April 2, 1957 J. W. SHAW 2,787,560

MICROWAVE RESISTOR MANUFACTURE

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FIG. 1.



FIG. 2.

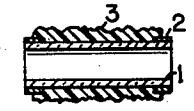


FIG. 3.

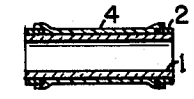


FIG. 11.

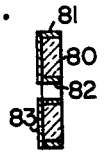


FIG. 4.

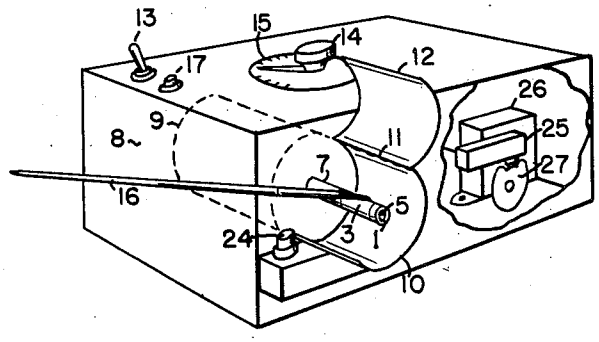


FIG. 5.

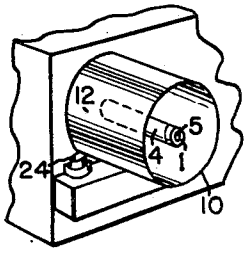
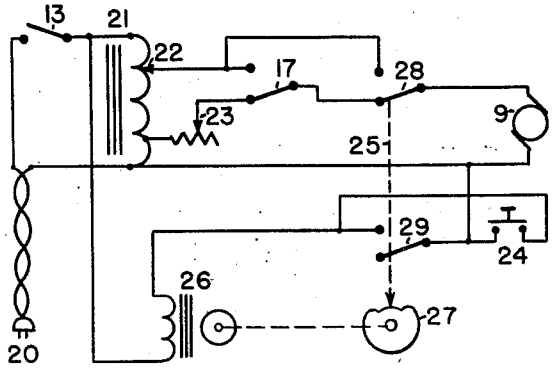


FIG. 6.



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FIG. 7.

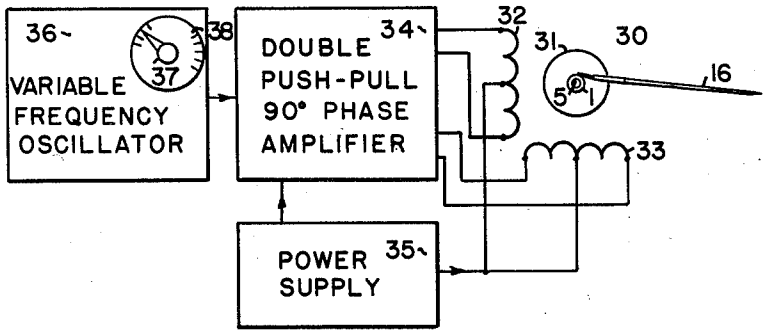


FIG. 8.

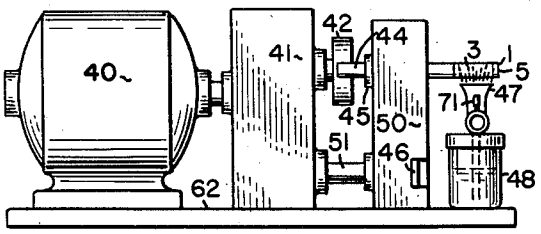


FIG. 9.

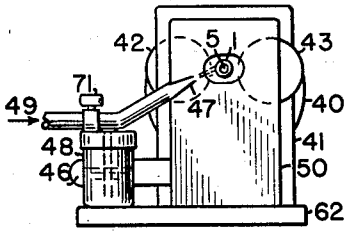
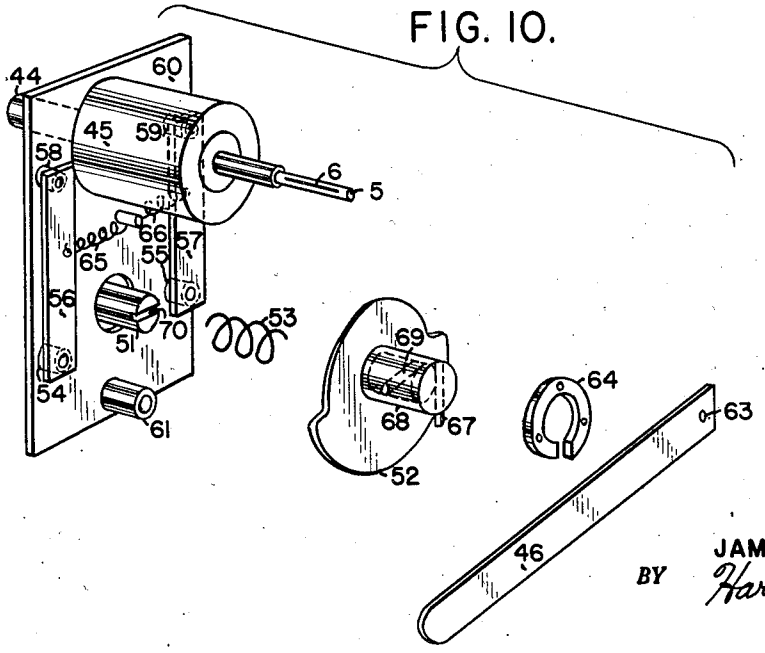


FIG. 10.



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MICROWAVE RESISTOR MANUFACTURE

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Application March 3, 1955, Serial No. 491,994

12 Claims. (Cl. 117—217)

This invention relates to the process of making electrical resistors of precise structural uniformity, particularly of the thin metallic film type. Such resistors are elements of pure resistance having a low standing wave ratio at radio frequencies of the order of billions of cycles per second.

In the microwave region of the radio frequency spectrum few electrical parameters can be relied upon as being pure entities. Even resistors tend to manifest reactive electrical properties, often increasing in apparent value with frequency and increasing the standing wave ratio of the device of which they form a part. These shortcomings arise from the fine structure of the substance forming the resistance element, the physical thickness of that element and from non-uniformities in thickness and resistance properties.

An object of my invention is to produce a resistor having unaltered resistive characteristics over a frequency range of from zero to billions of cycles per second.

Another object is to manufacture such a resistor in a simple manner, allowing the employment of persons of ordinary manipulative skill.

Another object is to manufacture microwave resistors to predetermined resistance values by a semi-automatic process.

Another object is to produce a resistor having a high degree of radial uniformity of thickness of a very thin metallic film.

Another object is to produce a resistor having a high degree of uniformity of resistance throughout the resistor element thereof.

Other objects of my invention will be apparent upon reading the following detailed specification and upon examining the related drawings, in which:

Fig. 1 shows a hollow cylindrical resistor carrier in longitudinal section,

Fig. 2 shows the same with resistive resinate applied,

Fig. 3 shows the same after centrifuging the resinate,

Fig. 4 is a perspective view of a typical production device for carrying out my invention,

Fig. 5 shows a portion of the device of Fig. 4 during the rapid rotating period,

Fig. 6 shows the schematic electrical circuit of the device of Fig. 4,

Fig. 7 schematically shows an alternate type of drive for the device of Fig. 4,

Fig. 8 shows a side elevation view of a mechanical device for carrying out an alternate method of my invention,

Fig. 9 shows an end elevation of Fig. 8,

Fig. 10 shows the mechanical timing structure of the device of Fig. 8, and

Fig. 11 shows a disk resistor in sectional elevation.

In accomplishing the objects of my invention I utilize a ceramic-like insulating carrier element normally having radial symmetry, as a cylinder, hollow cylinder, disk or cone. This is revolved at a speed of the order of 500 revolutions per minute while a liquid or quasi-liquid resistive compound is brushed or sprayed onto the surface chosen to support the resistive coating, usually the periphery of an element of cylindrical shape or one or both sides of a disk.

An important step in my method is that of precision centrifuging the carrier with the still liquid or quasi-liquid resistive compound thereon. The factors affecting this step are speed of centrifuging rotation, viscosity of the resistive compound and to some degree the period of rotation at centrifuge speed. Within certain limits these factors may be altered interchangeably to achieve a given resistance value while still meeting criteria required to give a proper microwave resistor. The result sought and accomplished is a thin and uniform film of resistive compound having a uniform composition over the surface chosen.

It will also be understood that the resistance value obtained is affected by the amount of noble metal in the resinate and which metal or metals are present. This resistive compound is preferably such that firing at a high temperature decomposes the resinous material and leaves a thin continuous metal film.

In completing the process the carrier is air dried, preferably at an elevated temperature, then fired to decompose the resinate and then auxiliary processes accomplished, such as applying a coating of heat resisting lacquer to protect the thin metal film. Further details and variants to this method will be hereinafter disclosed.

While glass, china and other materials may be used for the carrier element **1** in Fig. 1, I prefer to use the ceramic known to the trade as AlSiMag 493, or perhaps AlSiMag 196, manufactured by the American Lava Corp. It is desirable that the carrier have a smooth but not glazed surface, that it be capable of withstanding temperatures of at least 1,200° F., be essentially non-hydroscopic, have good electrical insulating qualities, be clean and be accurate in radial dimensions.

The carrier is first given a coating of silver in the form of two surrounding bands at the extremities thereof as shown at **2** in Fig. 1. This can be accomplished by applying a reducible silver mixture, such as No. 4822 of the Du Pont Co., which contains approximately 50% of very finely divided silver. It is important that the distance along the carrier between the bands be the same if uniformity of resistance value with given processing is desired. This may be achieved by brushing or spraying the silver mixture on from fixed positions or by simply providing a removable pressure adhesive tape mask over the central portion of the carrier which is to be reserved for the thin resistive film. After air drying for a few minutes and removal of any mask the carrier and its silver coating is fired at approximately 1,200° F. for a quarter hour.

The application and centrifuging of the resistive material **3** in Fig. 2 is carried out with necessary precision by the devices shown in Figs. 4 to 10. Referring to Fig. 4, the working portion of the machine is the slip-on (carrier) spindle **5**. Hollow carrier **1** makes a concentric sliding fit thereon, being held by the friction of a pair of spring wires **6** (Fig. 10) positioned in a slot in the spindle at the right-hand end thereof. It is obviously important that the carrier be radially symmetrically mounted and I have also found that appreciable vibration should be prevented by attention to balancing of the rotating parts.

Shaft **7** extends into case **8** and directly into an adjustable speed motor shown dotted at **9**. A partial enclosure of the working area is provided at all times. This is hemicylindrical shell **10**. At **11** this is provided with a hinge which holds lid **12**. When lid **12** is closed it

provides a substantially complete enclosure for intercepting excess resistive compound thrown off during the centrifuging step and also actuates switch 24.

In use, carrier 1 having silver end bands is slipped in place on spindle 5 and on-off switch 13 snapped on. Knob 14 is turned to a previously calibrated point on scale 15 according to the resistance desired. A camel hair or equivalent brush 16 is dipped in a container of resistive compound and applied to the carrier while it is rotating at low speed uniformly along the length thereof save for about half the axial width of each silver band. The material as thus applied is shown at 3 in Fig. 2. Roughness and radial thickness have been exaggerated for purposes of illustration.

Immediately after the application step lid 12 is closed, actuating switch 24 as mentioned by mechanical contact with the plunger thereof. The apparatus then appears as in Fig. 5. Actuation of switch 24 inaugurates the centrifuging cycle by starting an interval timer to be described below. After the time interval the spindle returns to the low speed and the device preferably turned off by switch 13 to allow the processed carrier to be removed and another to be installed upon shaft 5. The radially uniform appearance and reduced thickness of the resistive material after centrifuging is shown at 4 in Fig. 3. In placing the carrier 1 on spindle 5 care is taken to prevent grease from fingers, etc. from being placed on the portion of the carrier to be coated and in taking off the carrier care is taken not to abraid the film 4. Being subsequently air dried and fired the appearance of the film is the same as shown at 4 in Fig. 3 except that it is very thin, of the order of 1 micron, and cannot be illustrated in true thinness because of the obvious limitations of draftsmanship.

Turning now to the schematic circuit of the device, Fig. 6, plug 20 represents the usual means of obtaining 115 volts single phase alternating current power. This is turned on or off by batwing switch 13 (see also Fig. 4) and is thus applied to variable ratio ("Variac") transformer 21. The variable tap 22 thereof is adjusted by knob 14 (Fig. 4) to a predetermined resistance value on scale 15. A resistor 23 in series with the low voltage tap on the variable ratio transformer causes motor 9 to revolve at low speed for the application of the resistive compound when this portion of the circuit is in use. As previously mentioned upon completing the application step the operator closes lid 12 and operates switch 24 thereby. It is seen in Fig. 6 that this completes the circuit to timer motor 26. This motor is provided with a gear box as a part thereof so that the output shaft revolves once in seven seconds in a typical example. Cam 27 is shaped to actuate a double-pole double-throw switch 25 upwards for five seconds and downward for two seconds. When actuated upwards switch arm 28 is raised, connecting motor 9 to the high voltage tap 22 on transformer 21. Arm 29 is similarly raised to continue to supply power to timer motor 26. When cam 27 has made substantially one revolution both arms return to the lower switch positions, motor 26 stops and motor 9 returns to low speed. Switch 17 is a manual control to change from low to high speed on motor 9 regardless of the timer cycle for special or emergency conditions.

In Fig. 7 an alternate form of resistor centrifuge is shown. The physical nature of the device is roughly the same as shown in Fig. 4. The motor for centrifuging is indicated generally by numeral 30. It is a hysteresis two-phase synchronous motor having rotor 31 and relatively high impedance stators 32 and 33 which are suited for connection directly into the plate circuit of vacuum tubes comprising the double push-pull ninety-degree outphased amplifier 34. A usual power supply is 35. An example of the motor described gives a synchronous speed of 30,000 revolutions per minute for an audio frequency of 1,000 cycles per second. This speed, or others down to about 10,000 revolutions per minute, represent desirable centrifuging speeds and are obtained by adjusting oscillator knob 37 to frequencies between 1,000 and 333 cycles per second. Dial 38 may be calibrated in ohms, the highest frequency giving the highest resistance, for a given resistive compound. A suitable brushing speed of 500 R. P. M. is obtained with a frequency of 16.6 cycles per second. The resistive compound is applied by brush 16, or other equivalents to be later discussed, to carrier 1 on shaft 5.

Fig. 8 illustrates a centrifuge driven by a constant speed induction motor 40. Gear box 41 provides two fiber friction disks 42 and 43 having speeds of rotation of 1725 and 86 revolutions per minute, respectively. A mechanical cycle is started by pushing lever 46. This causes shaft 44 in bearing 45 to be mechanically moved first against slow speed disk 43 for about two seconds for coating purposes and immediately thereafter against high speed disk 42 for centrifuging for about two seconds.

In this embodiment the resistive material is sprayed onto the carrier from nozzle 47, which has a fan-tail shape to coat the whole resistive section of the carrier at once without moving the nozzle. I find that an area of approximately three hundredths of a square inch, an air pressure of the order 30 pounds per square inch and a viscosity of the resistive compound of an average of 37 centipoises gives resistors of desired resistance value and characteristics. The spray is formed by the usual aspirator, of which vessel 48 contains the resistive compound and air is introduced at 49 from conventional means not shown.

Case 50 houses the all-mechanical timer previously referred to. An exploded view thereof is shown in Fig. 10. Drive shaft 51 revolves at 10 R. P. M. from suitable gearing in gear box 41. Radial cam 52 fits partially over shaft 51, with compression spring 53 tending to separate the two. The radial cam also contacts follower rollers 54 and 55, these being attached to follower arms 56 and 57 which are pivoted at 58 and 59 to plate 60. Plate 60 is in turn pivoted at 61 to main base 62 (Fig. 8). Lever 46 is similarly attached to the main base at 63 and is adapted to press against axial cam 64, which is stationary as to rotation but is arranged to be urged toward cam 52 when lever 46 is pushed to the left.

With cam 52 in the position shown follower rollers 54 and 55 are equally separated from the vertical center line of plate 60, hence springs 65 and 66 are equally tensioned and plate 60 assumes a vertical position. This causes shaft 44 to be positioned midway between fiber friction disks 42 and 43 and thus not to revolve. (See Fig. 9.)

When lever 46 is pushed to the left by the operator axial cam 64 is pressed against pin 67 of shaft 68, which is connected to radial cam 52. This causes this cam structure to move toward drive shaft 51 and slot 70 to engage pin 69. With counterclockwise rotation of shaft 51 the large part of cam 52 (i. e., having the greater radius) is brought into engagement with follower 55. This increases the tension on spring 66 and moves the top of plate 60 to the right, thereby engaging shaft 44 with slow speed disk 43 under spring tension for traction.

This condition obtains until cam 52 has made a half revolution, after which the condition is exactly reversed and shaft 44 is driven by fast disk 42. (See Fig. 9.) After a half revolution of cam 52 under the latter condition the relation of pin 67 and axial cam 64 is such that the radial cam structure has moved sufficiently far to the right to disengage from drive shaft 51. Hence the timer mechanism stops and does not start again until the cycle is again started by pressing lever 46. Shaft 44, holding the resistor carrier 1 is also at rest. When driven by the slow disk the speed of shaft 44 is 800 R. P. M. and when driven by the fast disk it is 15,000 R. P. M.

With this embodiment particularly, the various resistance values desired are obtained by altering the viscosity of the resistive compound. This is not related to the spraying step, but rather because of centrifuging at a

constant speed. A range of viscosities of from 50 to 25 centipoises at 20° C. gives a resistance range of from approximately 12 to 250 ohms for a platinum resinate and the hollow cylindrical tube form of carrier 1.

I have determined that with the spraying method step of coating the carrier it is not necessary to reduce the speed of rotation below that required for centrifuging. It is merely necessary to rotate the carrier at centrifuging speed and spray it sufficiently for a brief instant to coat it completely, then to allow two seconds, in general, for centrifuging and the rotative part of the process is completed. In this alternative the machine of Figs. 8, 9 and 10 may be slightly altered by removing the slow fiber disk 43 and connecting instead a simple linkage from follower roller 55 to valve 71 in the air line of the aspirator. A portion of the former slow speed cycle is then used for spraying and an automatic spray and centrifuge cycle is thus obtained, promoting uniformity of processing.

It should be noted in passing that the spray technique of resinate application is not limited to the machine of Figs. 8 to 10, but may be employed with the devices of Figs. 4 and 7 as well. In any of the three arrangements the spray coating cycle may be performed at the low speed of the order of 500 R. P. M. and the centrifuging cycle at from 10,000 to 30,000 R. P. M. depending upon the resistance value desired, or both cycles may be executed at the centrifuging rate as has been explained.

Means for accomplishing variations of my method have been set forth above in which the factors (1) speed of centrifuging and (2) viscosity of the resistive compound have been the prime variables. Another factor has some effect and should be kept uniform in order to most fully obtain reproducible and predicted results. This is the period of time taken for the coating step and the interval between the completion thereof and the start of the centrifuging step. The first period should be relatively short and the second one uniform from resistor to resistor if greatest uniformity of product is to be obtained.

To some degree the viscosity of the resistive compound increases as soon as it is applied to the carrier because of the normal evaporation of the lighter elements of the vehicle. If the coating is to be uniform throughout the axial length of the carrier the viscosity of the compound must be uniform at the time of start of centrifuging. In order that the coating on one resistor have the same thickness as on the next one, the interval between application and centrifuging must be the same so that the viscosity will be the same. These factors are easily controlled in practice as long as the operator is aware of them and acts accordingly. With the spray step for application the axial uniformity is more or less automatically accomplished and with the automatic spray and centrifuge cycles of the machine of Figs. 8, 9 and 10 both factors are automatically maintained uniform.

My process may be carried out at ordinary room temperatures and by observing ordinary cleanliness. Regulated air temperature or filtered air are not required to obtain resistors of the same value within a few percent plus or minus of a median value and closer tolerance may be held by strict observance of uniformity or by the usual practice of selection; i. e., by measuring the resistance of completed resistors and sorting accordingly.

It is to be noted that the centrifuging step determines how much resistive compound remains on the carrier. The operator may inadvertently place twice the normal amount of compound on a particular carrier but the amount remaining after the centrifuging step will be the same as for a normal coating. Also, any non-uniform portions or foreign matter fly off with certainty and at the first part of the centrifuging step. I thus obtain several advantages over known methods of making resistors where merely dipping, brushing, squeegeeing, spraying or revolving for only the application step are practiced. In my work leading to this invention only when the centrifuging step was included as has been set forth was a necessary degree of success attained in the manufacture of microwave resistors.

In order for metal film resistors to be fully useful for microwave work it is necessary that the film be a relatively small fraction of the skin effect depth for such wavelengths. With prior techniques and low resistance values it has been difficult to observe this criterion. Low resistance values are frequently needed in the construction of coaxial attenuators, line terminations and similar devices. Values of from 0.1 to 1,000 ohms are more often required than are higher values. By utilizing an alloy of about one-third palladium and two-thirds gold I am able to produce uniform films with my process well under the necessary thickness and down to 0.1 ohm. By utilizing platinum and high centrifuge speeds I am able to obtain high resistance values without "spiraling," that is, without removing some of the film in a spiral along the carrier to considerably increase the length of the resistive path. The latter practice, of course, results in an inductive effect of unwanted degree and may not be tolerated in microwave apparatus of precision. Suitable resistive compounds are those consisting of resinous suspensions of platinum, gold and palladium which contain a few percent of the metallic salt and the rest the vehicle and are reduced to the pure metal by firing at a temperature of the order of 1,000° F. for approximately a quarter hour. The optimum time of baking or firing as it is more often called is that time which gives a minimum resistance for a given set of other production conditions.

With my process more than one coating of resistive compound may be applied in order to secure low resistive values. It is necessary that each coat be air dried but either all coats may be fired together or they may be fired as applied. Because of the centrifuging step the coatings are sufficiently thin that the skin depth ratio is not exceeded.

In microwave work a disk-shaped resistor is frequently required, as for T attenuators. Satisfactorily performing resistors of this shape are easily made by my process. In Fig. 11 silver coatings 81 and 82 are preferably placed on the inner and outer circumferences of a ceramic disk 80 by the step previously described. These give contact to the coaxial elements of the attenuator and to the resistance film as well. The disk carrier is coated on one or both sides with one of the resistive compounds previously mentioned and centrifuged on one of the machines described. The centrifuging step is about the same as for the cylindrical carriers 1 but the resistance for an equivalent treatment is less because of the shorter length of path of the carrier 80 as shown in Fig. 11. Although the dynamics of centrifuging is not as simple with the side-coated disk as with the outer-coated cylinder I have found that the uniformity of deposit is closely held. This reveals a cohesive force as one of the factors in the centrifuging step and represents one limit to the process. This limit is desirably placed, however, and aids in overall uniformity. Because of this my process is adapted for coating irregular shapes such as a tapered or conical resistor and even shapes of square rather than circular cross-section when the cohesive limit is used.

Specific values have been given in this specification to most fully teach how the invention may be performed. Wide variations may be taken from such values and other changes made in details, proportions, combinations and substitutions of one step or part for an equivalent in another process or embodiment without departing from the spirit of my invention.

Having thus fully described my invention and the manner in which it is to be practiced, I claim:

1. The process of constructing an electrical resistor having essentially exclusively resistive impedance through microwave frequencies comprising the steps of providing a non-conductive heat-resistant carrier, providing a decomposable quasi-liquid compound of a noble metal

resinate, revolving said carrier while coating the same with said resinate, revolving said carrier for a fixed time interval at a speed sufficiently high to throw off a major portion of said resinate by centrifugal force, solidifying said resinate by drying, and firing the coated carrier at a temperature sufficiently high to decompose said resinate to a uniform thin film of metal having essentially exclusively resistive impedance upon said carrier proportionate in thickness to that of the resinate determined by centrifugal force.

2. The process of manufacturing a microwave resistive-impedance electrical resistor comprising the steps of mounting an insulating refractory carrier upon a mandrel, revolving said carrier, simultaneously applying a quasi-liquid decomposable metallic-organic compound to peripherally cover said carrier, revolving said carrier at a substantially higher speed than for the application of said compound for a fixed period of time, said higher speed being such as to remove non-uniformly applied and excess compound to a radially uniform thin film thereof having a thickness substantially less than as applied, said thickness being determined by said speed, drying said compound, and firing the carrier-compound assembly to remove the organic component of said compound and to produce an adherent thin metallic film of uniform thickness upon the periphery of said carrier.

3. The process of claim 2 in which said process is repeated to form a second metal layer upon said carrier to increase the layer uniformity radially and to reduce the resistance value of said resistor.

4. The method of manufacturing a resistor having a predetermined electrical microwave reactanceless resistance which comprises the steps of rotating an insulated carrier, simultaneously applying a liquid-like decomposable organic compound having a reducible metallic component to an outer surface of said carrier, subsequently revolving said carrier for a fixed time interval at a speed sufficiently high to remove non-uniformly disposed compound and to reduce the radial thickness thereof a substantial amount to that required to give the predetermined electrical reactanceless resistance, air drying said compound, and firing the carrier-compound assembly to decompose the organic component of said compound and to produce a uniform thin film of metal upon the periphery of said carrier.

5. The method of claim 4 wherein the radial thickness of the metal film for non-reactive microwave resistive impedance is of the order of one micron thick.

6. The process of making a microwave electrical resistor which comprises the steps of providing a cylindrical insulating carrier with conductive bands at each end thereof, rotating said carrier, simultaneously applying a semi-liquid decomposable compound having a reducible metallic component to cover the periphery of said carrier along the length thereof including a portion of said conductive bands, subsequently revolving said carrier for a fixed time interval to reduce the radial thickness of said compound to a uniform thin electrically reactanceless coat by centrifugal force, air drying said compound at an elevated temperature and firing the coated carrier at a temperature sufficiently high to decompose said compound to a uniform thin film of metal upon the periphery of said carrier.

7. The process of manufacturing an ultra-high radio frequency resistor which comprises the steps of revolving a ceramic cylinder having conductive bands at each end, simultaneously applying a decomposable organic liquid having a reducible metallic component to cover the outer surface of said cylinder, revolving said cylinder at high centrifuging speed for a fixed period of time to limit the amount of said liquid adhering to said cylinder to a uniform thin electrically reactanceless film, drying said liquid at an elevated temperature, firing the thus coated cylinder to remove the organic component of said liquid and to form a uniform thin film of metal upon the outer surface of said cylinder, and applying a coating of lacquer to protect said thin film of metal.

8. The process of manufacturing a microwave thin-metal-film electrical resistor having a predetermined essentially reactanceless electrical resistive impedance which comprises the steps of providing a cylindrical non-conductive ceramic carrier, providing said carrier with thin conductive bands at each extremity thereof, revolving said carrier around the axis of the cylinder at a speed in the range of 200 to 1,400 revolutions per minute, simultaneously applying a heat-decomposable organic resinate resistive compound in liquid form having a reducible noble metal component to cover an outer surface of said carrier between and contacting said conductive bands, immediately thereafter revolving said carrier about the axis thereof at a speed in the range of 10,000 to 30,000 revolutions per minute for a fixed time interval to substantially reduce the radial thickness of said compound adhering to said carrier to correspond to the value of said predetermined resistance, the latter said speed being greater for higher values of resistance, drying said compound at an elevated temperature, firing the compound-coated carrier to remove the organic component of said compound and to form the essentially reactanceless metal film adherent to said carrier of the order of one micron radial thickness, and coating said film with a non-conductive lacquer for mechanical protection of said film.

9. The process of manufacturing a microwave thin metal film electrical resistor having a predetermined substantially pure electrical resistance which comprises the steps of providing a cylindrical non-conductive ceramic carrier, applying a band of reducible silver mixture at each extremity of said carrier, drying said mixture, firing said mixture at a temperature of the order of 1,200° F. for approximately a quarter hour to obtain thin metallic silver bands, revolving said carrier around the cylindrical axis at a speed in the range of 200 to 1400 revolutions per minute, simultaneously applying a heat-decomposable organic resinate resistive compound in the liquid state having a reducible noble metal component to coat an outer surface of said carrier between and contacting said metallic silver bands, immediately thereafter revolving said carrier around the cylindrical axis at a speed in the range of 10,000 to 30,000 revolutions per minute for a fixed time interval of the order of five seconds to reduce the radial thickness of said compound adhering to said carrier to a value corresponding to greater than said predetermined resistance, said latter speed being greater for higher values of resistance, drying said compound at an elevated temperature, firing the compound-coated carrier at a temperature of the order of 1,000° F. for approximately a quarter hour to remove the organic component of said compound and to form a noble metal film having substantially pure electrical resistance at microwave frequencies adherent to said carrier surface of the order of one micron radial thickness, repeating the steps of application, rapidly revolving, drying and firing to reduce the resistance of said film to the value of said predetermined resistance, and thereafter coating said films with a non-conductive lacquer to mechanically protect the same.

10. The process of manufacturing a metal film resistor having a predetermined pure electrical resistance at microwave frequencies which comprises the steps of rotating a non-conductive carrier at a high speed, simultaneously spraying a decomposable organic compound having a reducible metallic component upon an outer surface of said carrier for a brief period of time, continuing to revolve said carrier at said high speed for a further fixed period of time, said high speed being sufficiently high to remove all but a uniform thin film of said compound from the outer surface of said carrier, drying said compound, and

firing the sprayed carrier to decompose said compound to a uniform thin metallic film upon the outer surface of said carrier.

11. The process of manufacturing a thin metal film microwave disk resistor having a predetermined pure electrical resistance which comprises the steps of providing an insulative disk carrier having a concentric hole, forming thin conductive bands upon the inner and outer surfaces of said disk, revolving said disk around a horizontal axis coincident with that of said hole, applying a quasi-liquid decomposable resinate resistive compound having a reducible metal component to a side of said disk between and contacting said conductive bands, revolving said disk around said axis for a fixed time interval at a speed sufficiently high to reduce the thickness of said resistive compound to a thin film corresponding in thickness to said predetermined pure electrical resistance, drying said compound, and firing said disk and film to decompose said compound to a uniform thin metallic film upon the side of said disk having said predetermined pure electrical resistance.

12. A machine for coating an insulated carrier with resistive compound for forming a microwave electrical resistor comprising a housing, an adjustable speed motor having a horizontal shaft within said housing, said shaft extending without said housing, means upon said shaft for holding said carrier, means to coat said carrier with said compound, an electric power source of adjustable voltage,

a first switch for impressing a low voltage upon said motor to operate the same at a low speed, a time interval timer, said above-recited electrical means within said housing, a shield attached to said housing surrounding said shaft, said shield having a hinged closure portion, a second switch positioned for actuation by said closure portion when closed, actuation of said second switch starting the time interval of said timer, said thus actuated timer adapted to impress a high voltage upon said motor and upon termination of said time interval said thus actuated timer adapted to remove said high voltage from said motor.

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2,374,288	Hinkley	Apr. 24, 1945
2,440,691	Jira	May 4, 1948
2,551,712	Soby	May 8, 1951
2,562,199	McLellan	July 31, 1951
2,617,163	Jeter	Nov. 11, 1952
2,639,392	Warner	May 19, 1953
2,645,701	Kerridge	July 14, 1953
2,693,023	Kerridge	Nov. 2, 1954
2,703,296	Teal	Mar. 1, 1955
2,740,928	Ward	Apr. 3, 1956