inhibit oxide spalling.

According to the present invention there is provided an electrical resistor including an insulating substrate or core having a supporting surface and a resistance element on the supporting surface, comprising nickel, chromium and a substance selected from the group consisting essentially of aluminum, and at least one of transitional elements and rare earth elements in a corrosion inhibiting and stabilizing amount.

Also according to the present invention there is provided a method of making an electrical resistor including an insulating substrate or core having a supporting surface and a resistance element on the supporting surface, the method comprising adding to nickel and chromium, a substance selected from the group of elements consisting essentially of aluminum, and at least one of a transitional element and a rare earth element in a corrosion inhibiting and electrical stabilizing effective amount.

3.

This invention describes an improved nichrome film or metal film substitute for use in electrical resistors or with other high temperature use and the method of making the same that results in improved electrical stability. The improved stability results without significantly affecting the TCR of the resistors. These results are achieved by the addition of a transitional element and/or a rare earth element to the film resistor.

The nickel-chromium alloy typically consists of 30% nickel and 70% chromium or 70% nickel and 30% chromium, or some intermediate composition. Aluminum is frequently added to the nickel chromium in amounts sufficient to achieve a TCR of zero. When aluminum is added to the material, a typical composition is 33% nickel, 33% chromium, and 33% aluminum. To the basic nickel-chromium alloy, this invention anticipates addition of a transitional metal and/or a rare earth element. One or a combination of these elements is added in the range of 1.0% to 30% by weight, with the preferred range being 3.0% to 6.0% by weight. Optimum performance is achieved by an addition of 3.0% by weight.

Preferred members of the transitional elements which provide optimal results include scandium, yttrium, zirconium, and hafnium. Members of the rare earth group which provide optimal performance include cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, and thorium.

It is to be understood that a resistance element may consist of a film deposited upon the substrate or core, or may also consist of a wire wound around the resistor, or where a foil or strip is substituted for the film.

1 These films are produced by D.C. magnetically-enhanced
sputtering in argon. They have been deposited using standard
sputtering parameters for nichrome films on ceramic cylinders of
the type normally used to produce metal film resistors and on
5 glass or ceramic substrates used to produce thin film networks or
chips. The films deposited were typically in the range of 20 to
100 ohms per square. All other processing was identical to that
used with standard nichrome films.

10 Tests were run on examples reflecting the various
compositions and the results outlined in the tables that follow.
The first test which was conducted was a moisture test in which
two different types of resistors were placed into a chamber
containing a high percentage of humidity for 10 days. Two types
of resistors were tested under this method, one containing film
15 composition of nickel, chromium, and aluminum, the second group,
of resistors containing a film composition to which zirconium was
added. Twenty resistors of each type were tested to determine
the average change of resistance in percentage. As the table
indicates, improved performance was achieved when zirconium was
20 added.

25 The second type of test performed on three different types
of resistors was a load-life test. In this test, 20 resistors of
each of the three types were made to a 1/10 watt size and
subjected to 1/8 watt power to not exceed 125°C. One type of
resistor contained only nickel, chromium, and aluminum; the
second contained 1% zirconium; and the third contained 3%
zirconium. As the tables indicate, optimal performance was
achieved with the addition of zirconium, and the best performance
was achieved with a higher amount of zirconium added.

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The last test performed was a high temperature exposure test in which the ambient temperature surrounding the resistors was increased to 175°C. In the first group tested nickel, chromium, aluminum, and zirconium made up the film composition, and the resistors were exposed to heat for 250 hours. The resistor containing the higher amount of zirconium showed better performance. In the second group nickel, chromium, aluminum and zirconium were added to the film, with differing amounts of aluminum and zirconium. After exposure to 2017 hours of high temperature, it can be seen that a balance between aluminum and zirconium provided the best performance. Finally, three different types of resistors were exposed to 500 hours of high temperature. Good performance was observed when zirconium was added, better performance was observed when ytterbium was added, and the best performance was achieved when cerium and zirconium, were added. These tests demonstrate the improvements shown by this invention.

MOISTURE TESTING (MIL-R-55182)
(Ref. MIL-STD-202, Method 106)

<u>Approx. Film Composition*</u>				<u>Aver. Change of Resist. in %</u>
34 Ni	34 Cr	31 Al	1 Zr	-.002
34 Ni	34 Cr	33 Al		+.510

LOAD LIFE (125°C, 1/8 WATT)
(1/10 Watt Size)

<u>Approx. Film Composition*</u>				<u>Aver. Change of Resist. in %</u>
34 Ni	34 Cr	31 Al	1 Zr	.012
34 Ni	34 Cr	29 Al	3 Zr	.005
34 Ni.	34 Cr	32 Al		.104

6.

HIGH TEMPERATURE EXPOSURE (175°C)

<u>Approx. Film Composition*</u>						<u>Time</u>	<u>Aver. Change of Resistance in %</u>
34 Ni	34 Cr	30.5 Al	1.5 Zr			250	.246
34 Ni	34 Cr	29.0 Al	3.0 Zr			250	.096
42 Ni	42 Cr	13.0 Al	3.0 Zr			2017	.747
42 Ni	42 Cr	8.0 Al	8.0 Zr			2017	.947
34 Ni	34 Cr	27.5 Al	1.5 Ce	3 Zr		500	.022
34 Ni	34 Cr	29.0 Al	3.0 Zr			500	.079
34 Ni	34 Cr	29.0 Al	3.0 Yb			500	.036

*All percentages are estimated based on sputtering target configuration.

CLAIMS

1. An electrical resistor including an insulating substrate or core having a supporting surface and a resistance element on the supporting surface, comprising nickel, chromium and a substance selected from the group consisting essentially of aluminum, and at least one of transitional elements and rare earth elements in a corrosion inhibiting and stabilizing amount.

2. A method of making an electrical resistor including an insulating substrate or core having a supporting surface and a resistance element on the supporting surface, the method comprising adding to nickel and chromium, a substance selected from the group of elements consisting essentially of aluminum, and at least one of a transitional element and a rare earth element in a corrosion inhibiting and electrical stabilizing effective amount.

3. A resistor as claimed in claim 1, in which the amount of nickel is 30% to 70% by weight, the amount of chromium is 30% to 70% by weight and the amount of aluminum is 0.0% to 35% by weight.

4. A resistor as claimed in claim 3, in which the amount of nickel is 33% by weight, the amount of chromium is 33% by weight and the amount of aluminum is 33% by weight.

5. A method of making a resistor as claimed in claim 2, in which the amount of nickel is 30% to 70% by weight, the amount of chromium is 30% to 70% by



weight and the amount of aluminum is 0.0% to 35% by weight.

6. A method of making a resistor as claimed in claim 5 in which the amount of nickel is 33% by weight, the amount of chromium is 33% by weight and the amount of aluminum is 33% by weight.

7. A resistor as claimed in claim 1, in which the transitional element or rare earth element or mixture thereof is in the amount of 1.0% to 30% by weight.

8. A resistor as claimed in claim 7, in which the transitional element or rare earth element or mixture thereof is in the amount of 3.0% to 6.0% by weight.

9. A method of making a resistor as claimed in claim 2, in which the transitional element or rare earth element or mixture thereof is in the amount of 1.0% to 30% by weight.

10. A method of making a resistor as claimed in claim 9, in which the transitional element or rare earth element or mixture thereof is in the amount of 3.0% to 6.0% by weight.

11. A resistor as claimed in claim 1, in which the transitional element is selected from the group of metals consisting of scandium, yttrium, zirconium and hafnium.



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12. A resistor as claimed in claim 1, in which the rare earth element is selected from the group of elements consisting of lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium and thorium.

13. A method of making a resistor as claimed in claim 2, in which the transitional element is selected from the group of metals consisting of scandium, yttrium, zirconium, and hafnium.

14. A method of making a resistor as claimed in claim 2, in which the rare earth metal elements are selected from the group of elements consisting of lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium and thorium.

15. A resistor as claimed in claim 11, in which the transitional element zirconium is added in amounts of 1.0% to 6.0% by weight.

16. A resistor as claimed in claim 15, in which the transitional element zirconium is added in the amount of 3.0% by weight.

17. A resistor as claimed in claim 12, in which the rare earth element cerium is present in the amount of 2.0% by weight.

18. A resistor as claimed in claim 17, in which the rare earth element cerium is present in the amount of 1.0% to 4.0% by weight.



19. A method of making a resistor as claimed in claim 13, in which the transitional element zirconium is added in amounts of 1.0% to 6.0% by weight.

20. A method of making a resistor as claimed in claim 19, in which the transitional element zirconium is added in the amount of 3.0% by weight.

21. A method of making a resistor as claimed in claim 14, in which the rare earth element cerium is added in the amounts of 1.0% to 4.0% by weight.

22. A method of making a resistor as claimed in claim 21, in which the rare earth element cerium is added in the amount of 2.0% by weight.

23. An electrical resistor as claimed in claim 1, and constructed and arranged substantially as herein described.

24. A method of making an electrical resistor as claimed in claim 2, and substantially as herein described.



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