June 30, 1970 C. A. BAER 3,517,644

APPARATUS FOR MAKING METAL ALLOY RESISTORS

Original Filed June 23, 1965 2 Sheets-Sheet 1

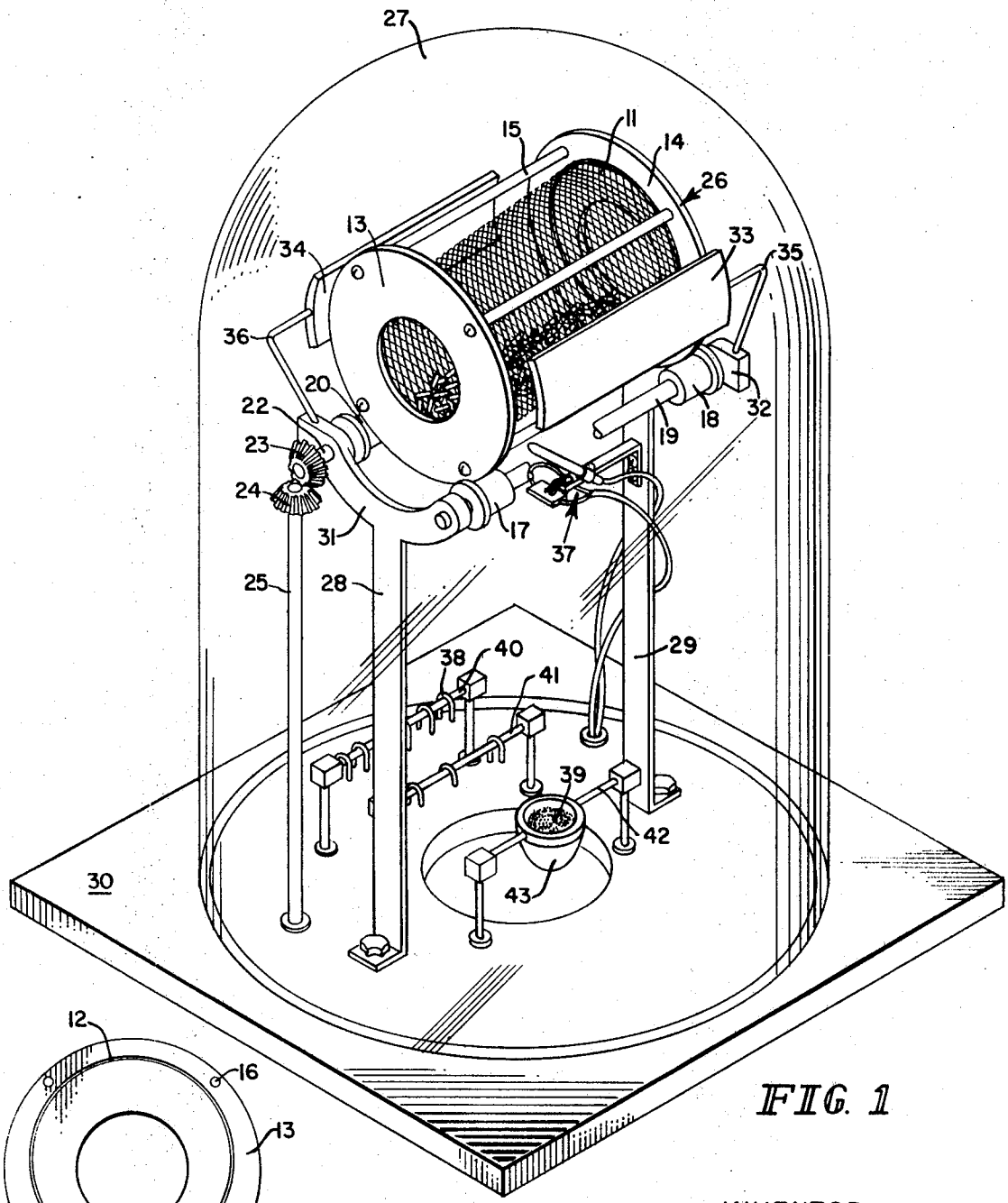


FIG. 1

FIG. 2

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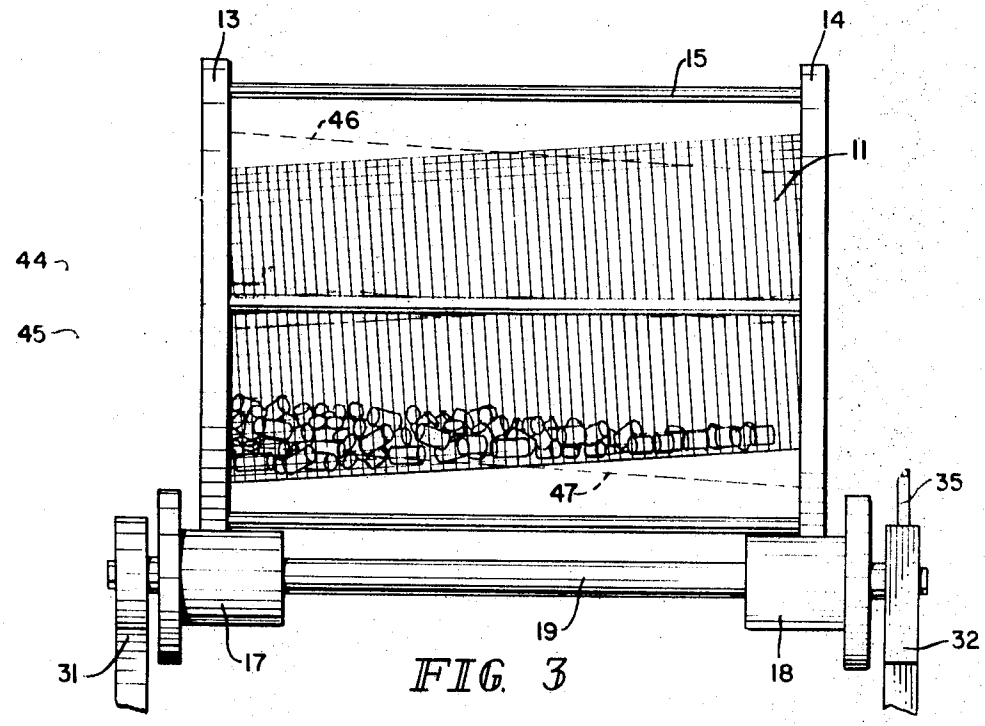


FIG. 3

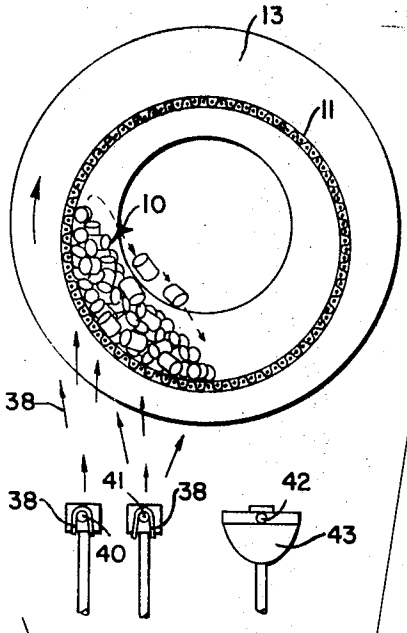


FIG. 4

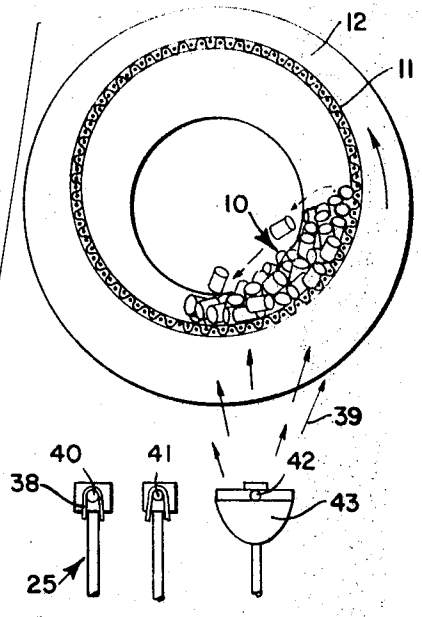


FIG. 5

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APPARATUS FOR MAKING METAL ALLOY RESISTORS

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Continuation of application Ser. No. 466,290, June 23, 1965. This application Dec. 16, 1968, Ser. No. 785,438
Int. Cl. C23c *13/08*
U.S. Cl. 118—49 9 Claims

ABSTRACT OF THE DISCLOSURE

A foraminous cylinder mounted in a vacuum chamber and having an axis at an angle to the horizontal is rotated about a horizontal axis, so that substrates retained therein are tumbled both radially and longitudinally. A heater and a vaporization source provide coating material which condenses on the substrates. A source for vaporizing a dielectric material may also be provided. A method of coating resistor substrates envisages loading the substrates into a foraminous container mounted in a vacuum chamber, rotating the container so as to impart both rotational and lateral motion to the substrates, heating the substrates to a suitable temperature, and evaporating a conductive film onto the substrates. A dielectric film may also be evaporated onto the substrates, and they may be annealed.

This application is a continuation of application Ser. No. 466,290, filed June 23, 1965, now abandoned.

The present invention relates to metal alloy film resistors and more particularly relates to means and methods for fabricating such resistors.

The application of uniform coatings onto the surface of discrete randomly oriented substrates by vapor deposition techniques has been a continuing problem. In order to obtain uniform coatings on tubular ceramic resistor bodies, the resistor bodies are normally mounted on individual supporting wire rods which are rotated above an evaporation source, or are individually mounted into a circular support member which rotates either around or above the evaporation source. The aforementioned procedures have a number of disadvantages, the main ones being the need for individually mounting and removing each resistor and the limitation as to the number of units which may be processed at one time. Attempts to overcome these difficulties have resulted in complex and expensive equipment which either automatically load and remove the resistors into and from a circular support means having a plurality of holders therein or moving the resistor bodies through the deposition chamber by means of a conveyor belt or through the use of an angled chamber.

More recent attempts have employed means wherein the resistor bodies are rotated during the coating process to insure the application of uniform coatings thereon. However, these have still resulted in complicated structures such as hoppers having two rotating rollers. The resistor bodies are fed from the hopper so that they are supported between and rotated by the rollers.

A prime object of the present invention is to provide an improved metal film resistor.

It is another object of the present invention to provide means and apparatus for providing a uniform coating in a film resistor in which individual handling of the resistor is eliminated.

It is an object of the present invention to provide an apparatus for coating resistor bodies wherein the bodies

are uniformly coated by random tumbling while being exposed to a metal vapor which condenses thereon to form a resistor film.

It is an object of the present invention to provide means and methods for large batch processing of resistor bodies simultaneously without the need of feed in and collecting equipment.

Still another object of the present invention is to provide a thin film resistor having improved resistive characteristics manufactured most economically and expediently.

The present invention, in another of its aspects, relates to novel features of the instrumentalities described herein for teaching the principal object of the invention and to the novel principles employed in the instrumentalities whether or not these features and principles may be used in the said object and/or in the said field.

Other objects of the invention and the nature thereof will become apparent from the following description considered in conjunction with the accompanying drawings and wherein like reference numbers describe elements of similar function therein and wherein the scope of the invention is determined rather from the dependent claims.

For illustrative purposes the invention will be described in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective of the coating apparatus;

FIG. 2 is an end view of the mounting plates;

FIG. 3 is a side view of the tumbling apparatus;

FIG. 4 is an end view of the container and substrates during the application of a resistive coating to the resistor bodies; and

FIG. 5 is an end view of the container and substrates during the application of a silicon monoxide film to the resistor bodies.

Generally speaking the present invention involves the fabrication of film resistors by tumbling a plurality of resistor bodies within a rotatable, cylindrical foraminous container at a rotational velocity sufficient to cause random tumbling of the resistor bodies to provide suitable statistical averaging of the surface exposure time to the vapor stream. The process is carried out in a vacuum chamber wherein both the tumbling apparatus and the evaporation sources are mounted. Coating deposited in this manner show a relatively narrow range of resistance values and a narrow range of value for the temperature coefficients of resistance within the processed lot. These characteristics are dependent upon the substrate temperature during coating, the coating composition, the coating thickness, and a number of other factors which will become apparent as hereinafter set forth.

According to the operation of the present invention, a plurality of resistor substrates **10** are placed within a rotatable, cylindrical screen container **11** which is mounted in groove **12** of eccentric end plates **13** and **14**. The container **11** and end plates **13** and **14** are held together by a plurality of spacer suport rods **15**. End plates **13** and **14** have a plurality of radially spaced apart apertures **16** along the periphery thereof so that the container may be mounted so as to rotate in an eccentric orbit thereby tending to mix resistor substrates **10** in a longitudinal direction and laterally back and forth during rotation. The tumbler unit rests on a plurality of rollers such as **17**. Rollers **17** and **18** are affixed to and rotate with shaft **19**. Rollers **20** and **21** (not shown) are affixed to and rotate with a similar shaft **22**. Shaft **22** terminates at one end in driven bevel gear **23** which meshes with driving bevel gear **24**. Gear **24** is driven by a motor driven shaft **25** and thus in turn imparts rotational motion to the cylindrical container **11**. Container **11**, in turn, causes shaft **19** to rotate and thus the

desired tumbling is effected. The aforedescribed tumbling unit **26** is mounted within a vacuum chamber **27** by means of support brackets **28** and **29** which are affixed to base plate **30** of chamber **27**. Brackets **28** and **29** terminate in C-shaped portions **31** and **32** so as to adapt to unit **26**.

In order to insure that the substrates are tumbled randomly to provide a suitable statistical averaging of the exposure time of the substrate surfaces to the vapor stream, two conditions must be met. While the rotational velocity of the container is not critical, the minimum rotational rate must be sufficient to produce the aforementioned random tumbling and the maximum rate would be just below the rate which would hold the substrates in a fixed relationship by centrifugal force to the inner wall of the container.

To further insure random tumbling, container **11** rotates eccentrically about its axis thereby causing the substrates to move back and forth from end plate **13** to end plate **14** as they are being tumbled. This is accomplished by attaching the end plates **13** and **14** eccentrically to the container so that they are 180° out of phase with respect to each other. Spacer support rods **15** are used to assemble plates **13** and **14** and container **11**. The end plates **13** and **14**, as represented in FIG. 2, have a plurality of apertures **16** therein which are discretely spaced near the periphery of the eccentric plate. Plates **13** and **14** may be misaligned so that they are up to 180° out of phase with one another. The rotation of the assembled container is then eccentric which imparts lateral motion as well as rotational motion to the substrates **10**. No mechanical means are required nor employed within container **11** to provide directional tumbling or motion. Contact of the substrates **10** with the ends **13** and **14** of the container **11** during rotation imparts a significant random motion directing the substrates generally back toward the center of the container. The eccentric axis of rotation insures complete random lateral flow of the substrates within the container during processing.

Temperature control of substrates **10** is achieved by radiation and conduction heating of the substrates. Radiation-type heater units **33** and **34** are positioned adjacent tumbler unit **26** and maintained at a temperature of 600° to 800° C. Substrates **10** are heated by direct radiation from heaters **33** and **34** and by conduction from the metal container **11** which is also exposed to radiation from the heater elements. Elements **33** and **34** are supported by mounting rods **35** and **36** respectively which are affixed to C-shaped portions **32** and **31** of support brackets **29** and **28** respectively. A thermocouple **37** is positioned adjacent container **11** to montor the substrate temperature.

The cylinder **11** and substrates **10** are rotated at approximately **20** revolutions per minute during the minimum 15 minute heat-up cycle in order to heat the substrates uniformly to the required temperature. In the case of a nickel-chromium-aluminum resistance film the required temperature is approximately 200° C.

The operating pressure in the vacuum chamber **27** in which the aforementioned mechanism and evaporation sources **38** and **39** are mounted in nominally 1×10^{-5} to 1×10^{-6} torr. as measured by ionization gauge (not shown).

The coating or deposition cycle involves the evaporation of a predetermined charge of aluminum and suitable chromium-nickel alloy either from a single evaporation source or from separate sources. As shown in FIGS. 1, 4 and 5, the source wires **38** are wrapped around multistranded tungsten wire filaments **40** and **41**. While one filament is sufficient, a plurality of filaments may be employed to insure adequate source material in the event that one filament fails. It also provides a means of simultaneously evaporating similar or dissimilar materials. Typically, a charge of 150 mg. of aluminum and 930 mg. of a nickel-chromium alloy such as Karma wire are wrapped about a multi-stranded tungsten wire filament. The filament is then heated to evaporation temperature of the metals and the metals are slowly evaporated from the filament. The filaments **40**, **41** and **42** are positioned approximately 6 inches below the container **11** and the metal evaporated up through the openings of the container and onto the individual substrates being tumbled within the rotating container. Resistance measurement, optical monitoring or crystal monitoring may be employed to control coating thickness and composition. Just prior to and during the evaporation cycle, the rotational speed of the cylinder is increased to between 60 and 80 r.p.m./minute in order to guarantee good coating uniformity on the substrates.

The evaporation cycle is continued for 8 to 10 minutes in order to transfer the major portion of the Al and Cr-Ni alloy from the tungsten filaments. The temperature monitoring thermocouple **37** positioned adjacent container **11** is held at a nominal temperature of 280° C.

A protective coating of SiO is then evaporated from source **39** which is contained in a resistively heated tantalum container **43**. The SiO coating minimizes the resistance value shift during stabilization to less than 5% and has no apparent adverse effect on subsequent operations. The thickness of the SiO film is determined empirically, but can generally be considered to be on the order of 2000 angstroms.

Upon completion of the evaporation cycle, the rotational speed of the container is again decreased to a nominal 20 revolutions per minute and held at this speed during annealing. Annealing of the evaporated coating is achieved by maintaining the substrates at a temperature of 300–350° C. for a time interval of about 15 minutes in order to achieve the desired electrical properties of the evaporated composite film. The substrates are then cooled to approximately 50° C. and removed from the container.

The uniformity of the evaporated coating on the substrates is good. At least 85% of the coated resistor bodies fell within ±10% of a specific value on initial test runs. Considering the nominal 10% variation in the area between gold terminations applied to the substrates prior to the vacuum processing, the uniformity of resistance values measured is indicative of a high degree of uniformity in the deposition of resistive films on resistor bodies as obtained by the present invention.

As was previously stated, the eccentric rotation of container **11** significantly improves the exposure of the tumbled substrates to the evaporated materials. The axis of rotation **44** and **45** as shown in FIG. 3 and the path of container **11** during rotation as shown by lines **46** and **47** illustrate the manner in which the substrates are not only tumbled, but carried laterally from end plate **13** to end plate **14**.

As shown in FIG. 4, during the deposition of the resistance film, cylinder **11** which is mounted in end plates **13** and **14** is rotated in a clockwise direction so that the resistor substrates **10** are held in the vicinity of the metal vapor stream from filaments **40** and **41**. During this cycle, the silicon monoxide filament **42** is inactive. After deposition of the resistance film, filaments **40** and **41** are turned off. The container is then rotated in a counterclockwise fashion so that the substrates **10** are held in the vicinity of the vapor stream from the SiO source **43** as shown in FIG. 5. In this manner the substrates are aligned with the respective evaporation sources.

FIGS. 4 and 5 further point out that the tumbling rate is not sufficient to hold the substrates **10** to the walls of container **11** by centrifugal force. Substrates **10** tend to climb up the container wall to a certain point and tumble backwards as indicated by the arrows.

The present invention eliminates the need for individually mounting substrates over a source, or for costly and complicated feed through mechanisms. It further eliminates the need for individually handling the units and the necessity of using masks for selective deposition during

processing. The present invention has broad application to coating fibers, rods, particles, electrical component substrates or any other relatively small, regular or irregular shaped objects or particles. In the case of resistors approximately 1,000 to 10,000 resistors may be processed simultaneously, depending upon the size of the substrate.

It is to be understood that the representative embodiment is illustrative. For example, the container, while depicted as being wire screen may be any foraminous material. The invention is applicable to the coating of resistor bodies as herein described but could be used equally well to coat bodies to form coils or condensors, particles, fibers, filaments, etc. It will be readily apparent to those skilled in the art that certain variations may be practiced without departing from the scope of the invention. I consider all of these modifications and variations to be within the foregoing description and defined by the appended claims.

Having thus described my invention, I claim:

1. An apparatus for coating resistor substrates comprising:

(a) a foraminous cylinder carrying said substrates

(b) axially aligned end plates disposed at the opposed ends of said cylinder, said end plates including means to mount opposed ends of said cylinders eccentric the center of said end plates so as to align the axis of said cylinder at an acute angle from the axis of said end plates,

(c) means to maintain said end plates in spaced substantially parallel relation,

(d) rotational drive means cooperating with said end plates,

(e) means for mounting said cylinder and end plates within a vacuum chamber,

(f) means within said vacuum chamber for heating said substrates, and

(g) means disposed within said vacuum chamber for discharging vaporized material into said cylinder.

2. Apparatus as in claim 1 wherein said cylindrical means is a cylindrical wire screen.

3. Apparatus as in claim 1 wherein at least one of said plates has an aperture therethrough for loading and removing said substrates.

4. Apparatus as in claim 1 wherein said means to mount said cylinder on said plates is an eccentric groove in each of said plates for receiving an end of said cylinder.

5. Apparatus as in claim 1 wherein said means to maintain said plates in spaced substantially parallel relation includes a plurality of spacer bars disposed between and connecting said plates.

6. Apparatus as in claim 1 wherein said drive means includes a pair of rotatable shafts having rollers thereon for carrying said end plates, means for imparting rotational motion to one of said shafts, and a pair of brackets affixed to said vacuum chamber for supporting said shafts.

7. Apparatus as in claim 6 wherein each of said brackets has a first end affixed to a floor of said chamber and a second end extending vertically therefrom, said second end terminating in a C-shaped member having leg portions for supporting said rotatable shafts.

8. Apparatus as in claim 1 wherein said means for discylindrical means.

9. Apparatus as in claim 1 wherein said means for discharging vaporized materials includes separate means for discharging conductive and dielectric material mounted adjacent said cylindrical means in juxtaposition.

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U.S. Cl. X.R.

118—418; 117—109, 217, 107.1