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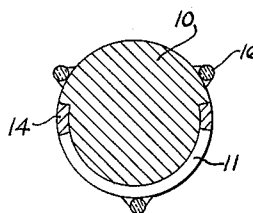
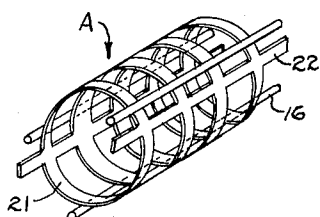
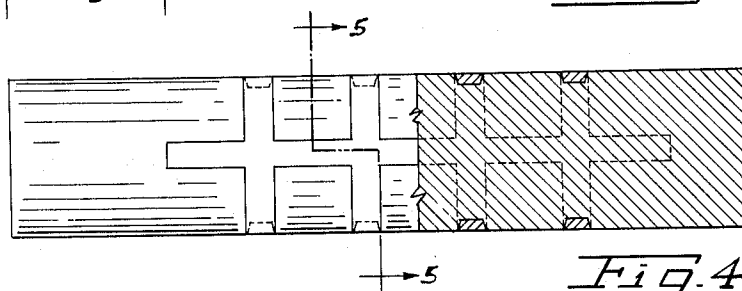
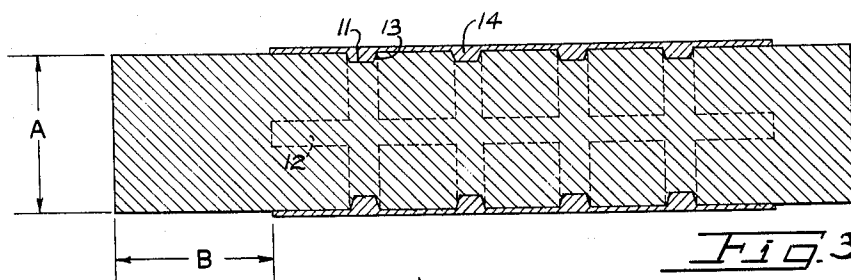
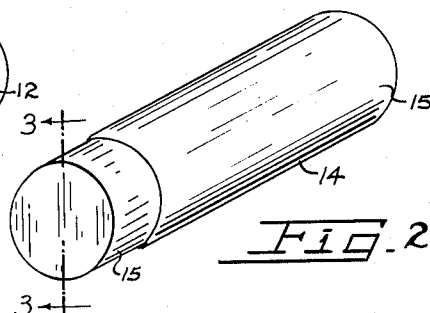
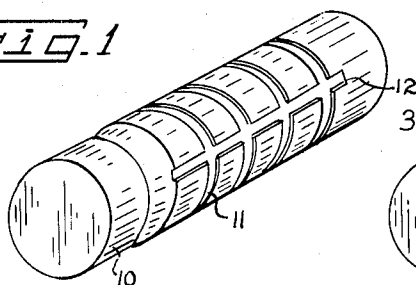
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CIRCUIT FABRICATION METHOD

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Fig. 1



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1

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CIRCUIT FABRICATION METHOD

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The present invention relates in general to a method for fabricating a slow wave circuit for electron discharge devices such as, for example, traveling wave tubes.

In the past, several different techniques have been utilized for fabricating slow wave structures for electron discharge devices such as used in traveling wave tubes and which, in many instances, are quite small. For instance, the most typical slow wave structure is a helical wire which can be fabricated by winding the wire on a mandrel of the desired diameter. In the conventional cases, the cross-section of the wire element up the helix is circular. However, often-times, a flat tape is used for the slow wave structure which has a rectangular cross-section. Naturally, from the very manner in which such circuits are wound these circuits are subject to twisting and bowing. Circuits having more intricate configurations pose additional problems. For example, the ring and bar structure which is made up of axially aligned spaced apart rings joined by opposed straps or bars forms a good slow wave structure which is naturally more difficult to fabricate. One way of fabricating such a circuit in the past has been to cut series of spaced-apart notches along the length of the tube on opposite sides of the tube so that the portion of the tube that is left forms the ring and bar structure. However, it becomes extremely difficult to accurately cut or machine notches from such a tube when the diameter of the tube is only a fraction of an inch.

The present invention is directed to a method for producing slow wave structures within very close tolerances and which can be produced accurately on a mass production basis.

In accordance with the present invention, the circuit is fabricated by first forming an impression or silhouette of the slow wave structure in a mandrel or body member and then filling the impression or silhouette with cohering metal particles which cohere together in the general form which the finalized circuit will take. The surface of the cohered metal particles is then finished to leave the desired thickness of particles for the circuit and the mandrel is then removed from the circuit leaving the circuit in a condition ready to be mounted in an electron discharge device.

Intricate and delicate circuits can easily be constructed in accordance with this invention and are free from tensions and stresses encountered in "wound" circuits. Additionally, variations in the circuit such as variations in the pitch of the circuit are easily accomplished with the present invention.

One particular method of filling the impression or silhouette in the mandrel with cohering metal particles is to spray the mandrel with a plasma jet spray containing particles of the metal from which the circuit is to be made until the silhouette or impression has been completely filled with particles which cohere together. The excess build-up of sprayed particles is then removed and the mandrel etched away from the circuit to provide a circuit of desired dimensions.

One of the advantages of this latter method of building up the circuit is that the cohering metal particles can be applied onto a cold mandrel or substrate so that the impression or silhouette of the slow wave structure can be machined or molded in the substrate or mandrel in the exact dimensions desired for the slow wave struc-

2

ture. Also, in such a case, the mandrel can be of a material such as, for example, cold rolled steel, which is relatively easily machined or worked so that the impression or silhouette, and thus the resultant slow wave structure, can be realized within very close tolerances.

Another method of applying the cohering metal particles to the mandrel is by vapor deposition. This technique offers the possibility of producing a denser structure than that produced by plasma jet spraying. For example, the circuit produced by vapor deposition is on the order of 99% dense as compared with a structural density on the order of 96% produced by plasma jet spraying.

On the other hand, vapor deposition is not as desirable as plasma jet spraying for the reason that, in order to deposit the metal particles by vapor deposition, the mandrel must be maintained relatively hot such as, for example, on the order of 500° C. This not only necessitates the use of a stronger and therefore harder-to-machine mandrel but also means that allowance must be made for the thermal expansion of the mandrel during elevation to this higher temperature when machining or molding the impression or silhouette of the slow wave structure into the mandrel.

Other objects of the present invention will become apparent upon reading the following specification and referring to the accompanying drawings in which similar characters of reference represent corresponding parts in each of the several views.

In the drawings:

FIG. 1 is a perspective view illustrating a mandrel machined with a slow wave circuit impression;

FIG. 2 is a perspective view of the mandrel shown in FIG. 1 covered with deposited cohered metal particles;

FIG. 3 is a longitudinal cross-sectional view of the mandrel shown in FIG. 2 taken along line 3—3 in the direction of the arrow;

FIG. 4 is a side view, partially broken away in section, of the mandrel shown in FIG. 3 with the surface of the mandrel finished to leave metal particles only within the silhouette or impression of the slow wave structure;

FIG. 5 is a cross-sectional view of the structure shown in FIG. 4 taken along line 5—5 in the direction of the arrows with the addition of circuit support rods; and

FIG. 6 is a perspective view of the completed slow wave structure.

While the invention will be described below by way of illustration for fabricating a ring and bar slow wave structure A such as utilized in traveling wave tubes and other electron discharge devices, it is to be understood that slow wave structures and delay lines having other configurations and for comparable applications can be fabricated utilizing the present invention.

Referring now to FIG. 1, there is shown a mandrel 10 such as of, for example, cold rolled steel, into which are machined a plurality of axially spaced apart annular recesses 11 which communicate with one another via a pair of diametrically opposed slots 12 extending the length of the pattern of recesses 11 on the mandrel 10. The diameter of the mandrel 10 is selected to be only slightly larger than the desired outside diameter for the completed circuit while the inside diameter of the recesses 11 and slots 12 is selected to be the same as the desired inside diameter for the completed circuit. The recesses 11 are adapted to receive material to form the rings 21 and the slots 12 adapted to receive material to form the bars 22 of the ring and bar structure A produced in accordance with the present invention and illustrated in FIG. 6.

In order to insure that the coating metal particles fill the corners of the recesses 11 and slots 12, the side walls

13 of these passageways are tapered slightly so that the cross-sections of the recesses and slots are narrower at their bases as illustrated in FIGS. 3-5. The mandrel 10 can be formed with the recesses 11 and slots 12 in any conventional manner such as by machining or by casting from a master die.

The central portion of the mandrel 10 in which the impression or silhouette of the slow wave structure is formed by the recesses 11 and slots 12 is cleaned and then covered with a layer 14 of cohering metal particles such as, for example, tungsten by plasma jet spraying the mandrel in a vacuum or an inert atmosphere utilizing finely divided powdered metal particles introduced into a plasma jet.

Sufficient metal particles are applied to the mandrel 10 to fill the recesses and slots completely and leave a small excess slightly greater than the outside diameter of the mandrel 10.

The coated mandrel is illustrated in FIGS. 2 and 3. During the coating step, the ends of the mandrel 10 are masked so that after the coating step and after the masking has been removed, the mandrel 10 is provided with uncoated or particle-free surfaces 15 at its ends.

Next, utilizing these particle-free surfaces 15 as a reference, the sprayed mandrel is mounted for turning, and the exterior surface reduced, such as by grinding, to the desired external diameter for the slow wave circuit. At this stage, the ring and bar circuit is complete but locked onto the mandrel 10.

Next, in accordance with the preferred embodiment of the present invention which is especially useful in cases where extremely fragile circuits are manufactured, the circuit is secured to a plurality such as, for example, three support rods 16 of, for example, ceramic or sapphire, which are equally spaced apart about the circumference of the mandrel. These support rods 16 are rigidly tacked to or secured to the cohered metal in the recesses 11 such as, for example, with a tie-wire or glazing material.

Next, the mandrel 10 is etched out utilizing conventional commercial acid solutions to leave the completed circuit A made up of rings 21 and bars 22 supported on support rods 16 ready to be assembled inside the vacuum envelope of a traveling wave tube.

As an alternative method for depositing the cohered metal particles on the mandrel 10 in the recesses 11 and slots 12, the technique of vapor deposition can be utilized. In performing this step, the mandrel which is maintained hot such as, for example, of the order of 500° C. during the deposition process, is made of a relatively higher melting point metal such as, for example, molybdenum. When the vapor deposition has taken place, the mandrel is cooled and processed in the same manner as a mandrel to which cohered metal particles have been applied by plasma jet spraying as described above.

The practice of the present invention is extremely useful in fabricating miniature slow wave structures which are quite difficult to fabricate by other conventional tech-

niques. For example, a typical circuit fabricated in accordance with the present invention may have an outside diameter of approximately $\frac{1}{4}$ " and a thickness for the rings 21 and bars 22 on the order of $\frac{1}{10,000}$ ".

While the invention has been described with reference to filling recesses and slots on the exterior surface of a mandrel, under certain circumstances it may be possible and convenient to cut the recesses and slots in the inside surface of a hollow die and apply the coating of cohered metal particles within this die. Therefore, the word "mandrel" is used hereinabove and in the claims to include such a die.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it is understood that certain changes and modifications may be practiced within the spirit of the invention as limited only by the scope of the appended claims.

What is claimed is:

1. The method of fabricating a slow wave structure comprising the steps of: machining a mandrel to form grooves into a substantially circular grille shape of a slow wave circuit; masking the ends of the mandrel; filling said grooves with cohering metal particles to a depth slightly greater than the depth of said grooves and extending over the mandrel; mounting the coated grooved mandrel by the uncoated ends for turning; turning said mandrel and simultaneously machining to reduce the exterior surface to the desired external diameter for the slow wave circuit; demounting the mandrel and slow wave circuit; securing a plurality of support rods to the slow wave circuit; and dissolving the mandrel from within the slow wave circuit.

2. The method of claim 1 wherein said step of filling said grooves with cohering metal particles includes building up cohering metal particles in the grooves by vapor deposition.

3. The method of claim 1 wherein said step of filling said grooves with cohering metal particles includes building up cohering metal particles in the grooves by plasma spraying the mandrel with metal particles.

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