May 20, 1969 C. E. ANDERSON ET AL 3,444,615

PROCESS OF MAKING A HELIX SUPPORT

Original Filed June 19, 1961

FIG. 1

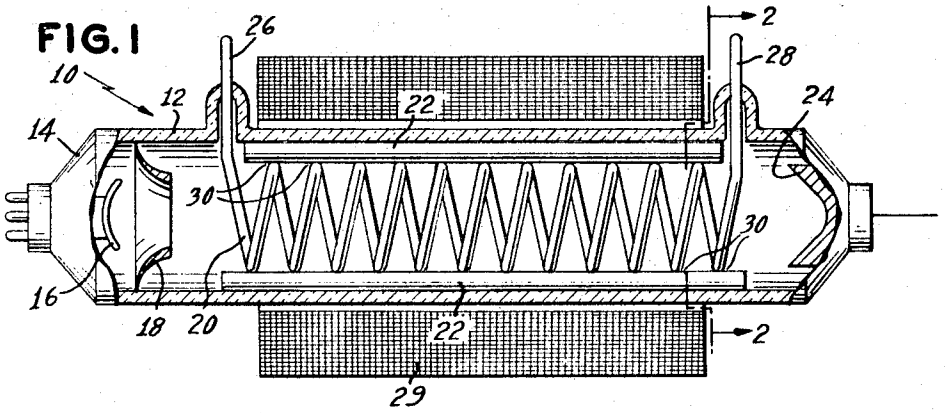


FIG. 3

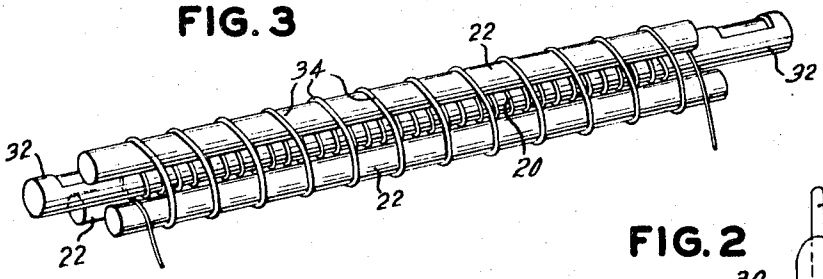


FIG. 2

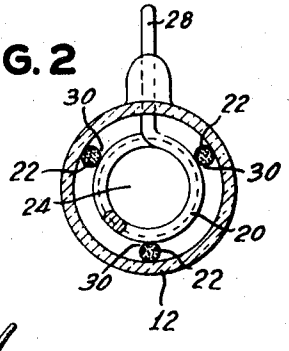
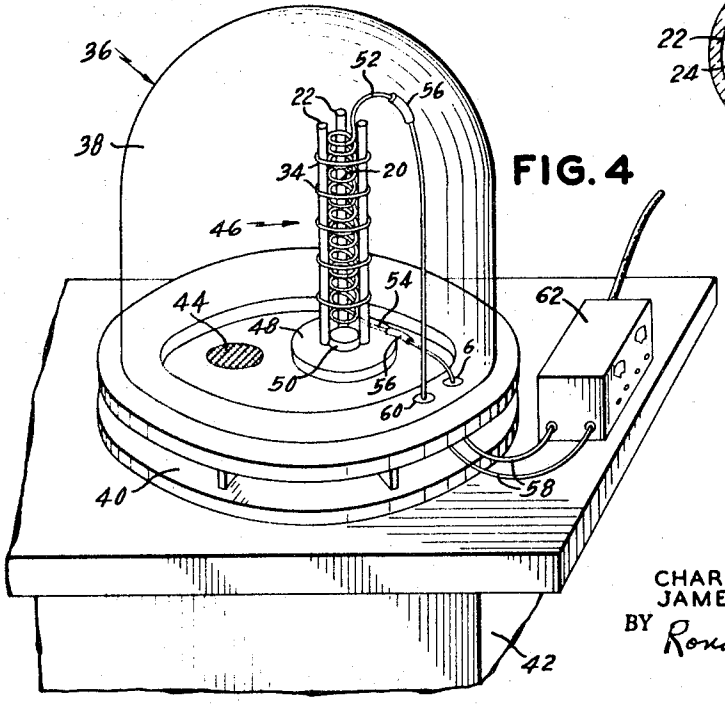


FIG. 4



INVENTORS
CHARLES E. ANDERSON
JAMES DUDFIELD
BY Ronald W. Reagin

ATTORNEYS

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PROCESS OF MAKING A HELIX SUPPORT

Charles E. Anderson, San Carlos, and James Dudfield, East Palo Alto, Calif., assignors to Litton Precision Products Inc., San Carlos, Calif., a corporation of Delaware

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Int. Cl. H01p 11/00; H01q 13/00

U.S. Cl. 29—600 9 Claims

ABSTRACT OF THE DISCLOSURE

The process for making the helix and associated support structure which forms the slow wave structure within a traveling wave tube includes the steps of winding a wire on a mandrel to form a long slender helix coil. A plurality of rod like insulating supports is then placed about the circumference of the helix and mandrel and secured in such position. Subsequentially, the mandrel is dissolved in a hot caustic solution leaving the support rods secured to the helix. A temperature elevating electric current is passed through the helix wire to metallically bond the support rods to the helix in the points of contact therebetween. In one embodiment, the helix coil initially is an electroplated nickel layer on a titanium wire, which during heating results in an alloying between the nickel and titanium which wets any contacting portion of the support rods and forms a bond therewith.

This application is a division of patent application Ser. No. 118,143, filed June 19, 1961 and now U.S. Patent 3,242,375 "Helix Support."

This invention relates to helices adapted for use in traveling wave devices, and more particularly to an improved method of construction and a supporting arrangement for a helical slow wave structure with insulating rods in a traveling wave tube.

In the prior art, traveling wave tube amplifiers and oscillators have employed a slow wave transmission circuit and an electron beam in interacting relationship with an electromagnetic wave propagating along the slow wave circuit. In general, these tubes include an evacuated envelope, an electron gun disposed at one end of the envelope for producing the electron beam, an anode electrode for collecting the electrons, and a supporting arrangement for holding the slow wave structure in alignment with the electron beam. The slow wave structure which is usually in the form of a relatively long slender conductive helix, must be rigidly supported and accurately aligned with the electron gun from which the beam of electrons is projected in order to maintain collimation of the electron beam with the helix. Accurate collimation of the electron beam, with respect to the helix, enables the electron beam to interact with the fields of the electromagnetic wave over the complete length of the helix to provide maximum interaction therebetween.

Many forms of supporting arrangements have been proposed heretofore for supporting the helix whenever it is utilized as the slow wave circuit of a traveling wave device. The most widely used arrangement has included a conductive helix mounted in a traveling wave tube with three or four insulating rods, such as glass or ceramic for example, attached externally along the length of the helix by affixing each rod to the turns of the helix by "glazing." The glazing material is usually glasslike powdered material mixed with a liquid binder to facilitate applying the glasslike material to the rods. The glass has a coefficient of expansion as close to that of the helix and support rods as possible. A thin film of the glasslike powdered material is

applied to the support rods before the rods are glazed to the helix. In the instance where the supports are glass, the glasslike material may be omitted. The support rods are secured lengthwise in spaced positions about the circumference of the helix and fired at a temperature sufficient to glaze the rods to the helix. The resulting slow wave structure is a unitary one wherein the helix is rigidly supported and may be assembled in the vacuum envelope of a traveling wave tube.

The arrangement discussed above has several disadvantages. From a method point of view, it is extremely difficult, if not impossible, to control the thickness of the layer of glasslike material applied to the rods. Thus, it is difficult to provide uniform glass fillets along the length of the helix. From a mechanical point of view, there is evidence that the glazed bond is not as strong as a metal bond and therefore is less capable of withstanding the high shock and vibration requirements demanded for extremely rugged military and missile application.

Furthermore, from an electrical point of view, it has been found that the numerous nonuniform glass fillets between the rods and the helix make it impossible to predict or control the dielectric loading from one helix to the next. Since the amount of dielectric loading in part determines the phase velocity and output power losses, it becomes impractical, if not impossible, to build traveling wave tubes which have uniform loss and phase velocity characteristics. Another electrical disadvantage of the glaze arises from the fact that the glazing material becomes excessively lossy as its temperature is raised. This property of the glaze has been known to cause a fifty percent drop in the output power of a traveling wave tube which utilizes the glazing technique.

Another widely used arrangement for supporting the helix is that of pressing the rods against the helix with the aid of a plurality of elastic holding clamps or wires at spaced intervals along the rods. The clamps or wires are normally inside the vacuum envelope, and consequently are made of nonmagnetic material which may lose its original size and temper due to the severe changes in temperatures. Since these clamps or wires are very close to the electromagnetic fields propagating in the helix, they must be dimensioned in such a way that they do not significantly disturb these fields. In addition, they must be easy to manufacture and install in order to make the cost of the traveling wave tube as economical as possible. In order to meet these requirements, the clamps or wires are generally made as small and as simple as possible and consequently may have little mechanical strength.

The primary disadvantage of such an arrangement is that the clamps or wires cannot be pressed too tightly around the rod without significantly distorting the helix. Since distortion of the helix is undesirable, the clamps or wires are not made very tight. Consequently, when the traveling wave tube is subjected to shock and vibration the helix and the electron gun may become misaligned to such an extent that the efficiency of the traveling wave tube may be greatly reduced.

In accordance with an illustrative embodiment of the present invention, a traveling wave device is provided with a helical slow wave structure for propagating electromagnetic wave energy. More particularly, there is provided a helical structure including a long slender conductive helix supported by a plurality of insulating rods metallically bonded externally along the length of the helix. The helical structure may be constructed by first winding a conductive wire plated with an alloying material on a cylindrical mandrel to form a long slender helix and holding a plurality of insulating rods in spaced positions about the circumference of the helix and mandrel. Next, the metallic mandrel is dissolved from the arrangement in a hot caustic solution, such as sodium hydroxide.

The mandrel may be any suitable material, such as aluminum for example, which may be readily attacked by the caustic solution. Neither titanium or nickel are soluble in alkali solution such as sodium hydroxide. Finally, the rigid helix and support rods are placed in an evacuated environment and elevated to a preselected temperature which causes the eutectic material to penetrate the helix and insulating rods at the points of contact between the helix and rods while simultaneously forming a metallic bond therebetween.

In accordance with another illustrative embodiment of the invention, the helix coil may be formed from an uncoated wire, such as titanium for example. Prior to winding the wire on the mandrel, the mandrel is covered with a protective coat of masking material by dipping, spraying or painting. Such masking materials are commonly known as "stop-off" materials for use in strong alkali plating solutions to prohibit the masked object from being electroplated when immersed in a chemical plating bath. In this illustrative embodiment, such a "stop-off" material was employed and is known as Bunatol No. 608 and is available from the L. H. Butcher Company of San Francisco, Calif.

After the helix is wound on the masked mandrel and the suppotring rods are secured to the helix and mandrel, the entire assembly is immersed in a suitable electroplating solution and the alloy material plated on the helix. Since the mandrel is masked with the Bunatol No. 608, only the helix is plated. The alloying material plated on the titanium helix may be any material, such as nickel, which will combine with the helix to form a eutectic material which has a melting point below that of either titanium or nickel.

The present invention obviates the foregoing and other disadvantages of the prior art by providing a slow wave transmission line structure which has the advantages of simplicity and ease of construction, as well as excellent electromagnetic wave phase velocity and power loss characteristics. It also provides a structure which is unusually rugged. The present invention also provides a method which enables one to reproduce helical slow wave structures which have substantially uniform phase velocity and power loss characteristics as the temperature of the structure is raised.

It should be noted at this point that the present invention provides a metallic bond between the supporting rods and the helix in which here are so fillets of significant size. The absence of fillets of significant size, compared with the size of the fillet commonly associated with glazing processes of the prior art, may be explained by the fact that there is an apparent penetration of the helix wire into the insulating support rods. The metallic coating which is applied to the helix wire forms a eutectic with the helix which forms a bond directly with the insulating rods. This unique feature of the helix wire penetrating into the insulating rods in part accounts for the excellent electrical and mechanical characteristics of the helical slow wave transmission circuit of the present invention and will be discussed hereinbelow in greater detail.

It is, therefore, an object of this invention to provide an improved method for bonding a plurality of slender insulating rods to a helix to provide a rigid assembly.

Another object of the invention is to provide an improved supporting arrangement which has excellent phase velocity and power loss characteristics.

A further object of the invention is to provide an improved supporting arrangement for the helix in which the dielectric loading along the length of the helix is substantially uniform and readily controlled.

Still another object of the invention is to provide an improved supporting arrangement for the helix in which the power losses along the length of the helix are substantially minimized at elevated temperatures.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of construction and operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which an illustrative embodiment of the invention is disclosed by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and does not define limitations of the invention.

In the drawings:

FIGURE 1 is a cross-sectional view of a traveling wave tube employing a supporting arrangement for a helix in accordance with the invention;

FIGURE 2 is a cross-sectional view of the traveling wave tube shown in FIGURE 1 taken along line 2—2; and

FIGURES 3 and 4 illustrate two of the steps in the method of construction of the supporting arrangement shown in FIGURE 1.

Referring now to the drawings wherein like or corresponding parts are designated by the same reference characters throughout the several views, there is shown in FIGURE 1 a linear beam type traveling wave amplifier device **10**. As shown in the illustrated embodiment of FIGURE 1, device **10** includes an evacuated envelope **12** which encloses an electron gun **14** including a cathode **16** and a control electrode **18** for producing and forming an electron beam, a slow wave transmission circuit, commonly called a helical structure, which includes a long slender helix coil **20** that extends axially from the gun region along the length of the vacuum envelope supported by several insulating rods **22**, the entire structure being concentric with the electron beam. At the remote end of the slow wave structure is a collector electrode **24** for collecting the electron beam. The device is completed by an input connection **26** for receiving an input signal to be amplified, an output connection **28** for coupling out the amplified signal to an external load circuit, both the input and output connection extending through the enclosure wall through hermetic seals, and an electric magnet **29** for supplying a longitudinal magnetic field to aid in focusing the electron beam.

Referring to the helical structure with more particularity, attention is directed to FIGURE 2, which is a cross-sectional view of the traveling wave tube shown in FIGURE 1 taken along the reference lines designated 2—2. As shown in FIGURE 2, the insulating support rods **22** contact the helix coil **20** tangentially at a plurality of points **30** where the rods touch each helix turn. As discussed hereinbelow, there are no fillets of significant size visible in the drawing. In practice, it has been observed that the microscopic fillets which are formed in accordance with the present invention are substantially undetectable with the naked eye. However, it is possible to see the resulting fillets by observing the bond between the rods and helix with a twenty-power microscope.

Referring now to FIGURES 3 and 4, the steps in the process for constructing the supporting arrangement of the helix coil **20** will be described. According to one illustrative embodiment of the invention the initial step in constructing the helix is that of electroplaing an electrically conductive wire, which is titanium for the embodiment presently under discussion. The electroplating material selected for this embodiment is nickel. The nickel is plated on the titanium wire in a relatively thin layer, for example about 0.00015 to 0.0002 inch thick. Deposition of the nickel may be conducted by employing any one of several commonly known plating techniques. The next step consists of precision winding of the coated wire onto a suitable mandrel **32**, for example aluminum, to form a long slender helix coil. After the helix is wound, several insulating rods, three in the present embodiment, are secured about the circumference of the helix and mandrel with a plurality of small tie wires **34** made of 0.010 inch tungsten wire. The composite assembly of mandrel, helix, support rods and tie wires is shown in FIGURE 3.

Among the materials suitable for use as the insulating rods **22** for this illustrative embodiment are any suitable high alumina content ceramic. For example, a ceramic having about ninety-nine percent alumina, No. AD–99 manufactured by the Coors Porcelain Company of Golden, Colo., has been used satisfactorily. A lower alumina content ceramic, such as No. AD–94 by Coors may also be satisfactory for use in the present invention.

Before the insulating rods **22** are metallically bonded to the helix, the entire composite assembly of mandrel, helix, rods and tie wires is placed in a hot caustic solution of sodium hydroxide, to dissolve the aluminum mandrel. Once this operation has been completed, the assembly is ready for the helix-to-support rod bonding step. However, before proceeding with the description, a brief explanation as to the function of the nickel plating will be given. As noted hereinabove, a coating of nickel material is plated onto the helix wire by an electroplating process. By employing such a process it is possible to plate the titanium wire with a very thin layer, on the order of 0.00015 for the illustrative embodiment, which is very uniform along the entire length of the wire and the deposition may be easily controlled.

In the prior art, the process of metallically bonding a ceramic material to a metal at a relatively low temperature was heretofore unknown in the traveling wave tube art. It has been discovered in accordance with the present invention that certain refractory metals, such as titanium for example, will form an apparent metallic bond with ceramic at a relatively low temperature if the nickel forms a eutectic with the helix. Thus, in the present illustrative embodiment, the nickel enters into an alloy with the titanium and no significant traces of the pure nickel remain after the bonding process is completed.

Continuing with the description of the process of constructing the helical structure, reference will be made to FIGURE 4. As shown in FIGURE 4, the tightly secured assembly of the nickel plated helix, the ceramic support rods and the tungsten tie wires is placed in an air-tight vacuum system generally designated **36** including a conventional bell jar or chamber **38**, a base **40** adapted to provide a vacuum-tight seal with the bell jar, and a vacuum pump apparatus (not shown) which is housed in cabinet **42**. The vacuum system is completed with a check valve **44** through which the chamber may be evacuated to provide an evacuated environment surrounding helical structure generally designated **46**.

As shown in FIGURE 4, the helical structure **46** is supported vertically at one end by a circular stand **48**. The ceramic rods fit relatively tight about a raised section **50** of the stand **48**. The free ends **52** and **54** of the helix are connected to a pair of connections **56**, which in turn are connected to a pair of electrical leads **58** extending through the air-tight vacuum system **36** by means of a pair of hermetically sealed passages **60**. Leads **58** are connected to an associated power supply **62** which is capable of accurately maintaining the power to the helix.

Consider now how the apparatus shown in FIGURE 4 is employed to bond the ceramic rods **22** to the turns of the helix **20**. The bell jar is evacuated first by the vacuum pump apparatus through check valve **44** to a predetermined pressure level, such as 2×10^{-6} mm. Hg for example, and held there for several minutes to insure that a good vacuum exists. Next, a predetermined potential is applied to the helix **20** from the power supply **62** through leads **58**. The potential imposed upon the helix coil causes electrical power to pass through the coil and raises its temperature. The temperature of the helix wire and the ceramic rods at the points of contact are raised to a point where the alloy nickel material causes the titanium to penetrate the surface of the ceramic rods and form an apparent metallic bond. During the heating process, the excess nickel is evaporated and no significant trace of the nickel is present on the helix after the bonding process has been concluded.

It has been found, that the bonding process may be conducted by heating the helix with about one hundred fifty watts, which raises the temperature of the helix and rods at the point of contact to about nine hundred fifty degrees centigrade. The temperature of the assembly is maintained at constant one hundred fifty watts power input from the power supply **62** for a predetermined period of time which has been obtained from experimental data derived in connection with the invention.

Continuing with the description of the process, the bonded titanium helix and ceramic rods are removed from the vacuum chamber and the helix is electroplated with a good electrical conductive material, such as copper for example. The thickness of copper plating is about 0.0001 inch and is uniform along the entire length of the helical structure. It is to be noted that other suitable conductive materials, such as silver or gold, may be employed instead of copper. It is well known that titanium does not have the excellent electrical conductive properties required for a slow wave circuit, and therefore the helix is electroplated to provide the required electrical properties.

Consider now the advantages to be derived by utilizing the method disclosed hereinabove to construct a helical structure and supporting arrangement. From a method point of view, the present invention provides a technique which insures the bonding of the ceramic support rods to the helix with fillets of uniform microscopic size. Consequently, the resulting metallic bond provides the electrical advantages of better phase velocity and power loss characteristics. More particularly, the microscopic size metallizedlike fillets do not produce a significant change in dielectric loading along the slow wave transmission line as the operating temperature of the tube increases. Thus, frequency modulation of the output frequency, which is a function of the phase velocity, is minimized or eliminated. The power loss along the helix as the temperature of the tube is raised at elevated temperatures is also significantly reduced. In addition, the present invention provides a helical structure which has the advantages of simplicity and ease of construction as well as ruggedness of construction.

In practice, it has been found that a helical structure operable at X-band, which is made of 0.008 inch diameter titanium wire forming a helix of about 0.066 inch in diameter, 58 turns per inch and about 5.0 inches long, and plated with copper about 0.0001 inch thick, has about 8 db attenuation along the entire length of the helix on cold test. While in operation there is no significant change in the attenuation of the tube which may be attributed to an elevation in the temperature of the structure. Thus, the undesirable temperature sensitive attenuation characteristic associated with the prior art glaze fillets is eliminated.

While the foregoing discussion serves to illustrate the general principles of the present invention, this discussion is not intended to be a limitation of the invention. It is to be understood that the above-described methods and arrangements are illustrative. For example, the helical wire disclosed in the specification has been titanium; it could be modified by utilizing a material having propetries similar to those of titanium. Thus, numerous other methods and arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. Accordingly, it is to be expressly understood that the invention is to be limited only by the spirit and scope of the appended claims.

What is claimed as new is:

1. A process comprising the steps of winding an electroplated wire on a mandrel, dissolvable in a caustic solution, to form a long slender helix coil, securing a plurality of separate support rods of insulator material in spaced positions about the circumference of the helix and mandrel extending along the length thereof, dissolving said mandrel in a hot caustic solution, and in a vacuum chamber passing a temperature elevating electric current through the helix wire to elevate its temperature and metallically bond said support rods to the helix at the points of contact be-

tween the rods and turns of the helix coil and vaporize the plating at other points of the helix, and thereafter plating said helix with an electrically conductive material.

2. A process comprising the steps of winding an electroplated wire on a mandrel, dissolvable in a caustic solution, to form a long slender helix coil, securing a plurality of separate insulating support rods in spaced positions about the circumference of the helix and mandrel extending along the length thereof, dissolving said mandrel in a hot caustic solution, and passing an electric current through the helix wire to elevate its temperature and to metallically bond said rods to the helix at the points of contact between the rods and the turns of the helix coil, and electroplating said helix with a relatively high electrically conductive material.

3. The process defined in claim 2 wherein said conductive material is copper.

4. A method of forming a supporting arrangement for an electrically conductive helix adapted for use in a traveling wave tube comprising the steps of winding a helix wire upon a mandrel, dissolvable in a caustic solution securing a plurality of support rods of insulator material in spaced positions about the circumference of the helix and mandrel extending along the length thereof, dissolving the mandrel in a caustic solution, heating said helix and rods to an elevated temperature by passing an electric current through the helix wire whereby said rods are metallized at the point of contact with said helix and are bonded thereto, electroplating said helix with a relatively high electrically conductive material, and assembling the resultant helical structure into a traveling wave tube.

5. A method of forming an arrangement for mounting a long slender helix in a traveling wave tube comprising the steps of winding a titanium wire electroplated with a thin layer of nickel on an aluminum mandrel to form a helix coil, securing a plurality of long slender ceramic rods in spaced positions about the circumference of said helix coil and mandrel extending along the length thereof, dissolving said mandrel in a hot caustic solution, and heating the assembly of said helix and rods in an evacuated container by passing a preselected current through said helix wire to a predetermined temperature which causes said rods to metallically bond to each turn of said helix coil and vaporization of the remainder of the thin layer of nickel.

6. In the method of forming a supporting arrangement for a long slender helix coil for a traveling wave tube, the combination of steps comprising: electroplating a titanium wire with a relatively thin layer of nickel material, winding said wire on a cylindrical aluminum mandrel to form a long slender helix coil, securing a plurality of relatively small ceramic rods about the circumference of the helix coil and mandrel with a plurality of small tungsten tie wires, dissolving said mandrel by dipping the entire assembly in a hot caustic solution, mounting the assembly including said helix, rods and tie wires in an evacuated

chamber and passing an electric current through said helix coil to elevate the temperature of said helix and rods to cause said titanium and said nickel to alloy and to cause said rods to be wet and metallically bond to each turn of the helix at the points of contact between the helix and rods, and the excess nickel plating being evaporated from said helix, and electroplating said helix with copper to increase the electrical conductivity of said helix.

7. A method of forming a supporting arrangement for an electrically conductive helix adapted for use in a traveling wave tube comprising the steps of winding a helix wire and a mandrel, said wire having a thin layer of an alloying material electroplated thereon, securing a plurality of insulating support rods in spaced positions about the circumference of the helix and mandrel extending along the length thereof, dissolving the mandrel in a caustic solution, heating said helix and rods to an elevated alloying temperature by passing an electric current through the helix wire whereby said rods are metallized and wet by said alloying material at the point of contact with said helix and are brazed thereto, electroplating said helix with a relatively high electrically conductive material, and assembling the resultant helical structure into a traveling wave tube.

8. A method of forming a traveling wave type tube comprising the steps of forming an elongated metallic slow wave transmission circuit, coating said slow wave circuit with a thin coating of material which forms a low melting point alloy with the metal of said slow wave circuit, securing a plurality of porous insulating support rods in spaced positions around the slow wave circuit, and heating the slow wave circuit in a vacuum environment until the thin coating is melted to bond the contacting portions of the slow wave circuit to the insulating support rods and vaporize the thin coating at the noncontacting portions, and thereafter plating said slow wave circuit with an electrically conductive material.

9. The process as defined in claim 8 including the additional step of plating said slow wave circuit with a highly conductive material.

References Cited

UNITED STATES PATENTS

2,798,843	7/1957	Slomin et al.	29—502
2,812,499	11/1957	Robertson	140—71.5 X
2,859,512	11/1958	Dykslerhuis et al.	29—473.1
3,040,415	6/1962	Rayburn	29—25.42
3,201,720	8/1965	Bradford et al.	315—3.5 X
3,031,737	5/1962	Conley.	

JOHN F. CAMPBELL, *Primary Examiner.*

R. W. CHURCH, *Assistant Examiner.*

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29—25.14, 471.1, 473.1, 474.1, 502, 605; 140—71.5