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Ang et al.

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[54] **HIGH STABILITY THIN FILM ALLOY RESISTORS**
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[52] **U.S. Cl.**..... **117/227**, 29/620, 117/107, 204/192
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[58] **Field of Search** 117/227, 107; 75/165; 204/192; 29/620

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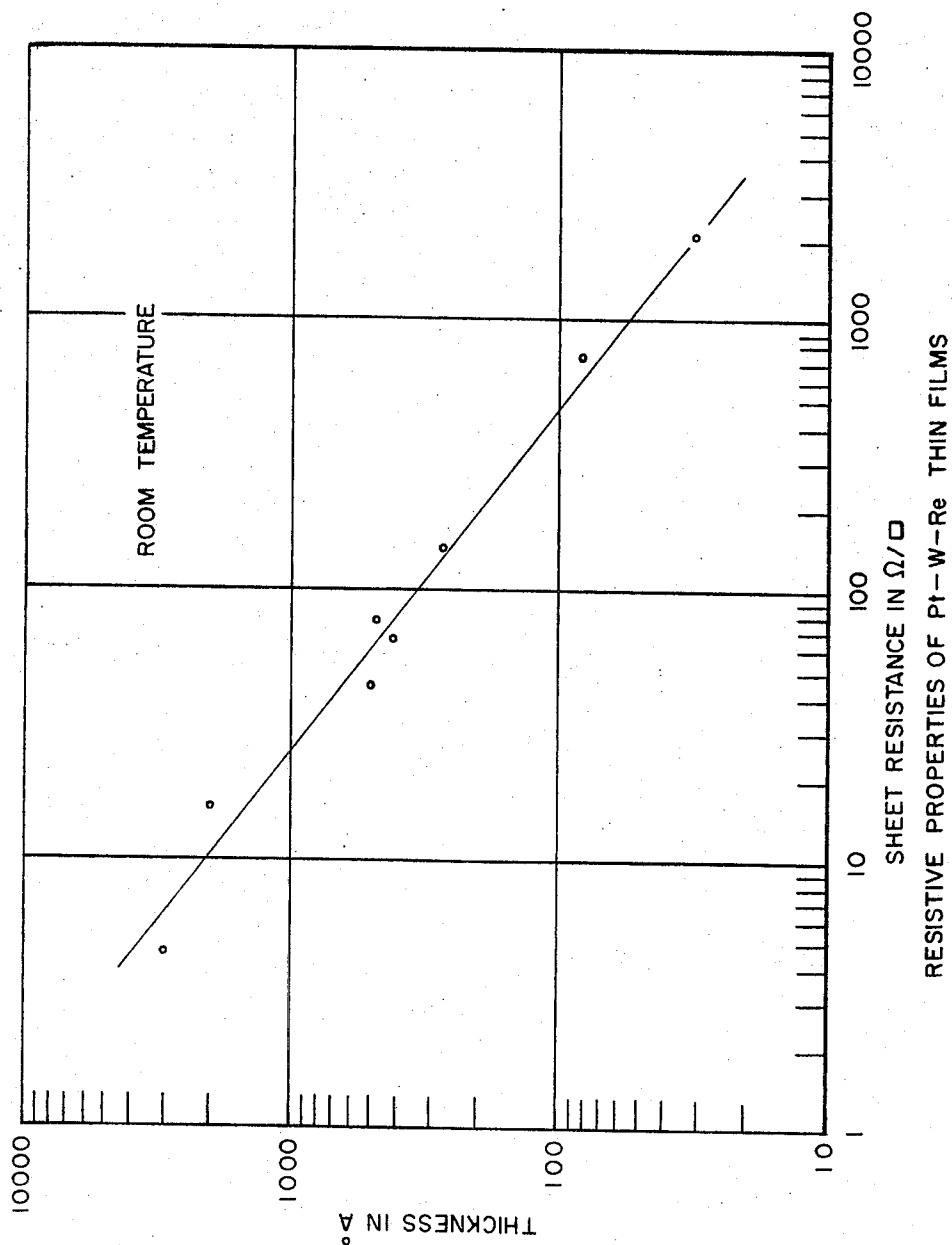
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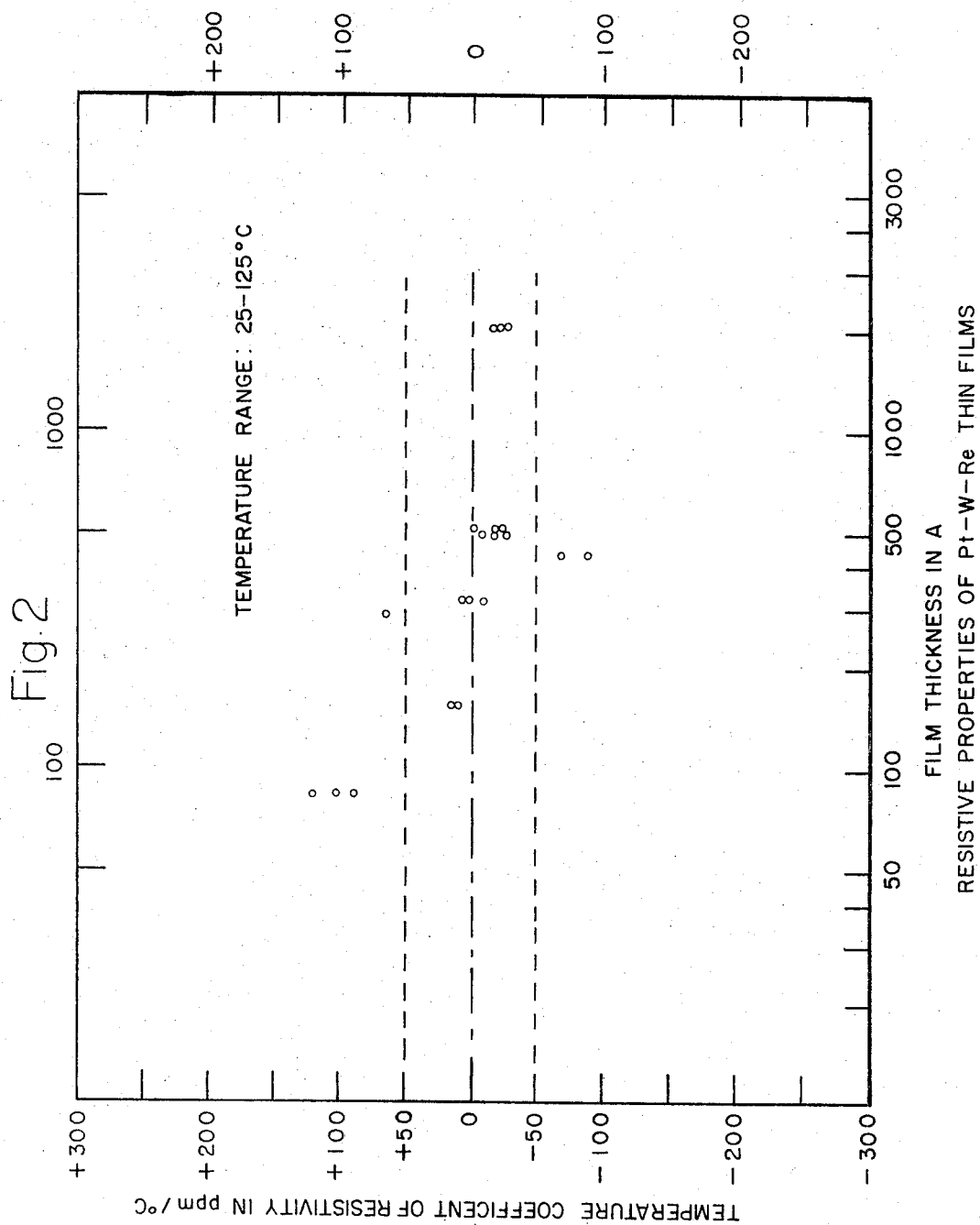
[57] **ABSTRACT**
High stability thin film alloy resistors can be made from a constant conductivity alloy comprising a predominant amount of platinum, rhodium, iridium, palladium, gold, or silver and a minor amount of at least two metals selected from tungsten, rhenium, tantalum, molybdenum, hafnium, zirconium, or niobium. The constant conductivity alloy is deposited onto a non-conducting substrate to a thickness of between 10 and 5,000 angstroms.

10 Claims, 2 Drawing Figures

Fig. 1



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HIGH STABILITY THIN FILM ALLOY RESISTORS

BACKGROUND OF THE INVENTION

Previously, thin film resistors have been made from tantalum, refractory metal nitrides, and nickel-chromium alloys. Although each of the prior art thin film materials have been satisfactory for most micro-electronic purposes, advanced applications require properties which these materials cannot meet. For example, microelectronic circuits today require a higher degree of stability and reliability in a greater number of environmental situations. The chromium, chromium alloys, tantalum, and refractory metal alloys currently in use are susceptible to corrosion by reaction with environmental gases and residual solvents from device processing. Accordingly, these materials, especially when in the form of films, are chemically modified in time which leads to changes in the electrical properties. Some prior art materials do possess high corrosion, but their resistivities are usually too low for many applications. One example, of these materials is the 98% gold-2% chromium alloy which has a resistivity of only 30 micro ohm-cm. Two of the frequently used prior art materials are 80% nickel-20% chromium and reactively sputtered tantalum. In thin film form, these materials have sheet resistances of 200 ohms per square, but with thermal coefficients of resistivity from minus 300 to plus 200 ppm/°C over the -25°C to 125°C temperature range. Future microelectronic applications will require much lower temperature coefficients of resistivity than those of nichrome and sputtered tantalum, in addition to the high stability provided by extreme corrosion resistance.

U.S. Pat. No. 3,463,636 discloses a bulk form of a constant conductivity alloy of similar composition as disclosed herein. The distinguishing feature, however, is that when films of less than 5,000 angstroms are sputtered onto a substrate in a circuit pattern, outstanding and unique resistor properties may be obtained. For example, the resistivity of a film of the present alloy may be several times greater than the resistivity of the bulk alloy which is about 172 to 190 $\mu\Omega$ -cm. In addition to this property difference, the temperature coefficient of resistivity exhibited by the film is smaller than that exhibited by the bulk form. Temperature coefficients of resistivity for the films of this invention exhibit ± 50 ppm/°C in a temperature range of -25°C to +125°C whereas the bulk material exhibits about +72 to +367 ppm/°C in the same temperature range.

SUMMARY OF THE INVENTION

The present invention is related generally to a thin film resistor comprising a predominant amount of a noble metal and a minor amount of at least two refractory metals which have been deposited on a substrate to a thickness of less than 5,000 angstroms, generally, 10 to 500 angstroms. Thin film circuits are produced preferably by sputtering a compacted blend of metal powders onto a dielectric substrate. Formation of the circuit pattern is most readily achieved by back-sputtering the deposited metal, although photolithographic masks and chemical etches have been used also. Thin film resistors produced in either manner exhibit low and controllable temperature coefficients of resistivity, long term electrical stability in environmental high stress conditions, and high power density capabilities.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 shows the increasing sheet resistance in ohms per square as it relates to the decreasing thickness in angstroms at room temperature; and

FIG. 2 depicts the range of temperature coefficients of resistivity in parts per million per degree centigrade of 23 readings at various film thickness in angstroms.

The graphical representations in FIG. 1 and FIG. 2 more clearly show the trends represented by the values in the Table. FIG. 1 shows good consistency with the rule of thin film conduction, i.e., the thinner the film, the higher the sheet resistance.

FIG. 2 shows the clustering of thermal coefficient of resistivity points which were obtained from the last column in the Table. Seventeen of the twenty-three data points which were obtained fall within the range ± 50 ppm/°C, with the smallest value being 0.

The ternary alloys used in this invention are comprised of a major portion of a noble metal selected from the group consisting of platinum, rhodium, iridium, palladium, gold, or silver which is alloyed with a minor portion of two refractory metals selected from tungsten, rhenium, tantalum, molybdenum, hafnium, zirconium, and niobium. These metals are formulated in proportions of 50% to 90% by weight of the noble metal with 50% to 70% by weight being preferred, and 10% to 50% by weight of two or more of the refractory metals and 30% to 50% by weight being preferred. Sputtering targets may be fabricated from a blend of constituent powders which have been isostatically-compacted, or from an alloy prepared by melting the constituent metals. Although sintering of the powder metal compact is preferable, it is not critical to the success of the sputtering operation, and likewise if alloys specimens are used, remelting to improve homogeneity is preferable but not critical.

Substrates used in this invention may be selected from substantially any of the dielectric materials which can withstand the temperatures encountered in a sputtering operation. Specifically, materials which are suitable for use as substrates may be selected from silicon, ceramic, quartz, or glass.

There are several methods of producing metallic films in accordance with this invention. Vapor deposition, vacuum evaporation, sputtering, and screen printing are a few specific examples of the various methods which may be employed. Selection of the most suitable method will depend upon the metallic system involved, the thickness of the films required, and the types of product application.

A more complete understanding of the present invention may be obtained by reference to the following example.

EXAMPLE

A mixture containing seven grams of powdered platinum and 3 grams of powdered tungsten-25% rhenium alloy were blended and isostatically compacted at 60,000 psi into a 3/4 inch diameter by 1/32 inch thick target. A specimen substrate of alumina-boro-silicate glass, 1.75 inch by 1.25 inch, and the alloy target were placed in a MRC sputtering chamber and pumped to

less than 5×10^{-6} torr. The target was sputter-cleaned first for 1/2 hour at 100 watts at 10 microns pressure of argon. Maintaining RF power, the substrates were rotated to the sputtering position approximately 1.25 inches from the target. A film of 154 angstroms thickness having a composition of 69.5% by weight platinum, 21.8% by weight tungsten, and 8.7% by weight rhenium was deposited on the substrate. The resultant thin film pattern was determined to have an initial resistance of 3,687 ohms at room temperature and after exposure to 125°C for 236 hours in air, the resistance at room temperature was determined to be 3,692 ohms, or a change of +0.10%. The power handling capability of this film was determined to be approximately 100 watts per square inch, in an essentially non-dissipating medium.

Several additional specimens were made and their resistance properties determined. The following table sets forth the values obtained.

TABLE

Film No.	Thickness in Å	Composition % Pt-W-Re	Sheet Resistance $\Omega/\square$	Resistance K Ω	TRC in ppm/°C (25-125°C)
6	32	69.0-20.7-10.3	2100	250	Not measured
7	83	69.6-18.3-12.1	757	42.78 41.03 58.82	+124 +90 +104
9	154	69.5-21.8-8.7	162	6.31 5.06	+14 +16
8	282	67.8-20.6-11.6	140	9.87 8.66 10.08	+39 +34 +69
4	315	68.3-18.7-12.0	70	4.84 4.95 5.46	-8.3 +6.1 +9.2
10	430	69.9-18.5-11.6	69	3.52 2.95 3.50	-63 -85 -44
11	490	70.8-17.8-11.4	63	4.76 5.11 5.44	-6 -21 -15
12	505	69.6-18.5-11.9	45	10.96 10.65 10.35	-18 -19 0
3	2025	68.3-20.0-11.7	16	1.11 1.05 1.02	-18 -19 -19

We claim:

1. A thin film resistor comprising:

a. a film of less than 5,000 Angstroms of a constant conductivity alloy consisting essentially of (i) from 50% to 90% by weight of a metal selected from the group consisting of platinum, rhodium, iridium, palladium, gold, and silver and (ii) from 10% to 50% by weight of at least two metals selected from the group consisting of tungsten, rhenium, tantalum, molybdenum, hafnium, zirconium, and niobium, on a

b. substrate selected from the group consisting of silicon, ceramic, glass and quartz.

2. A thin film resistor according to claim 1 wherein:

the constant conductivity alloy consists essentially of (i) from 50% to 70% by weight of a metal selected from the group consisting of platinum, rhodium, iridium, palladium, gold, and silver and (ii) from 30% to 50% by weight of at least two metals selected from the group consisting of tungsten, rhenium, tantalum, molybdenum, hafnium, zirconium, and niobium.

3. A thin film resistor according to claim 1 wherein; the alloy film is between 10 and 5,000 Angstroms in thickness.

4. A method for making a thin film resistor comprising:

a. positioning a nonconducting substrate and a metal alloy source consisting essentially of from 50% to 90% by weight of a metal selected from the group consisting of platinum, rhodium, iridium, palladium, gold, and silver, and from 10% to 50% by weight of at least two metals selected from the group consisting of tungsten, rhenium, tantalum, molybdenum, hafnium, zirconium, and niobium, in an enclosed chamber,

b. evacuating said chamber and back filling with argon,

c. depositing said metal alloy to a depth of less than 5,000 Angstroms.

5. A method according to claim 4 wherein:

said metal alloy is deposited to a depth of 10 to 5,000

angstrom.

6. A method according to claim 4 wherein; said alloy is sputter-cleaned prior to sputter depositing onto said substrate.

7. A method according to claim 4 including the further step of forming a resistor pattern of said metal alloy by back sputtering.

8. A method according to claim 4 including the further step of forming a resistor pattern of said metal alloy by chemical etching of a photolithographic pattern.

9. A method according to claim 4 wherein; said substrate is selected from the group consisting of silicon, ceramic, quartz, and glass.

10. A method according to claim 9 wherein:

said metal alloy consists essentially of (i) 50% to 70% by weight of a metal selected from the group consisting of platinum, rhodium, iridium, palladium, gold, and silver and (ii) from 30% to 50% by weight of at least two metals selected from the group consisting of tungsten, rhenium, tantalum, molybdenum, hafnium, zirconium, and niobium.

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