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RESISTOR COMPRISING SPACED METAL COATINGS ON A RESISTIVE LAYER AND TRAVELING WAVE TUBE UTILIZING THE SAME

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Fig. 1.

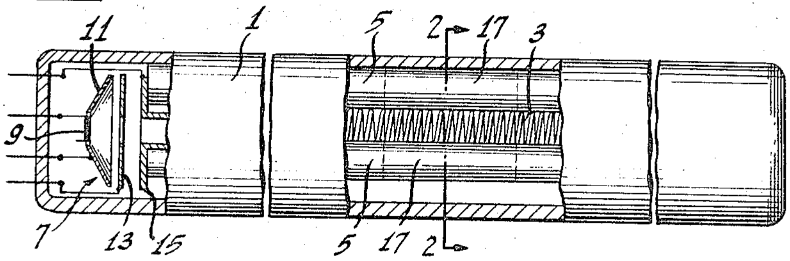



Fig. 2.

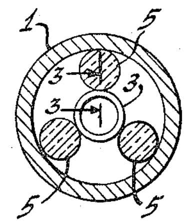



Fig. 3.

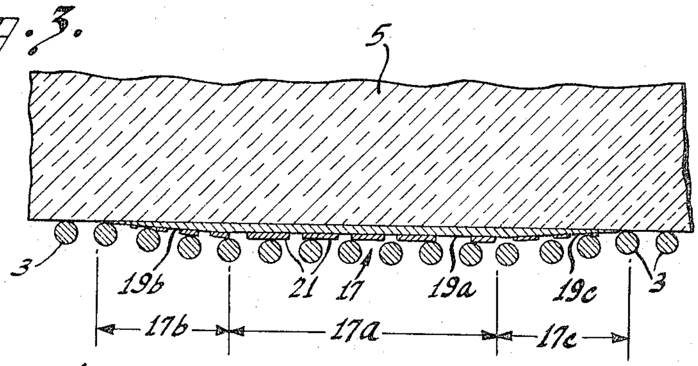
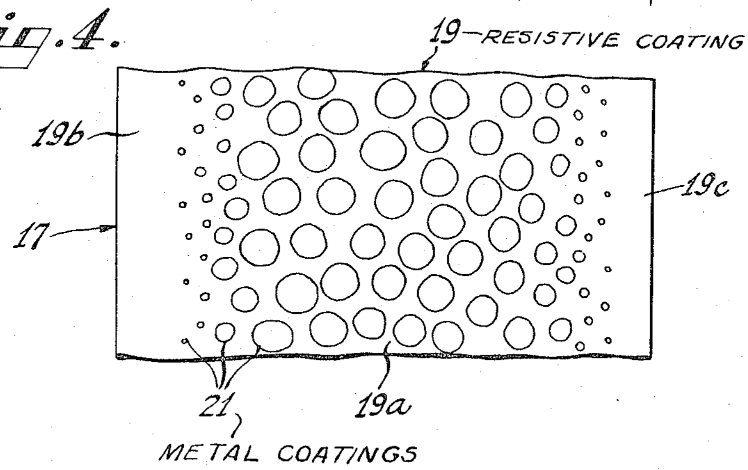



Fig. 4.

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3,368,103

# RESISTOR COMPRISING SPACED METAL COATINGS ON A RESISTIVE LAYER AND TRAVELING WAVE TUBE UTILIZING THE SAME

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## ABSTRACT OF THE DISCLOSURE

A novel resistive element comprising a discontinuous conductive layer in contact with a continuous resistive layer may be made by projectng fluent carbonaceous material, such as graphite, onto a predetermined portion of a nonconductive base, such as ceramic, to form a resistive layer, and then electrolytically depositing a metal on the resistive layer, terminating the depositing before the metal forms a continuous coating. An attenuator for a traveling wave tube may be made by projecting onto a portion of a rotating cylindrical ceramic rod to form a resistive annular band thereon, followed by the deposition of the discontinuous metal layer. The edges of the resistive layer may be tapered in resistance by slowly moving the carbon source away from the rotating rod during the depositing step.


The present invention relates to an electric resistor. The resistor of the invention is especially suitable for use in a traveling wave tube, but a resistor of the invention may be used elsewhere. In a traveling wave tube, an electron beam is projected along an elongated helix or other slow wave propagating structure for interaction with waves traveling therealong. In an amplifier, an input signal is coupled to one end of the helix and the amplified signal is extracted from the other end of the helix. Due to imperfect impedance matches at the input and output couplings, there is a tendency for waves to be reflected back and forth along the helix. Such reflection leads to regeneration and oscillations. To avoid this problem, it is customary to provide a resistive or lossy region or element, preferably at a point along the helix where the amplitude of the forward wave is low, to absorb or attenuate reflected waves. Such attenuators are usually made by spraying or otherwise forming a thin coating of some form of carbon, such as graphite, onto a portion of the nonconductive helix support, which may consist of three ceramic rods. However, it is sometimes difficult if not impossible to provide sufficient conductance with a thin coating on the short length of support rod between adjacent helix turns to effectively attenuate the waves on the helix. The surface resistance of the attenuator coating should be less than 100 ohms per square. The resistivity of carbon is about $800\times10^{-6}$ ohm-cm., thus a coating thickness of about .1 micron is necessary to produce a surface resistance of 100 ohms per square. To make the resistance less than 100 ohms per square, the thickness must be greater than .1 micron. However, it is difficult to make a satisfactory adherent carbon coating thicker than about 0.1 micron, because of the tendency of the carbon particles to flake off. Also, the thickness of the attenuator coating should be kept to a minimum in order to avoid distortion of the helix. Moreover, it is desirable to taper the resistance at the ends of the attenuator to avoid reflections of waves therefrom. Most of the other available resistive materials have either too high or too low a resistivity to be useful as traveling wave attenuators. If one attempts to make a resistor suitable for this purpose by depositing areas of a metal on a nonconductor, the result is either a very low resistance if the areas touch



each other or very high resistance if the areas do not touch each other, and it is very difficult to produce intermediate values of resistance.

The object of the present invention is to provide an improved electric resistor having any desired intermediate value of resistance.

Another obect is to provide an improved traveling wave tube attenuator.

Still another object is to provide an attenuator or resistor having a central region of relatively low resistance and end regions with resistances tapering to very high values.

A further object is to provide a new and improved method of making an attenuator having tapered resistance ends.

In accordance with the invention, a continuous resistive layer is formed on a nonconductive base, a metal is deposited on the resistive layer to form conductive areas thereon, and the deposition is terminated before the metal forms a continuous layer.

In the drawing,

FIG. 1 is a side view, partly cut away in section, of a traveling wave tube embodying the present invention;

FIG. 2 is a transverse section view taken on the line 2—2 of FIG. 1;

FIG. 3 is an enlarged fragmentary detail view taken on the line 3—3 of FIG. 2; and

FIG. 4 is a plan view showing a portion of the cylindrical attenuator of FIG. 3 rolled out onto a flat plane.

FIGS. 1 and 2 show a traveling wave tube, which is conventional except for the improved attenuator of the present invention. The tube comprises an envelope 1 containing an elongated metal helix 3, supported by three symmetrically disposed ceramic rods 5, and an electron gun 7, comprising a thermionic cathode 9, focusing electrode 11, and accelerating electrodes 13 and 15, for projecting a beam of electrons through the helix 3 to a collector (not shown) at the other end of the tube. Each of the ceramic rods 5 is coated with an attenuator 17 in contact with some of the turns of the helix 3. The attenuators 17 may be limited substantially to the area of contact with the helix. However, for ease of manufacture, the attenuators are usually provided in the form of annular bands entirely surrounding the ceramic rods.

As shown in FIGS. 3 and 4, each attenuator 17 comprises a resistive coating 19 of carbon, or other resistive material, on which a multiplicity or large number of conductive islands of metal have been deposited in a controlled manner. The function of the conductive islands 21 is to short out certain portions of the carbon coating and thereby reduce the effective surface resistance of the attenuator as a whole. The effective resistance of the carbon coating 19 and conductive islands 21 is also less than the resistance of a thicker carbon coating having a thickness equal to the sum of the thicknesses of the coating 19 and the islands 21. The distribution of the islands 21 can be either irregular, as shown in the drawing, or regular. In depositing the metal onto the carbon coating, care must be taken that most of the metal areas are spaced from each other, and hence constitute true islands. However, some of the areas may touch each other, and form larger islands, without unduly reducing the surface resistance of the attenuator. If sufficient areas were to touch each other to form a substantially continuous path across the coating, the attenuator would have too low a resistance and thus be inoperative for the purpose intended. As shown in FIG. 3, some of the conductive islands 21 are in contact with the helix 3.

In making an electric resistor element of uniform lateral resistance, the coating 19 of carbon or other resistive material may be formed by any conventional method, such as spraying, dipping, painting, evaporation, silk-screening, and gas or solid pyrolytic formation. The metal islands 21 may be deposited on the resistive coating 19 by an atomizing spray, evaporation, sputtering, silk-screening, photo-etching or electrolytic deposition. The resistive material is preferably carbonaceous, that is, either containing or composed of carbon. However, other resistive materials may be used, including various semiconductive materials such as SiC, ZnS, CdSe, InSb, PbTe, Ge (doped) and Si (doped). The resistive coating may also be a very thin evaporated layer of a metal such as tungsten, molybdenum, tantalum and rhenium that does not alloy with the metal chosen for the conductive islands 21. The conductive islands may be of any conductive metal, such as copper, silver, gold, nickel, platinum, cobalt, tin, cadmium, iron, etc. For use as a traveling wave tube attenuator, the metal must be one that is suitable for use in vacuum tubes.

In the example shown in FIGS. 3 and 4, the attenuator 17 has a central portion 17*a* having an axial length of about 1 inch and substantially uniform resistance, and two tapered end portions 17*b* and 17*c* each having an axial length of about ½ inch and a resistance that varies from that of the central portion to that of the bare ceramic rod 5. The diameter of the ceramic rod 5 may be 100 mils, and the helix 3 may be of 10 mils diameter wire and have 50 turns per inch.

One method of making the tapered attenuator 17 of FIGS. 3 and 4 is as follows. First, an elongated ceramic rod 5 is rapidly rotated about its longitudinal axis and a carbonaceous material is sprayed in a divergent stream from a small source onto the central portion during a selected number of rotations of the rod. Then the source is slowly moved away from the rotating rod, thus gradually widening the sprayed area, until the end portions 17*b* and 17*c* have been covered, at which time the spraying is stopped. This produces a resistive coating 19*a* of uniform thickness and resistance in the central portion 17*a*, and resistive coatings 19*b* and 19*c* on the end areas that taper in thickness from that of the central portion to zero at the outer edges, with a corresponding variation in lateral conductivity.

The carbonaceous material may be applied by spraying the ceramic base with a solid organic material, such as nitrocellulose, then heating the coated base to a high temperature, about 900° C. for nitrocellulose, in a non-oxidizing atmosphere, to decompose the coating and drive off all non-carbon constituents thereof. The atmosphere may be either reducing, such as dry hydrogen, or inert, such as nitrogen. A typical nitrocellulose that has been found suitable has the chemical formula:

$$C_{12}H_{17}(ONO_2)_3O_7$$

This pyrolytic process produces an excellent adherent coating of pure carbon on the ceramic base, which may be of any known ceramic material having a melting point substantially higher than the decomposition temperature used. As an example, the surface resistance of the carbon coating may be about 400 ohms per square along the central coating 19*a*, tapering to about a megohm per square at the ends of the end coatings 19*b* and 19*c*.

After the carbon coatings 19*a*, 19*b* and 19*c* have been formed, the coated ceramic rod 5 may be immersed in an electrolytic bath of copper, for example, and copper islands 21 are plated onto the carbon coating. In one example, it was found that a voltage of 3 volts applied to the electrodes of the bath for 1½ minutes produced a combination of islands 21 and resistive base 19*a* having the desired surface resistance, about 25 ohms per square. By plating for a longer period of time, the surface resistance could be made any lower value, down to that of a continuous copper layer. Conversely, by plating for a shorter period, the surface resistance could be made any higher value, up to that of the bare carbon coating. Moreover, it was found that although the copper islands deposited on the central coating 19*a* were approximately uniform in size, the islands deposited on the end coatings 19*b* and 19*c* not only decreased in size away from the central portion but also terminated short of the outer edges of the tapered carbon coatings, as shown generally in FIG. 4. It is apparent that the conductivity of the thinnest part of the tapered carbon layer was insufficient to electroplate any copper thereon. Thus, both the carbon and the copper coatings in the end portions 17*b* and 17*c* of the attenuator are tapered in surface resistance by this method of manufacture. Secondary overlays of gold over the copper were also found to be satisfactory.



The thicknesses of the carbon and copper coatings are greatly exaggerated in FIGS. 3 and 4 for clarity of illustration. Actually, the thickness of the central carbon coating 19*a* is usually less than 0.1 micron, and the thickness of the copper islands 21 in the central portion 17*a* is even less.

Instead of using the pyrolytic method described above, the carbon coating 19 may be formed on the ceramic rod 5 by spraying the rod with a suspension of graphite particles in a liquid, such as water, and heating to evaporate the liquid leaving a carbon coating on the rod. The tapered ends 19*b* and 19*c* may also be formed by spraying the rotating ceramic rod through a mask having a rectangular aperture arranged at a skew angle to the rotating rod, or one parallel to the rod but having ends of tapered width. The metal islands 21 may also be deposited on the carbon coating 19 by spraying, evaporating or sputtering metal in fluid form through a mask having a particular pattern of apertures.

What is claimed is:

1. An electric resistor comprising:
(a) a substantially continuous layer of resistive material; and
(b) a discontinuous conductive layer comprising a large number of spaced metal coatings on said resistive layer distributed over the surface of said layer, each coating forming a conductive island shorting out a portion of said surface of said resistive layer, whereby the combined surface resistance of said two layers is substantially less than the surface resistance of said resistive layer alone; and
(c) a conductor in contact with at least three of said spaced metal coatings.

2. An electric resistor comprising:
(a) a base of nonconductive material;
(b) a substantially continuous layer of resistive material on said base;
(c) a discontinuous conductive layer comprising a large number of spaced metal coatings on said resistive layer distributed over the surface of said layer, each coating forming a conductive island shorting out a portion of said surface of said resistive layer, whereby the combined surface resistance of said two layers is substantially less than the surface resistance of said resistive layer alone; and
(d) a helical conductor in contact with at least three of said spaced metal coatings.

3. An attenuator for a traveling wave tube, comprising:
(a) a helix support rod of nonconductive material for said traveling wave tube;
(b) a continuous layer of resistive material on a portion of said rod; and
(c) a discontinuous conductive layer comprising a multiplicity of spaced metal coatings on said resistive layer distributed over the surface of said layer, each coating forming a conductive island shorting out a portion of said surface of said resistive layer, whereby the combined surface resistance of said two layers is substantially less than the surface resistance of said resistive layer alone.

4. An attenuator for a traveling wave tube, comprising:

(a) a ceramic helix support rod for said traveling wave tube;
(b) a continuous layer of carbon on a portion of said rod; and
(c) a discontinuous conductive layer comprising a multiplicity of spaced metal coatings on said carbon layer distributed over the surface thereof; each coating forming a conductive island shorting out a portion of said surface of said carbon layer, whereby the combined surface resistance of said two layers is substantially less than the surface resistance of said carbon layer alone.

5. A traveling wave tube comprising:
(a) an envelope;
(b) means for projecting a beam of electrons along a predetermined path in said envelope;
(c) a conductive helix for propagating waves along said path for interaction with said beam;
(d) helix support means including at least one non-conductive support rod in said envelope extending along and contacting said helix; and
(e) an attenuator on a portion of said rod intermediate the ends thereof, said attenuator contacting a plurality of turns of said helix and comprising:
(1) a continuous layer of resistive material on said portion of said rod; and
(2) a discontinuous conductive layer comprising a multiplicity of spaced metal coatings on said resistive layer, each coating forming a conductive island shorting out a portion of the surface of said resistive layer, whereby the combined surface resistance of said two layers is substantially less than the surface resistance of said resistive layer alone.

6. A traveling wave tube comprising:
(a) an envelope;
(b) means for projecting a beam of electrons along a predetermined path in said envelope;
(c) a conductive helix for propagating waves along said path for interaction with said beam;
(d) helix support means including at least one ceramic rod in said envelope extending along and contacting said helix; and
(e) an attenuator on a portion of said rod intermediate the ends thereof, said attenuator contacting a plurality of turns of said helix and comprising:



(1) a continuous layer of carbon on said portion of said rod; and
(2) a discontinuous conductive layer comprising a multiplicity of spaced metal coatings on said carbon layer, each coating forming a conductive island shorting out a portion of the surface of said carbon layer, whereby the combined surface resistance of said two layers is substantially less than the surface resistance of said carbon layer alone.

7. A traveling wave tube as in claim 6, wherein the resistance of said attenuator is lower at the ends than in the middle thereof, to minimize the reflection of waves thereby.

8. A traveling wave as in claim 7, wherein the resistance of said attenuator is about 25 ohms/square for about 1 inch in the middle and tapers at each end to about 1 megohm/square over about the next ½ inch.

9. A traveling wave tube comprising:
(a) an envelope;
(b) means for projecting a beam of electrons along a predetermined path in said envelope;
(c) conductive means for propagating electromagnetic waves along said path for interaction with said beam; and
(d) an attenuator for said waves comprising:
(1) a continuous layer of resistive material; and
(2) a discontinuous conductive layer comprising a multiplicity of spaced metal islands on said resistive layer distributed over the surface thereof, each island shorting out a portion of said surface of said resistive layer, whereby the combined resistance of said two layers is substantially less than the surface resistance of said resistive layer alone;
(e) said conductive means being in contact with some of said islands.


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