June 13, 1961 D. R. ARMSTRONG 2,988,667

GRID STRUCTURE AND METHOD OF MAKING THE SAME

Filed Aug. 20, 1957 2 Sheets-Sheet 1

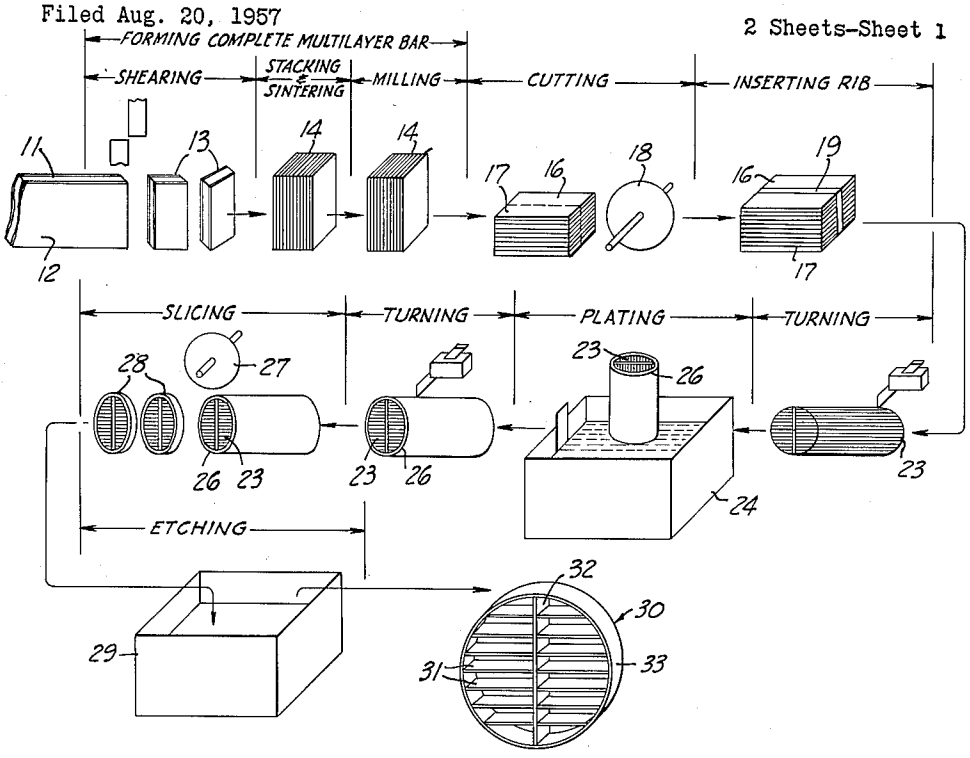


FIG_1_

FIG_2_

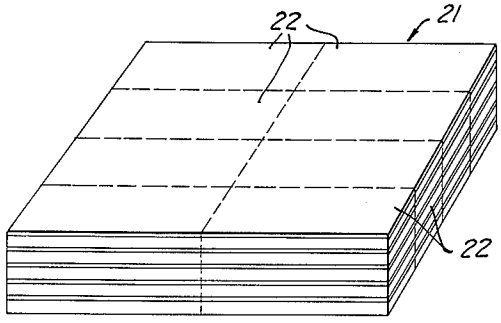
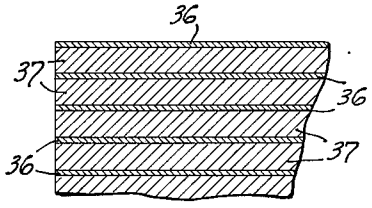


FIG_3_



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GRID STRUCTURE AND METHOD OF MAKING THE SAME

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FIG_4_

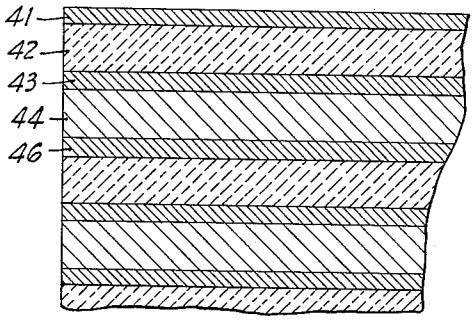


FIG_5_

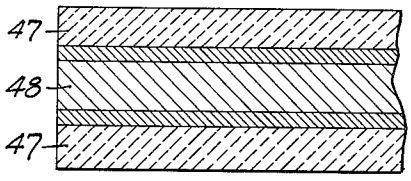


FIG_6_

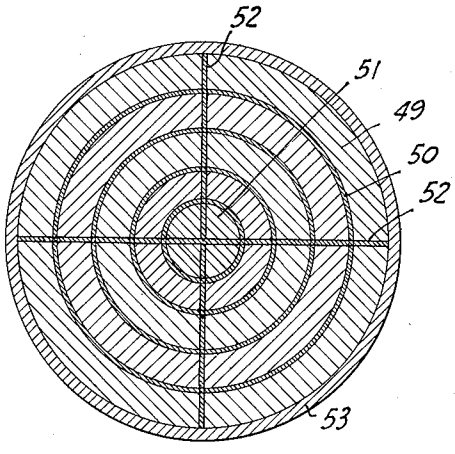
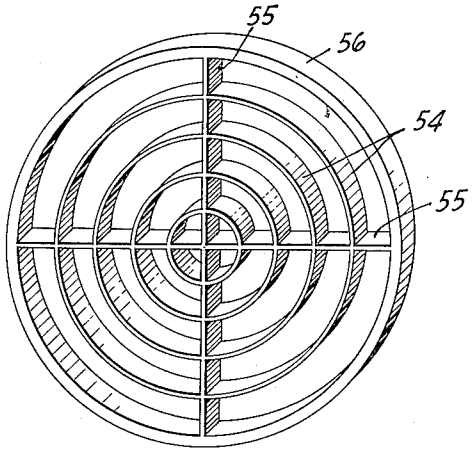


FIG_7_



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GRID STRUCTURE AND METHOD OF MAKING THE SAME

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This invention relates to a grid structure for electron tubes and to methods of making the same.

In grid structures it is desirable to minimize the electron interception. It is also desirable to form a grid structure which is mechanically strong. Certain prior art grid structures are made of fine wire screening. These structures are rather weak and present a large electron intercepting area. Others are made in the form of a honeycomb or the like to cut down the electron interception area. However, when two or more grids of this type are employed in a tube, it is difficult to align the grids. As a result, the electron interception is increased.

It is a general object of the present invention to provide an improved grid structure and method of making the same.

It is another object of the present invention to provide a grid structure and method of making the same which is relatively strong and which has low electron interception.

It is another object of the present invention to provide a grid structure and method of making the same which grid includes a plurality of vanes with one or more reinforcing ribs attached thereto.

It is a further object of the present invention to provide an improved method for making vane type grid structures for electron tubes.

It is another object of the present invention to provide a grid structure and method of making the same which includes a plurality of vanes with one or more relatively strong ribs joined thereto to support and rigidify the grid structure.

It is still a further object of the present invention to provide a grid structure and method of making the same which has a simple, reproducible pattern whereby two or more grids may be easily aligned.

These and other objects of the invention will appear more clearly from the following description when read in conjunction with the accompanying drawing.

Referring to the drawing:

FIGURE 1 is a flow chart, in diagrammatic form, of one method of producing a grid structure in accordance with the invention;

FIGURE 2 is a perspective view of a composite plate which may be cut up to form sections for insertion of rib material;

FIGURE 3 is a sectional elevational view of a composite plate or bar formed from alternate layers of base and grid metal;

FIGURE 4 is a sectional elevational view of a composite plate or bar suitable for forming refractory type grids;

FIGURE 5 is a sectional elevational view of another composite plate or bar suitable for forming refractory type grids;

FIGURE 6 is a cross-sectional view of a grid rod constructed in accordance with another embodiment of the invention; and

FIGURE 7 is a perspective view of a grid structure formed from the rod of FIGURE 6.

Referring to FIGURE 1, the first few steps illustrate one method of forming composite strips which are used to form the grid structure of the invention. The first step in the method is the selection of a strip base metal **11** coated with a layer of grid metal **12** of which the grid vanes are to be constituted. The thickness of the layer **12** corresponds generally to one-half the desired thickness of the final vanes, as will presently become apparent.

The strip **11** is sheared into smaller strips **13** which have a width corresponding generally to the desired width of the final grid structure. Alternatively, the invention may be carried out by starting directly with coated strips of the desired size. The strips **13** are de-greased and stacked. In certain instances it may be desirable to apply pressure to the stack, as for example, by placing the stack in a vise, or the like, to squeeze the stack and flatten out any irregularities in the strips. The stack is then placed in a suitable jig, for example, a graphite jig.

The jig and stack are placed in an oven. The temperature of the assembly is increased to near the melting point of the grid metal. The assembly is kept in the oven until the grid metal flows together (is sintered) to form a composite bar **14** which has alternate layers of base metal and grid metal.

The composite bar **14** is next placed in a milling machine where it is milled square in cross section with the sides perpendicular to the layers.

The next step is to cut the bar lengthwise in a direction perpendicular to the layers into two or more sections. For example, this may be achieved by pushing the bar along a grooved jig into an abrasive wheel **18**. It is apparent, of course, that other suitable methods may be employed for cutting the bar. As illustrated, the bar is cut up into two sections **16** and **17**. The sections **16** and **17** might be formed directly by employing narrower strips and stacking the same. However, it is difficult to form and stack the smaller strips.

The sections **16** and **17** are then placed in a jig with a strip of brazing alloy **19** between them. The assembly is again placed in an oven and heated until the brazing alloy melts and the sections of the bar are brazed back together. The alloy strip **19** forms a supporting rib, as will presently be described. The brazing alloy is preferably selected to have a melting point which is below the melting point of the grid material. The rib **19** formed by the brazing material may be thicker than the final grid vanes and may be made of a stronger material whereby the vanes are rigidly supported, as will presently be apparent.

It is, of course, apparent that the composite sections **16** and **17** may be formed from a composite plate of the type shown in FIGURE 2. Thus, large sheets of the various metals are sintered into a composite plate **21**. The plate can then be mechanically operated upon, as for example by sawing, to form a plurality of sections **22** which have a thickness equal to the thickness of the bar and a width equal to half the thickness. The sides of the sections are then milled flat. A pair of these sections is then placed side by side and the reinforcing brazing alloy rib **19** is inserted between the same to form a bar, as previously described.

The bar which is formed in any of the ways described is mounted in a lathe and turned to a circular cross-

section (rod) **23** having a diameter substantially equal to the diameter of the desired grid structure. The rod is chemically cleaned and placed in a plating bath **24** where it is plated with a metal which may be the same as that which forms the vanes, for example. Preferably, the rod is rotated as it is plated and the current periodically reversed to give a competent plated surface **26**.

When the plated surface **26** has built up to a suitable thickness for the mounting ring, to be presently described, the rod is removed from the plating bath **24**. It may be mounted in a lathe and again turned to correct the outside diameter and to true the same. However, for many applications the plated surface **26** may be suitable and this step is not required.

The rod is sliced with an abrasive wheel **27**, or otherwise suitably cut, into relatively thin slices or wafers **28**. The slices have a thickness which corresponds to the desired final depth of the vanes which form the grid. The slices **28** are polished and placed in a selective etching bath **29** which serves to dissolve out the base metal and leave the grid metal, the brazing alloy and the plated surface intact.

The resulting grid **30** consists of spaced vanes **31** which are thin and deep. The vanes are spaced apart a distance corresponding to the thickness of the base material removed and have a thickness equal to approximately twice the thickness of the original layer **12** and a depth corresponding to the thickness of the wafers **28**. The supporting rib **32** lies perpendicular to the vanes **31** and is attached to the adjacent ends of the vanes. The vanes **31** and rib **32** are supported at their ends by the supporting ring or washer **33** which provides means for mounting the grid within the electron tube. As previously described, the rib **32** is stronger than the grid vanes and reinforces the grid structure to make it strong and rigid.

For example, one particular grid was constructed as described by selecting a copper-clad 1010 steel strip 3" wide by .015" thick. The strip was copper-clad 10% of its overall thickness. This strip was cut into smaller strips which were 3" long by ¼" wide. The strips were de-greased, stacked and sintered to form a bar having a square cross-section ¼" on the side. The bar was sintered by placing the stacked assembly in a graphite jig and placing the jig and stack in a hydrogen furnace at 1100° C. for 15 minutes. The sides of the composite bar were milled flat perpendicular to the strips. The bar was then split and a rib of .004" "Nicoro" brazing alloy was placed between the two sections. The assembly was then placed in an oven and brazed into a solid bar. The bar was then turned in a lathe to form a rod having ¼" diameter. A copper strike was placed on the surface of the rod and the rod was placed in a cyanide plating bath. The plating current was held at approximately 100 amps per square foot with a current reversal for 20% of the time. The temperature of the bath was maintained at about 160° F. When the plating reached a sufficient thickness, the bar was removed and turned in a lathe as previously described. The bar was then sliced with an abrasive wheel into slices which were .010 inch thick. The ends of the slices were polished on a crocus cloth and the slices placed in a 10% sulphuric acid bath. The slices were boiled until the steel dissolved out and effervescence ceased. The particles of carbon which clung to the grid structure were removed by wet hydrogen firing at approximately 900° C. The resulting grid consisted of vanes which were .003 inch thick and .010 inch deep, spaced .012 inch apart. They were supported by a vane of similar dimensions across the center. With these dimensions, the metal occupies approximately 20% of the area of the grid.

It is apparent that the dimensions may be changed as required by appropriately selecting the thickness of the base material and the thickness of the grid metal layer. It is advisable from the point of view of electron interception to reduce the width of the vanes as much as possible and to leave as much space between them as possible. In order to preserve rigidity and effect heat conduction, however, the cross-sectional area of the vanes cannot be made too small. Thus, it is preferable to employ vanes having a thin, deep cross-section. The spacing of the vanes is generally determined by the required degree of coupling between the grid and the electron stream which it controls.

Rather than starting with copper-clad base material, the invention may be carried out with the additional step of plating the grid material on the base material. It is also possible to form the composite plate or bar by employing alternate layers of grid and base material and melting the grid material so that it adheres to the base material. Referring to FIGURE 3, a stack of alternate layers of grid material **36** and base material **37** for carrying out this step is illustrated.

Another type of grid structure which may be formed with the method of the invention is one which includes grid vanes formed of refractory grid material, for example, molybdenum, having a surface layer of conductive material, for example, copper.

Referring to FIGURE 4, a stack of strips or sheets suitable for forming a composite bar for a grid structure of the above character is illustrated. The stack includes layers of grid metal **41**, refractory grid material **42**, grid metal **43**, base metal **44**, grid metal **46**, etc., alternated as illustrated. The stack is then heated to form a composite plate or bar which is then employed as previously described.

In FIGURE 5 another stack for forming a refractory type grid is shown. The stack includes refractory grid material **47**, and clad or plated base material **48**. The stack is then heated to form a composite plate or bar.

In one particular example, alternate layers of copper-clad steel and molybdenum were placed in a hydrogen furnace and heated to form a composite bar. The bar was then operated upon to form a grid structure, as previously described. The final structure included copper-clad molybdenum grid vanes. The temperature control in this method of forming a composite bar is less critical than in the others described.

Rather than plating to form the grid mounting ring, it may be desirable to insert the rod into a copper tube and then to braze the two together. Further, it is apparent that if greater rigidity is required, narrower sections may be employed and a larger member of supporting ribs introduced.

The teaching of the invention also permits the construction of a grid which includes annular vanes. Thus, a series of concentric tubes of base metal **49** having a layer **50** of grid material applied thereto are selected. The tubes are assembled one within the other with a central rod **51** having a layer **50** of grid material applied thereto.

The assembly is then placed in an oven and sintered to form a composite rod. The rod may then be cut longitudinally into four sections and supporting ribs **52** inserted therein. That is, a brazing alloy is inserted between the sections and the assembly is brazed in a furnace. The assembly might then be inserted in a tube **53** of supporting material and the complete assembly again brazed to form a composite rod having a supporting ring. Alternatively, the ring may be plated, as previously described.

The other steps of the operation would be similar to those previously described. That is, the rod would be cut up into relatively thin slices or wafers which are then selectively etched to form the grid structure. The grid structure would include a plurality of parallel concentric annular vanes **54** which are supported by the supporting ribs **55** with the complete assembly supported in the ring or washer **56**.

Thus, it is seen that an improved grid structure and method of making the same is provided. The electron

interception by the grid is minimized. One or more supporting ribs which are composed of a strong alloy serve to support the grid vanes. The resulting grid structure is rigid and strong. The grid is formed as a simple, reproducible pattern which makes it relatively easy to align a plurality of grids in an electron tube for minimum electron interception.

I claim:

1. A grid structure for electron tubes comprising a plurality of parallel vanes, each said vane being discontinuous in a plane extending transversely of said vanes, a supporting rib extending through said vanes along said plane, the adjacent ends of said vanes abutting the associated rib and bonded thereto, and a mounting ring engaging the ends of said rib and bonded thereto to provide means for mounting the structure in an electron tube.

2. A grid structure for electron tubes comprising a plurality of parallel flat vanes, each of said vanes being discontinuous in a plane which extends transversely of said vanes, a flat supporting rib extending through said vanes along said plane, the adjacent ends of said vanes abutting said rib and bonded thereto, said rib having a lower melting point than said vanes, and a mounting ring engaging the ends of said rib and the other ends of said vanes to provide meas for mounting the structure in an electron tube.

3. The method of producing a grid structure for an electron tube, which method comprises the steps of forming composite sections of alternate layers of base material and grid material, brazing said sections together with an alloy along a plane at an angle with respect to said layers, slicing said brazed sections to form a plurality of slices having a thickness substantially equal to the depth of the final grid, and removing the base material to form a grid structure including a plurality of vanes which have substantial depth in comparison to their thickness and a supporting rib formed by said brazing alloy secured to said vanes.

4. The method of producing a grid structure for electron tubes, which method comprises the steps of forming composite sections of material having alternate layers of grid material and base metal, securing a supporting rib between two of said sections at an angle with respect to said layers to form a composite bar, slicing to form a plurality of slices having a thickness substantially equal to the depth of the final grid, and removing the base metal by a chemical reagent to form a grid structure including a plurality of vanes which have a substantial depth in comparison to their thickness with a supporting rib engaging adjacent portions of the vanes and serving to support the same.

5. A method as in claim 4 in which said sections are formed by stacking base metal plated with grid metal and heating the stack.

6. A method as in claim 4 in which the sections are formed by stacking alternate layers of grid and base material and heating the stack.

7. A method as in claim 4 wherein the composite sections are formed by stacking layers of refractory type grid material, a metallic grid material, and a base metal, and heating the stack.

8. A method as in claim 4 wherein the composite sections are formed by stacking alternate layers of refractory type grid material and plated base material and heating the stack.

9. A method as in claim 4 wherein the composite sections are formed by stacking layers of refractory type grid material plated with conductive metallic material with layers of base metal and heating the stack.

10. A method of producing a control grid for electron tubes which comprises the steps of assembling a plurality of sheets of metal into a stack, each of said sheets comprising a base metal and a layer of grid material on each side thereof, heating the stack to form a composite sheet having alternate layers of base metal and grid material, cutting said composite sheet to form a plurality of sections, securing at least one supporting rib between at least two of said sections to form a composite bar which includes the supporting rib, slicing to form a plurality of slices having a thickness substantially equal to the depth of the final grid, and removing the base metal by a chemical reagent to form a grid structure including a plurality of vanes which have a substantial depth in comparison to their thickness and a supporting rib holding the same.

11. The method of producing a control grid for electron tubes which comprises the steps of assembling a plurality of elements, each of said elements comprising a base metal and a layer of grid material on at least one side thereof, heating the assembly to form a composite member having alternate layers of base and grid material, cutting said member transversely of said layers to form at least two composite sections, brazing said sections together, slicing the structure to form a plurality of wafer-like slices, and removing the base metal by a chemical reagent to form a grid structure which has a plurality of vanes having substantial depth in comparison to their thickness with a supporting rib disposed at an angle with respect thereto.

12. A method as in claim 10 in which the composite sheet is formed by stacking base metal coated with grid metal and heating the stack.

13. A method as in claim 10 in which the composite sheet is formed by stacking alternate layers of grid and base material and heating the stack.

14. A method as in claim 10 in which the composite sheet is formed by stacking layers of refractory type grid material, a metallic grid material, and a base material and heating the stack.

15. A method as in claim 10 wherein the composite sheet is formed by stacking alternate layers of refractory type grid material and coated base metal and heating the stack.

16. The method of producing a grid structure for electron tubes which comprises the steps of assembling sheet material into a stack, said sheet material comprising base material and grid material, heating the stack to form a composite member having alternate layers of base material and grid material, cutting said member at an angle with respect to said layers to form a plurality of composite sections, brazing said composite sections together to form a composite bar, machining said bar to form a rod, adding a jacket of grid material around said bar, slicing said rod into a plurality of wafer-like elements, subjecting the wafer-like elements to a chemical reagent which selectively removes the base metal and leaves the grid material and brazing material whereby a grid is formed which comprises a ring serving to support a plurality of parallel grid vanes with at least one supporting rib formed by said brazing material.

17. A method as in claim 16 in which said jacket is formed by electroplating.

18. A method as in claim 16 wherein said jacket is formed by brazing a tube onto said rod.

19. The method of producing a grid structure for electron guns which comprises the steps of assembling a plurality of cylindrical members to form a rod, said cylindrical members comprising base metal and grid material, heating said rod to form a composite rod having alternate annular members of base and grid material, cutting said rod into two sections, brazing a supporting rib between said sections to again form a composite rod, slicing said rod into a plurality of wafer-like slices, and subjecting the wafer-like slices to a chemical reagent which selectively removes the base metal and leaves the grid material and brazing material whereby a grid is formed which comprises a plurality of annular vanes and a supporting rib.

20. A method as in claim 19 with the additional step of forming a jacket of grid material about said rod which jacket serves to engage the ends of said supporting rib.

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