United States Patent [19]

Kosmahl

[11] **Patent Number: 4,890,036**

[45] **Date of Patent: Dec. 26, 1989**

[54] **MINIATURE TRAVELING WAVE TUBE AND METHOD OF MAKING**

[75] Inventor: **Henry G. Kosmahl**, Olmsted Falls, Ohio

[73] Assignee: **The United States of America as represented by the United States National Aeronautics and Space Administration**, Washington, D.C.

[21] Appl. No.: **130,058**

[22] Filed: **Dec. 8, 1987**

[51] **Int. Cl.**[4] **H01J 25/34**

[52] **U.S. Cl.** **315/3.5**; 315/3; 331/82

[58] **Field of Search** 315/3.5, 5, 5.12, 3; 331/82

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,924,738	2/1960	Chodorow	315/3.5
3,443,146	5/1969	Buck	315/3.5
4,439,746	3/1984	Epsztein	331/82

Primary Examiner—Robert L. Griffin
Assistant Examiner—T. Salindong
Attorney, Agent, or Firm—James A. Mackin; Gene E. Shook; John R. Manning

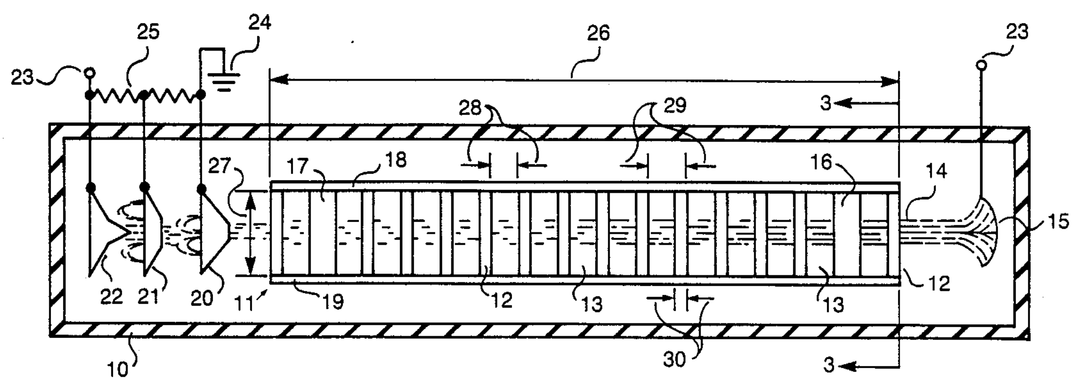
[57] **ABSTRACT**

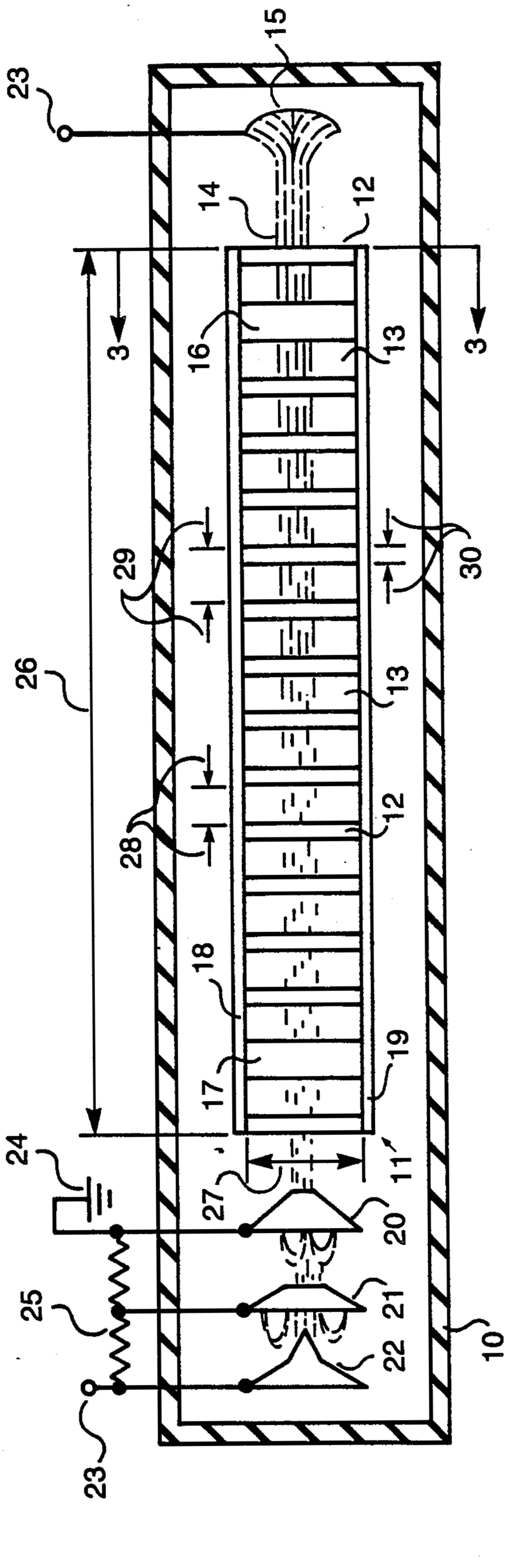
It is an object of the invention to provide a miniature traveling wave tube which will have most of the advantages of solid state circuitry but with higher efficiency and without being highly sensitive to temperature and various types of electromagnetic radiation and subatomic particles as are solid state devices.

The traveling wave tube which is about 2.5 cm in length includes a slow wave circuit (SWS) comprising apertured fins with a top cover which is insulated from the fins by strips or rungs of electrically insulating, dielectric material.

Another object of the invention is to construct a SWS of extremely small size by employing various grooving or etching methods and by providing insulating strips or rungs by various deposition and masking techniques.

12 Claims, 3 Drawing Sheets





23
15
14
12
3
16
13
3
29
30
26
13
28
12
18
19
17
24
11
27
20
21
25
22
10
23

FIG. 1

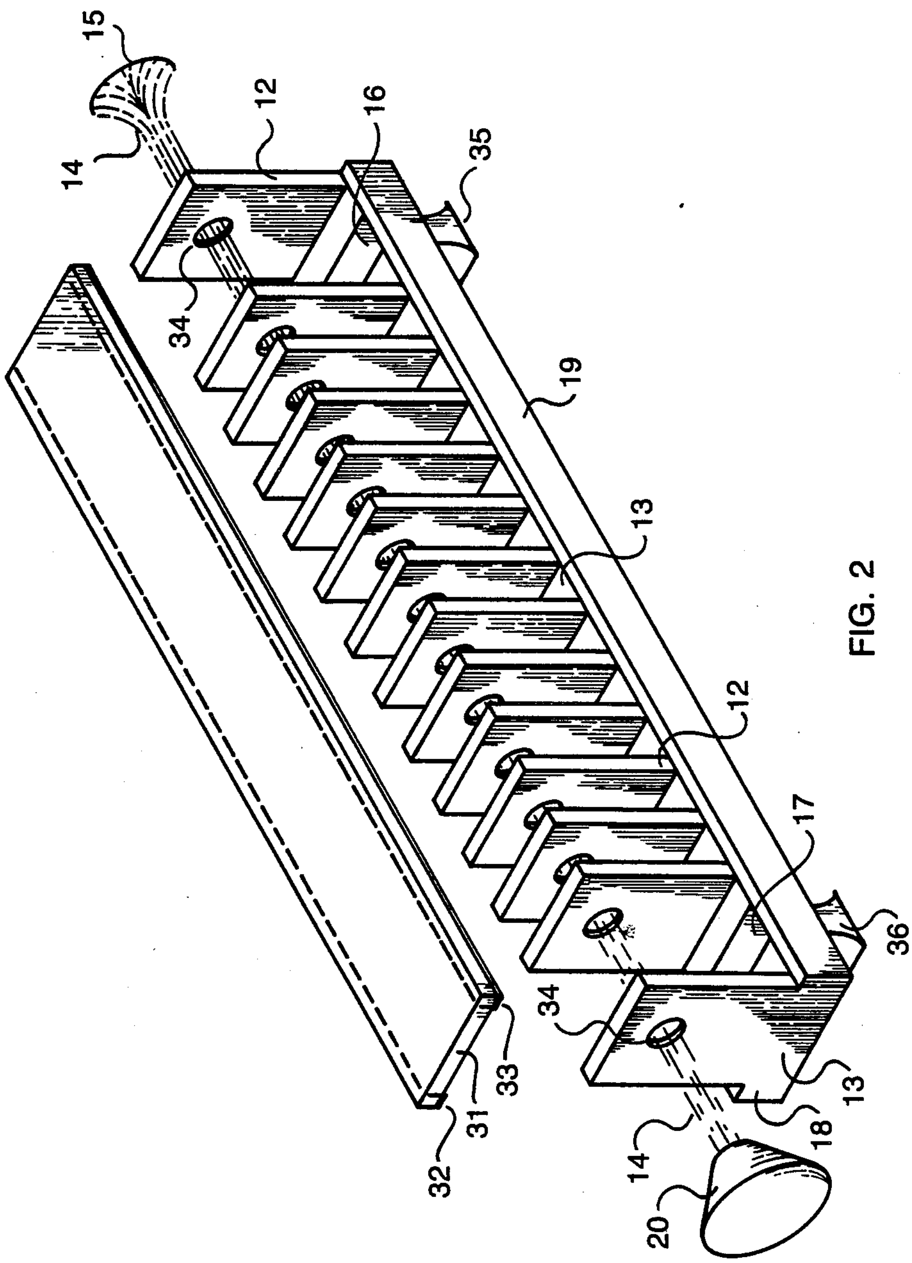


FIG. 2

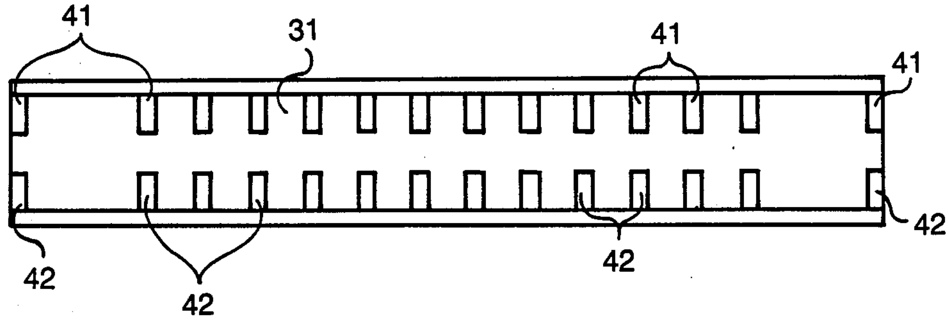


FIG. 4

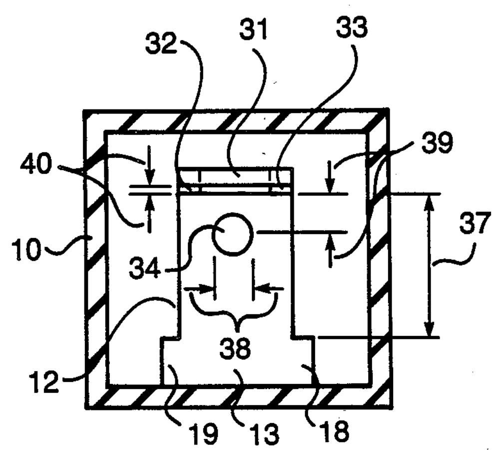


FIG. 3

MINIATURE TRAVELING WAVE TUBE AND METHOD OF MAKING

ORIGIN OF THE INVENTION

This invention was made under NASA contract NAS3-24565 and has been assigned to the Administrator of the National Aeronautics and Space Administration.

TECHNICAL FIELD

This invention relates to traveling wave tubes (TWT) and is directed more particularly to a miniature TWT.

Because of the burgeoning use of satellites for communications, transmitting tubes operating in the 5 to 60 GHz range are required in order that a greater number of messages may be carried in a particular radio frequency signal. Further, present and future needs will utilize phased array antennas or radar systems made up of a large number of small individual transmitters of relatively low power of from 0.1 to 10 watts for each transmitter. Each array may consist of, for example, 100 transmitters. Such arrays are electronically steerable and each transmitter may radiate RF directly into open space.

Many phased array antennas utilize solid state devices to provide a large number of individual transmitting units which are electrically steerable. Unfortunately, solid state devices are sensitive to temperature and extraneous radiation such as gamma rays, x-rays, neutrons, and protons. Furthermore, solid state devices have a lower power output, a narrower frequency range and a lower efficiency than TWTs utilizing an electron beam.

For passage of an electron beam, some TWTs of the prior art provided notches in the top edges of the propagating plates or fins to avoid the impossibility of mechanically assembling such structures with accurately aligned apertures for the beam. However, for TWTs operating above, for example, 5 GHz, the spacing when a top cover is added is entirely insufficient for the beam.

Accordingly, it is an object of the invention to provide a traveling wave tube having many of the advantages of solid state devices such as miniature size and suitability to non-mechanical construction.

It is another object of the invention to provide a traveling wave tube having 1 to 5 watts power output, 3 kV or less electron accelerating voltage and operating in the 5 to 60 GHz range.

Still another object of the invention is to provide a miniature TWT with apertured propagating fins, wherein the apertures are accurately aligned and are at a point of high impedance to a slow wave.

An additional object of the invention is to provide a traveling wave tube which may not require severs.

BACKGROUND ART

U.S. Pat. No. 4,439,746 to Epsztein discloses a microwave oscillator in which a wave guide cavity is provided with upstanding, apertured vanes and having coupling slots provided in the cavity between successive pairs of vanes.

U.S. Pat. No. 3,443,146 to Buck discloses a traveling wave tube wherein the delay structure discloses apertured propagating members extending from at least one wall of the tube, the propagating members being connected to one another at alternate positions by bars to form the equivalent of a helix slow wave structure.

U.S. Pat. No. 2,924,738 to Chodorow discloses a slow wave structure with interdigital apertured fins. The fins have alternating negative and positive potentials.

Many traveling wave tubes are known which include helically wound or coupled cavity slow wave structures.

DISCLOSURE OF THE INVENTION

In accordance with the invention, there is provided a miniature, low-voltage TWT including a slow wave structure comprising successive apertured fins extending from a bottom base member. The top cover plate is disposed on the fins opposite the base member with an electrically insulating layer disposed between the fins and the top cover. The electrically insulating layer is a dielectric material having a dielectric constant of 10 or less.

Techniques such as vapor deposition, sputtering, or ion beam implantation in a pattern which will be in register with the top edges of the apertured fins. Strips of dielectric material may be mechanically disposed between the fins and the top cover plate.

Preferably a cold cathode is utilized to provide an electron beam which interacts with an injected RF signal and passes through the apertures in the fins. At the end of the tube opposite the cathode, a multi-stage depressed collector may be incorporated to capture the spent electrons at high efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic top view of a travelling wave tube embodying the invention.

FIG. **2** is an oblique view schematic drawing of the amplifying SWS and its top cover.

FIG. **3** is a cross sectional view of the TWT of FIG. **1** taken along the line **3**—**3**.

FIG. **4** is a bottom view of a top cover plate for the SWS showing rung insulating layer members each rung having a gap.

For purposes of clarity, the drawings are not to scale and dimensions are not in proportion to actual sizes.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. **1**, there is shown a traveling wave tube **10** constructed of an electrically insulating material such as glass. Disposed inside the TWT **10** is a slow wave circuit **11** comprised of a plurality of thin, apertured fins **12** which all extend in a common direction from a base member **13**. The SWS may be copper or silicon. If silicon is employed, a plating of an electrically conductive material such as gold or copper must be applied to the silicon.

With relationship to an electron beam **14** emitted by a cathode **15**, the fin **12** at the extreme right of the SWS **11** may be considered as a first upstream fin while the fin **12** at the extreme left of the SWS may be identified as the last downstream fin. Thus, an input coupling slot **16** in the base member **13** is located immediately downstream of the first fin **12** while an output coupling slot **17** is positioned upstream of the last fin **12**. The cathode **15** is preferably a cold cathode but a miniature thermionic cathode may be used.

The coupling slots **16** and **17** are preferably the same width as the fins **12** in order to provide the correct matching to impedance matching transformers horns which will be attached to the slots **16** and **17** as will be described presently. If the coupling slots **16** and **17** are as just described, that is, the same width as fins **12**, there will be no structure to support the first and last fins **12**. Accordingly, flanges **18** and **19** are provided along the length of the base plate to provide the necessary support for the first and last fins **12**.

At the end of TWT **10** opposite the cathode **15** there is provided a multistage depressed collector comprised of collector plates, **20**, **21**, and **22**. A high voltage, on the order of 1–3 kV, is applied between a terminal **23** and ground **24** across a voltage divider **25**. Collector electrode **20** is connected to the ground point and collector electrode **22** is connected to the high negative voltage terminal **23** while the collector electrode **21** is connected to an intermediate point on the voltage divider **25**. The voltage divider **25** is exemplary only, as a high efficiency traveling wave tube would utilize well known components other than resistors to provide an intermediate voltage for collector plate **21**.

The length of the SWS is indicated by the double ended arrow **26** while the width of the fin **12** is indicated by the double ended arrow **27**. Opposing arrows **28** specify the spacing between fins **12** while double ended arrows **29** indicate the distance from the front surface of a particular fin to the front surface of the next downstream fin **12** (the period of the SWS). The thickness of the fins **12** is shown by the opposing arrows **30**.

Referring now to FIG. **2**, there is shown an oblique schematic view of the SWS **11** of FIG. **1** wherein parts identical to parts in FIG. **1** are identified by like numerals. As shown, the slow wave circuit **11** is provided with a top cover plate **31** having longitudinal strips of electrically insulating material **32** and **33** attached to its lower surface. The insulating strips **32** and **33** run lengthwise along the edges of the top cover plate **31** to establish a separation between the strips. The purpose of the separation is to avoid any buildup of charge on strips **32** and **33** and to provide a space between the top of the fins **12** and the cover plate **31** for the slow wave to propagate along the electron beam while the circuit wave travels a much longer path up and down the fins **12**, the bottom base walls and then around the top of each of the fins **12** into the next fin. An accumulation of charge on strips **31** and **32** could cause arcing at various points on the SWS **11**.

The fins **12** are provided with respective aligned apertures **34** through which electron beam **14** passes. In order to match the impedance of the input coupling slot **16** and the output coupling slot **17** to wave guides, respective horns or matching transformers **35** and **36** are attached to the base member **13**.

Referring now to FIG. **3**, parts corresponding to those of FIGS. **1** and **2** are identified by corresponding numerals. A double ended arrow **37** indicates the height of the fin **12** while opposed arrows **38** show the diameter of the aperture **34**. The distance of the center of aperture **34** from the top edge of fin **12** is indicated by opposing arrows **39** while opposing arrows **40** show the thickness of the insulating strips **32** and **33**.

FIG. **4** is a bottom view of a top cover plate **31** for an alternate embodiment of the invention in which the electrically insulating layer attached to the cover plate **31** is in the form of a row of rungs **41** and a row of rungs **42**, each row extending inwardly from respective opposite edges of the cover plate **31**. The rungs **41** are directly opposite respective rungs **42**.

The rungs extend inwardly only to the extent that they not interact with the electron beam to become charged as discussed previously with respect to the separation of the electrically insulating strips **32** and **33** of FIG. **2**. The rungs **41** and **42** are precisely located so they will be in register with respective ones of said fins **12** when the top cover plate **31** is disposed against the top edges of the fins **12**.

The miniature TWT **10** of FIG. **1** utilizes a voltage of only 1 to about 3 kV to accelerate the electrons of the beam **14**. The current of the electron beam is also quite low being in range from about 1 to 10 mA.

A TWT embodying the invention for operation in the 5 to 60 GHz range and at 1 to 5 watts of power will have the approximate dimensions as set forth in Table I below.

TABLE I

Arrow Numeral	Function	Dimensions (metric)
26	TWT length, 30 GHz	about 2.5 cm
27	Fin width	$\lambda_0/4$ or less
28	Distance between fins	(0.2–1.0 mm)-(0.1–0.7 m)
29	Spacing of fins (period)	0.2–1.0 mm
30	Fin thickness	0.1–1.0 mm
37	Fin height	1.0–10 mm
38	Aperture diameter	0.25–1.0 mm
39	Distance from top of fin to aperture center	0.1–0.3 times fin height
40	Thickness of electrically insulating layer	0.1–1.0 times fin spacing

where λ_0 is the free space wavelength.

The center of the aperture **34** is about 0.7 to 0.9 times the dimension **37** (fin height) from the base **13**. This position is also defined as 0.1 to 0.3 times the dimension **37** from the top edge of the fin **12**.

To construct a SWS in accordance with the invention an elongated block of material such as copper or silicon is cut to the length of the required SWS. Next a passageway is drilled through the block from end to end. The location of the passageway is dictated by opposing arrows **39** of FIG. **3** as specified in TABLE I above. One of the long surfaces of the block is then subjected to transverse electron discharge grooving, transverse ion beam etching, or reactive sputtering to remove material. The removal of material is continued until the fins **12** formed by the grooving process are of the desired height.

The second fin from each end of the SWS are eliminated during the grooving process to provide space for the respective input and output coupling ports, **16** and **17**, respectively. The coupling ports **16** and **17** are formed by one of the same processes used for the grooving and are sized for impedance matching with the coupling transformers or horns **35** and **36** of FIG. **2**. These transformers or horns are attached by soldering or the like to the coupling openings **16** and **17** in the base plate **13**. If the SWS is made from silicon, plating with an electrically conductive material will be required as mentioned previously.

A top cover the same length as the SWS and of the same material is provided to be disposed against the top edges of the fins **12** opposite the base plate. A thin layer of electrically insulating material is disposed as strips **32** and **33** on the bottom surface of the top cover plate to separate it from the fins **12**. The strips **32** and **33** may be Mylar, mica, quartz, boron nitride, aluminum oxide, polytetrafluoroethylene, or the like either attached to the top cover by a suitable adhesive or lain lengthwise on the fins before the cover is put in place. The electrically insulating strips **32** and **33** may also be formed by the electro-deposition, ion beam implantation, vapor deposition, or sputtering of materials such as diamond, aluminum oxide, boron nitride, quartz, or polytetrafluoroethylene.

Another embodiment of top cover plate **31** shown in FIG. **4** utilizes inwardly extending rungs **41** and **42** which, as explained previously, are in register with the fins **12** of the SWS **11**. To form the rungs **41** and **42**, the bottom surface of the top cover plate **31** is masked by various well known techniques with a slit provided at the desired position of each rung member. The electrically insulating dielectric material is then deposited by one or more of the various means discussed previously. The masking material is then removed and the top cover is cleaned and placed on the fins **12**. The top cover may be retained in place by various clips or straps, by adhesives or by soldering.

It will be understood that various changes and modifications may be made to the above-described invention without departing from its spirit and scope as set forth in the claims appended hereto.

I claim:

1. A miniature traveling wave tube (TWT) having a slow wave circuit (SWS) utilizing an electron beam, the SWS comprising:

an elongated base member having an input port and an output port, said ports being at opposite ends of said base member;

a plurality of parallel rectangular fins extending in the same direction from said base member, each of said fins having an aperture, the apertures all being aligned on an axis parallel to said base member for passage of the electron beam through the aperatures, the center of each aperture being positioned a measured distance from a top surface of said base member, said measured distance being between 0.7 and 0.9 times the distance from said top surface of the base member to a top edge of each respective fin, the alignment of the apertures being established by a drilled passageway in a block of material from which the base and fins are formed;

an elongated top cover disposed adjacent to top edges of said fins and opposite said base member;

an electrically insulating layer selected from the group of dielectric materials consisting of diamond, aluminum oxide, boron nitride, quartz and polytetrafluoroethylene disposed between said top cover and said fins, said electrically insulating layer being in contact with said fins and said top cover and comprising at least two strips of the dielectric material extending perpendicular to the rectangular fins and separated sufficiently to avoid interaction with the electron beam;

and wherein said electrically insulating layer has been disposed on the top cover by vapor deposition, electrodeposition, sputtering or ion beam deposition.

2. The SWS of claim **1** wherein the insulating layer has a dielectric constant preferably less than 10.

3. The SWS of claim **1** wherein said electrically insulating layer comprises two rows of inwardly extending, opposed rungs bonded to a bottom surface of said top cover, said rungs being spaced to be in register with said fins and wherein the respective opposed rungs extend inwardly no farther than a distance at which they would begin to interact with the electron beam.

4. The SWS of claim **1** wherein said base member said fins and said top cover are copper.

5. The SWS of claim **1** wherein the center of each aperture is at about 0.9 the distance from the base member to a top edge of the fin adjacent the electrically insulating material.

6. A method of making a miniature traveling tube (TWT) utilizing a slow wave structure (SWS) and an electron beam comprising the steps of:

providing an elongated block of electrically conducting material having a height greater its width;

drilling a passageway through said block from end to end;

removing material transversally to the length of said elongated block at a plurality of predetermined locations between from a top surface toward a bottom surface thereby forming a base member and fins having apertures which are aligned, the center of each aperture being positioned a measured distance from a top edge of its respective fin, said measured distance being between 0.1 and 0.3 times said height of the respective fin;

disposing by electrodeposition, vapor deposition or sputtering strips of an electrically insulating dielectric material lengthwise along the edges of a bottom surface of a top cover plate to insulate the top cover plate from the fins, said strips being separated sufficiently to avoid interaction with the electron beam;

disposing said top cover plate with the electrically insulating material contacting each of said fins, said cover plate being juxtaposed on said fins thereby forming a SWS; and

disposing the SWS in a TWT electrically insulating housing with the apertures aligned on the electron beam.

7. The method of claim **6** wherein said electrically insulating material has a dielectric constant preferably less than 10.

8. The method of claim **6** wherein the dielectric strips are selected from the group of materials consisting of diamond, aluminum oxide, boron nitride, quartz, and polytetrafluoroethylene.

9. The method of claim **6** including the steps of

applying a mask to said one surface of said cover plate before disposing said electrically insulating material thereon, said mask having a plurality of slits extending inwardly from opposite edges of the cover plate, said slits being positioned to be in register with said fins when the cover plate is disposed on said fins, said electrically insulating material being deposited on the cover plate through the slits to form rung members; and

removing said mask prior to disposing said cover plate on said fins with the rungs in register with the fins.

10. The method of claim **9** wherein said rung members extend inwardly only sufficiently so that the insulating layer deposited in said slits will have no significant interaction with the electron beam of the TWT.

11. The TWT of claim **1** and including an elongated flange on each side of the SWS base member to maintain the structural integrity of the SWS when the coupling ports are the same width as the fins.

12. The method of claim **6** wherein said block of elongated electrically conductive material is substantially wider for that portion of the block which will serve as the SWS base whereby forming coupling ports in the base will not affect the integrity of the SWS.

* * * * *