

[54] METHOD FOR PRODUCING A FIELD EFFECT CONTROL DEVICE

[76] Inventors: **Jerry W. Hagood**, 307 Mountain Gap Rd. S.E., Huntsville, Ala. 35803; **Joe Shelton**, 700 Tatom St. N.W., Huntsville, Ala. 35805; **Ralph L. Norman**, 3644 Marymont Dr. N.W., Huntsville, Ala. 35810

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[56] References Cited

UNITED STATES PATENTS

3,195,219	7/1965	Woodcock et al.	29/25.17 X
3,562,881	2/1971	Barrington et al.	29/25.17 X
3,745,402	7/1973	Shelton et al.	313/351 X

Primary Examiner—Roy Lake

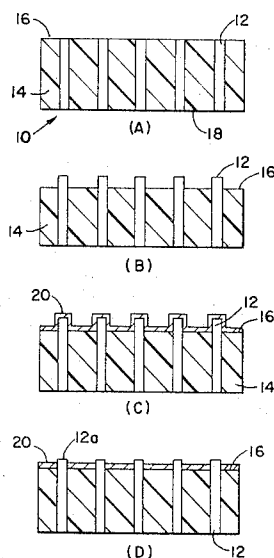
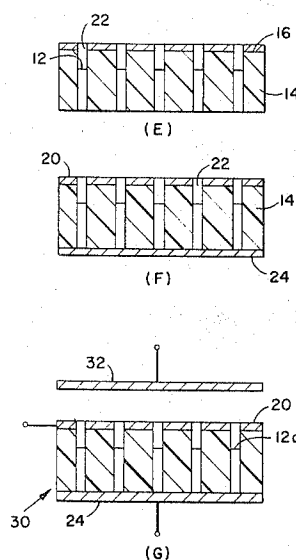
Assistant Examiner—R. Daniel Crouse

Attorney, Agent, or Firm—Edward J. Kelly; Herbert Berl; Jack W. Voigt

[57] ABSTRACT

A field effect control device useful as an electronic switch or an amplifier, has as the basic element a field effect emitter comprising a large array of emitting fibers encompassed with an insulating oxide support structure and a control electrode formed across the surface of the oxide. Novel construction of the device is by etching a surface of the field effect emitter to expose the fiber ends. The control electrode is deposited across this surface, covering both the insulator and the protruding emitter pins. The fiber ends are polished to exposure and etched to a predetermined level below the insulator surface. The control electrode, not affected by the etching solution, remains on the surface of the control device with holes therethrough left by the etched-back fibers, the holes being precisely aligned with the fibers. A conductive backing plate connected to the fibers allows a voltage to be coupled thereto and a collector electrode disposed opposite the control electrode allows the field to be developed for operation of the control device.

8 Claims, 8 Drawing Figures



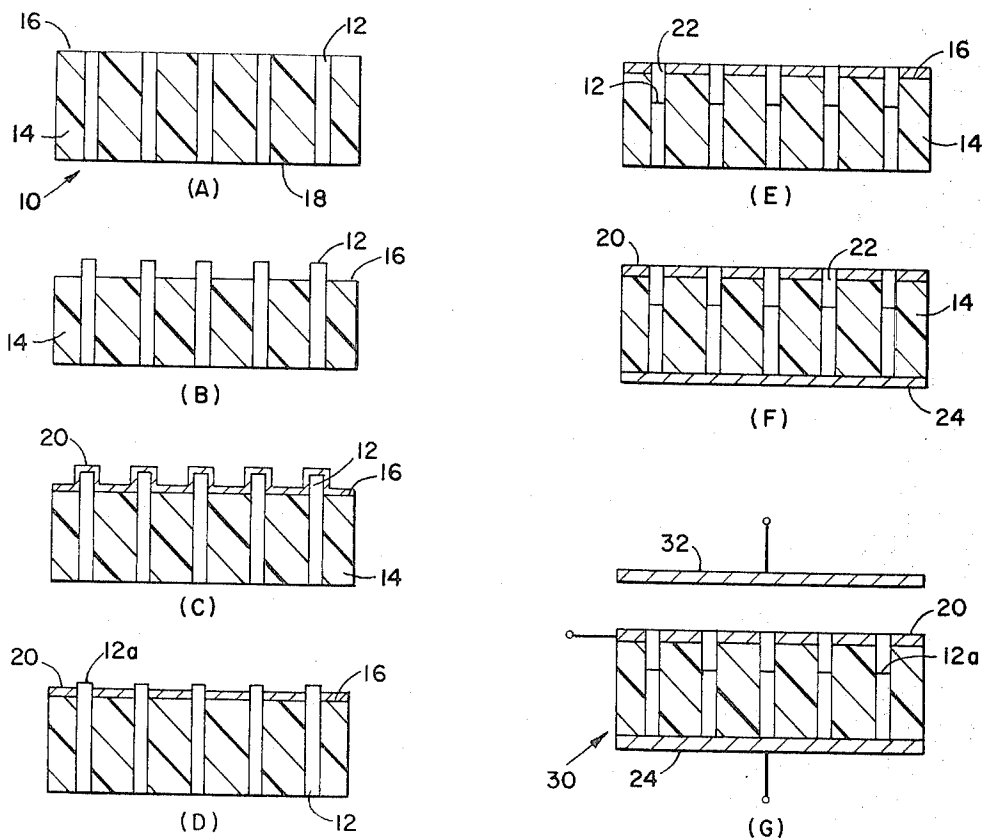


FIG. 1

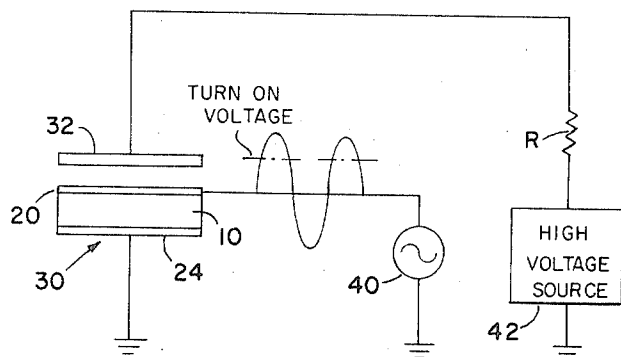


FIG. 2

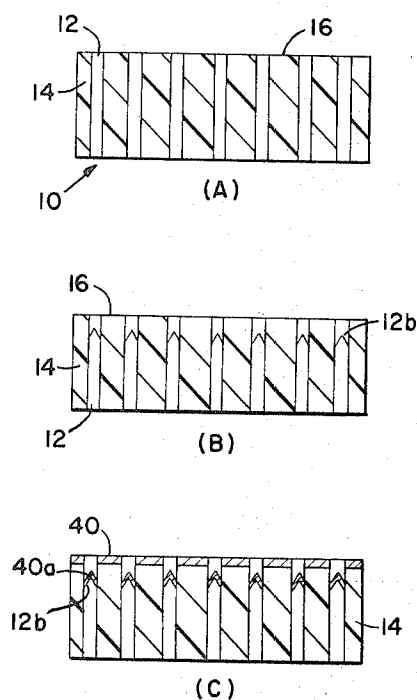


FIG. 3

METHOD FOR PRODUCING A FIELD EFFECT CONTROL DEVICE

DEDICATORY CLAUSE

The invention described herein may be manufactured, used, and licensed by or for the Government for Governmental purposes without the payment to us of any royalty thereon.

BACKGROUND OF THE INVENTION

Structures for forming electric fields for emission of electrons have many practical applications as disclosed in the prior art. The field effect emitter is disclosed in U.S. Pat. No. 3,745,402 to Shelton et al., co-inventors in the instant invention. The field effect emitter is disclosed as having over a million parallel emitting tungsten fibers per square centimeter and is encompassed in an oxide matrix which supports and insulates the fibers or pins. In operation, the quantity of electrons emitted is controlled by the electric field provided. The tungsten fibers are less than one micron in diameter and are arranged in parallel for emitting electrons from the ends thereof.

In U.S. Pat. No. 3,665,241 to Spindt et al., a field emission cathode structure is disclosed with a method for producing the cathode. A fine mesh screen is disposed over a conductive substrate and material is projected through the screen onto the substrate whereby sharp cones are formed. The screen may be removed or left in place. The importance of alignment of the holes through the screen with the emitter points is disclosed by Spindt et al., to be crucial for practical operation of the cathode if a screen is to be used during operation of the cathode. Other problems attendant to construction of field emission cathodes and associated electrodes are disclosed in these references.

SUMMARY OF THE INVENTION

A novel method is disclosed for constructing a field effect control device wherein a field effect emitter having a large plurality of emitting fibers is provided with a control electrode on the surface thereof for field effect control. A surface of an existing field effect emitter is etched to reduce the insulator oxide and expose the emitter fibers. An etch-resistant conductive material is then deposited on the surface of the emitter. The emitter surface is then polished to remove the etch-resistant material from only the metal fibers. The fibers are then etched down below the surface of the insulator, leaving holes through the surface conductor in alignment with the recessed fiber ends. Appropriate conductive and collector electrodes are provided, resulting in a field effect control device of high accuracy, overcoming many of the attendant problems associated with similar prior art devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS 1A through 1G are cross-sectional views of a field effect emitter during various stages of the method of producing the control device.

FIG. 2 discloses a typical circuit embodying the inventive control device.

FIGS. 3A through 3C are cross-sectional views of alternative steps in a method of producing the control device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like numbers represent like parts in the several drawings, FIG. 1 discloses the sequence of steps in the method of making the field effect control device. A field effect emitter 10 is shown in FIG. 1A. Emitter 10 may comprise as few as approximately a million emitting fibers 12 of tungsten per square centimeter of emitting surface area. The tungsten pins are encompassed in an insulating matrix of uranium or zirconium oxide 14 or another appropriate oxide-metal combination. The emitter 10 has surfaces 16 and 18 cut normal to the longitudinal axes of parallel fibers 12. A typical preferential etch comprising of 20 milliliters (ml) of glacial acetic acid, 40 ml saturated aqueous solution of CrO_3 , 6 ml concentrated nitric acid, and 4 ml concentrated hydrofluoric acid is used to remove the top layer of insulating material from around the metal fibers of surface 16. As noted in FIG. 1B, fibers 12 are resistant to this etch and the surface of the fiber rods are exposed by the etching action on insulator 14. After this etching a coating or mask of metallic conductor 20 such as gold Au is deposited over the entire surface 16 including metal fibers 12, as is shown in FIG. 1C. As shown in FIG. 1D, the ends 12a of fibers 12 are next exposed by polishing the surface conductor 20 with a diamond paste. The diamond paste and waste is removed by ultrasonic cleaning after polishing. The gold is removed from the fibers by the polishing action but remains on the oxide insulator. The fibers are then etched below the insulator surface as shown in FIG. 1E. Using another preferential etch such as 2 mgs of NH_4NO_3 in 100 ml concentrated H_2SO_4 , the tungsten fibers 12 are etched below the layer of gold. Gold is impervious to this etching solution. During etching the emitter may be subjected to ultrasonic motion to remove the etched material from the holes 22 in gold mask 20 and insulator 14. After etching and cleaning, a back plane of conductive material 24 is connected to the back side of fibers 12 and serves as one of the connecting points for electrical supply to the fibers as shown in FIG. 1F. As shown in FIG. 1G the field effect control device 30 is completed by the addition of an anode or collector 32 spatially disposed across from the gold mask 20. An emitting surface or plane is formed by the ends 12a of fibers 12. Control mask 20 remains attached to surface 16 and becomes the control electrode for the device. The collector 32 serves to collect electrons emitted by the fibers when a suitable electric field is developed therebetween with control electrode 20 functioning to increase or decrease the field according to the potential coupled thereto.

Obviously, the etching solutions may vary with the particular elements used as the emitter fibers 12, insulator 14, or control mask 20. Regardless of the elements or etch the mask is placed over the entire conductor-insulator surface prior to etching, which allows perfect alignment of the emitting fibers and the holes of the control mask 20 through which emitted electrons must pass during operation of the device. The finished device will function as an amplifier or as a switch. When utilized as a switch a low voltage is applied to the control mask turning the device on and permitting the flow of electrons from the field effect emitter to the collection anode which is connected to a higher voltage through a load. Removing the control voltage turns off

the device which then has an infinite impedance resulting in zero leakage current.

A typical embodiment of the field effect control device 30 in an electron tube embodiment is shown in FIG. 2 where control mask 20 is attached to an alternating voltage source 40 whose peak positive value exceeds the voltage required for turn on of the field effect emitter 10. This action results in the creation of a pulse of current in the output of the tube for each portion of the positive half cycle of the input voltage which exceeds the emission threshold for field emitter 10. The collector 32 is coupled in series with a load R and the high voltage power source 42. A common connection is made between emitter backing plate 24, source 40, and source 42 to complete the circuit. Obviously other types of input and load circuits allow control device 30 to provide various types of output signals. For example, other embodiments may include the use of the control device to provide a pulse amplifier output which is operated only when the voltage input pulse on control mask 20 exceeds a level determined by the mechanical spacing between the emitter points 12a and the control mask 20.

Advantages of the field effect control device include extremely high resistance in the off condition with very high breakdown voltage resulting in zero leakage current for the off condition, operation as a high voltage switch utilizing low voltage control, operation as a voltage controlled rectifier for extremely high voltage, and an amplifier when the signal wave form is superimposed on a bias voltage applied to the control mask. Such an amplifying device would be extremely resistant to damage from radiation effects, a problem with semiconductor devices. The control device also avoids problems of heaters and shock mounting required with the use of normal vacuum tube electron devices.

An alternate method for construction of the control mask over the emitter pin is as shown in FIG. 3. In FIG. 3A the field effect emitter 10 is shown prior to any etching thereof. A preferential etch of 2 mgs of NH_4NO_3 in 100 ml concentrated H_2SO_4 is used to remove metal from fibers 12 until they are below the level of the insulating material 14 and are pointed as shown in FIG. 3B. The fiber diameter is less than 1 micron prior to pointing thereof by the etching action. A metal conducting film 40 is deposited (FIG. 3C) on the exposed surface of the insulating material, the film serves as the control mask for the device. The recessed points 12b will also be covered by the metalizing film 40a. The vertical walls of the recessed area wherein the metal points reside separates the metalized areas, allowing operation. The field effect control device is then completed by addition of a conductive backing plate and a collector electrode as shown in FIGS. 1F and 1G.

It is to be understood that the form of the invention, herewith shown and described is to be taken as a preferred example of the same, and that various changes in the arrangement of parts may be resorted to, without departing from the spirit or scope of the invention. Accordingly, the scope of the invention is to be limited only by the claims appended hereto.

We claim:

1. A process for producing an electrical field effect control device comprising the steps of:
providing a field effect emitter material having a plurality of parallel metal fibers per unit area encompassed by an insulating material,

exposing respective first and second ends of said parallel fibers along respective first and second surfaces of said insulating material,
etching said insulating material across said first surface with a first etching agent to reduce the thickness of said insulator and thereby further expose said fibers,
depositing an etch-resistant layer of conductive material over the etched surface of said emitter material,
polishing said conductive material with an abrasive to re-expose said metal fibers without exposing said insulator material,
etching said exposed metal fibers across the surface of said emitter material with a second etching agent for reducing the length of said fibers to a plane or level below the surface level of said insulator,
joining a conductive backing plate to said second ends of said parallel fibers for conducting an electrical potential thereto, and
providing a collector electrode spatially disposed across from said etch-resistant, conductive material in a plane parallel with said first surface of said emitter material, and thereby providing said field effect control device.

2. The process as set forth in claim 1 wherein said coating of conductive material is gold.

3. The process as set forth in claim 2 wherein said insulating material is uranium oxide and said metal fibers are tungsten.

4. The process as set forth in claim 3 wherein etching of said insulator surface is done with a preferential etch of 20 milliliters of glacial acetic acid, 40 milliliters of saturated aqueous solution of CrO_3 , 6 milliliters of concentrated nitric acid, and 4 milliliters of concentrated hydrofluoric acid.

5. The process as set forth in claim 4 wherein etching of said exposed fibers is with a preferential etch of 2 milligrams of NH_4NO_3 in 100 milliliters concentrated H_2SO_4 .

6. A process for producing an electrical field effect control device comprising the steps of:

providing a field effect emitter material having a plurality of parallel, metal fibers per unit area encompassed by an insulating material,

exposing respective first and second ends of said parallel fibers along respective first and second surfaces of said insulating material,

etching said exposed metal fibers across said first surface with a first etching agent to reduce the length of said fibers to plane below the surface level of said insulator,

depositing a layer of conductive material over the etched surface of said emitter material,

joining a conductive backing plate to said second ends of said parallel fibers for conducting an electrical potential thereto, and

providing a collector electrode spatially disposed across from said conductive layer in a parallel plane with said first surface of said emitter material, thereby providing said field effect control device.

7. The process as set forth in claim 6 wherein said insulating material is zirconium oxide and said metal fibers are tungsten.

8. The process as set forth in claim 7 wherein etching of said exposed fibers is with a preferential etch of 2 milligrams of NH_4NO_3 in 100 milliliters concentrated H_2SO_4 .

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