

April 29, 1969

O. HEIL
RIDGED DIELECTRIC WINDOW WITH TITANIUM
SUBOXIDE SOLELY ON RIDGES

3,441,784

Original Filed Oct. 7, 1963

Sheet 1 of 3

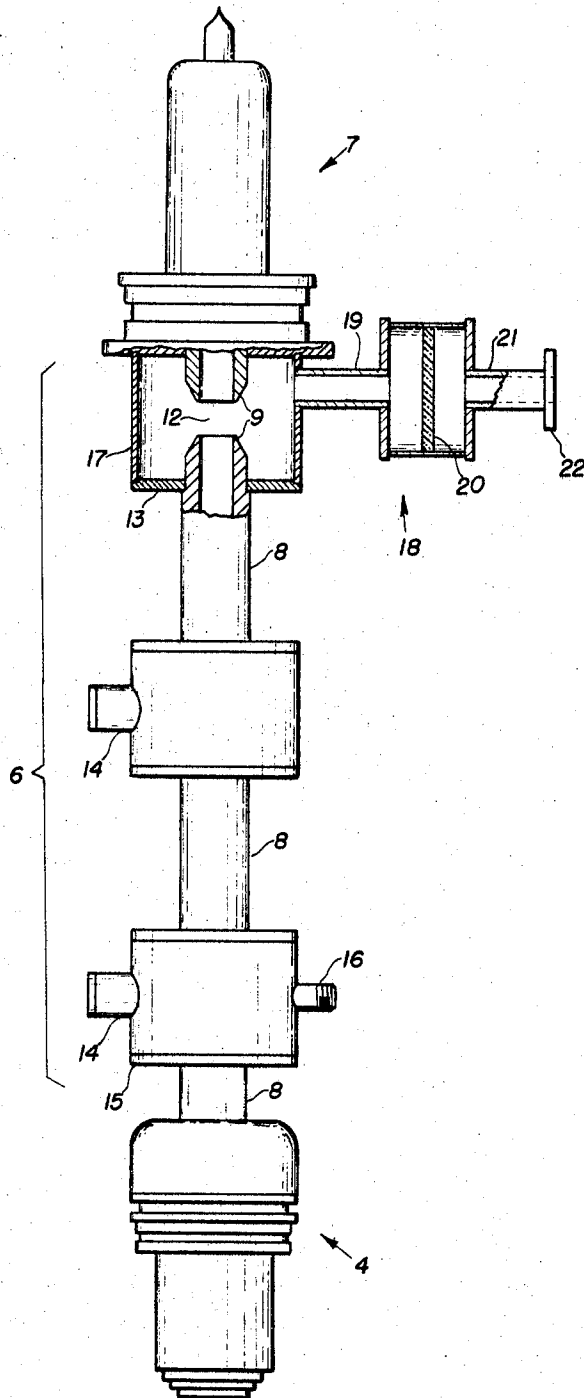


Fig. 1

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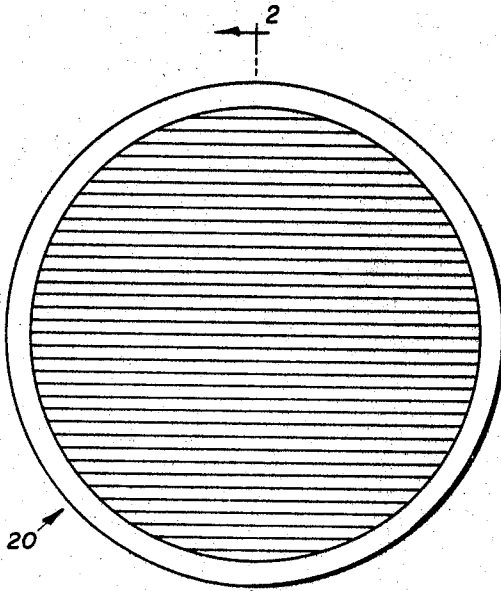


Fig. 1a



Fig. 2

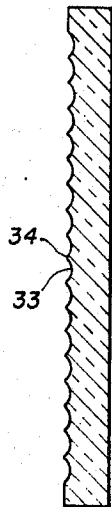


Fig. 3

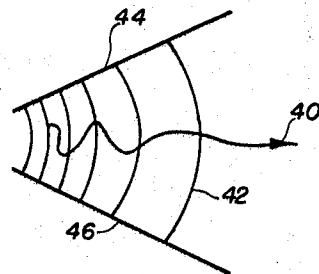


Fig. 4

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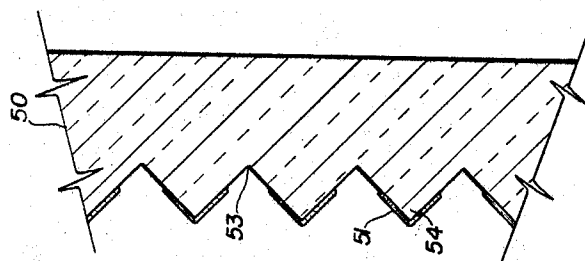
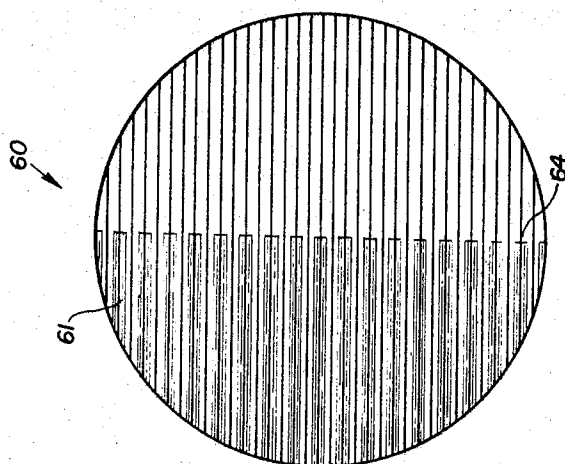
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Sheet 3 of 3



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Oskar Heil, San Mateo, Calif., assignor, by mesne assignments, to Varian Associates, a corporation of California
Continuation of application Ser. No. 314,181, Oct. 7, 1963. This application Apr. 26, 1967, Ser. No. 634,438
Int. Cl. H01j 25/02

U.S. Cl. 315—5

12 Claims

ABSTRACT OF THE DISCLOSURE

A window structure of dielectric material and transparent to electromagnetic fields present in microwave tubes and used in the output transmission system of the tubes has its surface on which the electromagnetic field is incident structured to reduce electron multipactor. A plurality of spaced peaked ridges are located along the dielectric surface at an angle with respect to the direction of the lines of force formed by the electric field components of the electromagnetic field. Titanium suboxide material is deposited solely at the peaks of the ridges.

This is a continuation of my application Ser. No. 314,181, filed October 7, 1963, now abandoned.

This invention relates to the reduction of secondary electron emission on the surface of a dielectric body bombarded by electrons and more particularly relates to the reduction of electron multipactor phenomena on the surface of a dielectric body exposed to electromagnetic waves.

In the electron tube industry, one of the limiting factors determining the amount of power which can be extracted from an electron tube containing electromagnetic wave energy with frequencies above 3000 megacycles involves the capability of the output transmission system to handle the high energy output. The output transmission system often contains a "window" transparent to high frequency electromagnetic energy that is formed of dielectric material. The window is generally used to maintain a vacuum seal in the tube so as to prevent the entry of water, water vapor, dust or other extraneous matter therein. The limiting factor in the output transmission system is that the amount of high frequency electromagnetic wave energy which a window is capable of passing has not kept pace with the amount of high frequency electromagnetic wave energy which an electron tube is capable of generating. Thus, while it is possible with state-of-the-art electron tubes to generate very high frequency electromagnetic wave energy, it is difficult to extract the energy from the electron tube because of the limitations imposed by the output transmission system, especially where such output transmission system utilizes a dielectric window as used in microwave tubes, such as klystrons, for instance.

Output windows transparent to electromagnetic energy are usually fabricated from dielectric materials having a coefficient of secondary electron emission greater than unity when subjected to bombardment by electrons whose energy levels lie within a certain range. This secondary electron emission coefficient characteristic renders the dielectric materials susceptible to destructive heating due to "single surface multipactor" phenomena which occur when the dielectric body is exposed to high frequency electromagnetic fields. This phenomenon is explained at length in an article appearing in the IRE Transactions of the Professional Group of Electron Devices, volume ED-8, number 4, dated July 1961.

It is an object of this invention to provide a dielectric body having spaced means along the surface thereof to eliminate or substantially reduce electron multipactor,

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It is a further object of this invention to provide a window which will permit a large amount of electromagnetic wave energy to pass through the window.

It is another object of this invention to provide a waveguide window assembly constructed in a manner to decrease secondary electron bombardment of the window and thereby decrease the amount of heat generated in the window.

A still further object of this invention is the provision of a resonant cavity portion for a klystron tube which communicates with an output coupling arrangement having an output window that is provided with a surface having spaced means therealong which eliminate or substantially reduce electron multipactor.

Briefly, this invention provides arrangements for eliminating or substantially reducing electron multipactor phenomena in windows transparent to electromagnetic wave energy. According to this invention, the window's surface is grooved to form ridges with coatings of electron multipactor reduction titanium suboxide material thereon.

These and other objects and features, the nature of the present invention and its various advantages, will appear more fully upon consideration of the attached drawing and the following detailed description of the drawing.

Referring to the drawing:

FIGURE 1 is an elevational view of a klystron tube incorporating a radio-frequency output window wherein the last resonant cavity together with a portion of the output waveguide coupling arrangement is shown in vertical section;

FIGURE 1a is an enlarged perspective view in elevation of the window used in the output waveguide coupling arrangement of FIGURE 1;

FIGURE 2 is a cross-sectional view taken along the line 2—2 of FIGURE 1a;

FIGURE 3 is a cross-sectional view of an output window depicting a different arrangement of grooves from that shown in FIGURE 2;

FIGURE 4 is a diagrammatic view of the curved potential lines existing in the vicinity of the grooves of FIGURE 2;

FIGURE 5 is an enlarged cross-sectional view similar to FIGURE 2 showing another embodiment of this invention;

FIGURE 6 is a view similar to FIGURE 1a showing a variation of the embodiment depicted in FIGURE 5;

Referring to the figures, FIGURE 1 shows a klystron which includes an electron gun section 4, a radio-frequency interaction section 6, and a collector section 7. As is well known in the art, the electron gun section, the radio-frequency section, and the collector section are hermetically united in axial alignment to enable the projection of an electron beam through a series of drift tube sections 8, each terminating within a cavity in a conically tapered end portion 9 spaced from the associated end of an adjacent drift tube section to provide an interaction gap 12 therebetween. Drift tube sections 8 are supported in axially spaced alignment by relatively heavy transversely extending annular metallic plates 13, preferably fabricated from oxygen-free high-conductivity copper.

Tuners 14 are provided in each of the first two cavities in the interaction section 6. Input cavity 15 contains an input loop 16 part of which is shown in FIGURE 1. Output cavity 17 is provided with an output coupling arrangement 18 which comprises a rectangular waveguide section 19 coupled to the output cavity 17.

A dielectric output window 20 prepared in accordance with the teachings of the embodiments of the invention is mounted in a cylindrical waveguide section 21 connected between the rectangular waveguide section 19 and rectangular waveguide section 21. The rectangular wave-

guide section 21 has a flange 22 for coupling the output of the klystron to a load.

This invention is also applicable to external resonant cavities utilizing an internal cylindrical dielectric window in the vicinity of the drift tube. The cylindrical dielectric windows are prepared in accordance with the teachings of the embodiments of the invention.

Referring to FIGURES 1 and 1a, the output window 20 is transparent to radio-frequency electromagnetic energy and maintains a vacuum seal for the klystron of FIGURE 1. One embodiment of the improved output window 20 of this invention is shown in FIGURE 2 wherein the output window 20 is provided with a plurality of parallel V-shaped grooves 23 along the surface thereof. In the particular embodiment as illustrated in FIGURE 2, the grooves 23 and crests 24 are an integral part of the dielectric surface. The grooves 23 have an interior angle preferably between 60 and 120 degrees. For thermal conductivity purposes, the 120° angle is even more preferred. The adjacent points at the crests 24 formed by the grooves 23 are, preferably, spaced at a distance ranging from .015 to .060 inch. The parallel grooves 23 are positioned at an angle with respect to the direction of the lines of force formed by the electric field directly in front of the window and preferably, are disposed substantially perpendicular to the direction of the lines of force formed by the electric field.

The windows of silica are made by grinding a fused silica disk by a diamond wheel which can be followed by fire polishing, or an alternate method of forming a grooved silica window can be achieved by simply hot pressing the silica material with a grooved metal plate. Alumina windows are made by pressing the desired amount of alumina powder between grooved hardened polished steel plates. The outer cylindrical edge can be ground to size after firing.

FIGURE 3 shows another arrangement of the grooves wherein rounded U-shaped grooves 33 are depicted. Crests 34 are formed by the grooves 33.

There are three effects caused by the grooves dielectric window 20 on electrons located in front of the window 20. The lines of force of the electric field in front of the window 20 are normally straight, but the grooves 23 cause the lines of force of the electric field to become curved in the region of the grooves as can be seen in FIGURE 4.

The curved lines 42 between the two lines 44 and 46 show the lines of force of the electric field existing between the sides of the grooves 23. The lines of force are much closer towards the bottom of the grooves which means that an electron in the vicinity of the bottom of the grooves will move away from denser field towards the less dense field. This will occur when the electrons have small amplitudes which is usually at the time when electromagnetic energy is initially transmitted through the window. Thus, the motion of an electron away from the bottom of the grooves 23 is shown by the arrow 40 in FIGURE 4.

The second effect of the grooves 23 is on electrons having large amplitudes and thus will not be present in the bottom portion of the grooves 23. The electric field distribution caused by the grooves 23 is such as to cause a slight jitter in the electron motion of the electrons in front of the grooves 23. This effect tends to move electrons away from the surface of the window 20.

The third effect created by the grooves 23 is also on electrons having amplitudes larger than the widths of the grooves 23.

Electrons from the electric field adjacent the vacuum side of the window 20 will strike the crests 24 formed by the grooves 23 because the crests 24 are disposed at an angle with respect to the direction of the lines of force formed by the electric field. Consequently, secondary electrons will be released from the surface of the dielectric window 20. Since the dielectric window 20 has a

coefficient of secondary emission greater than unity, the number of secondary electrons emitted will exceed the number of electrons bombarding the crests 24 of the window 20. The result of the net loss of electrons on the crests 24 of the dielectric window 20 is the formation of a positive charge on all the crests 24. The portions of the grooves 23 below the crests 24 will be negatively charged with respect to the crests 24 and hence, the electrons moving in front of the window 20 will face a D.C. periodic field. The resultant motion of the electrons in front of the window 20 will be a wave type movement caused by their attraction to the crests 24 and their repulsion from the portions of the grooves 23 below the crests 24. The resultant net force on the electrons in front of the window is a force in a direction away from the window surface.

FIGURE 5 shows another embodiment of this invention wherein a titanium suboxide coating 51 is located on crests 54 formed by grooves 53 in dielectric window 50. The spaced coating, which has a secondary electron emission coefficient less than unity, is applied by preferably sputtering a titanium oxide source on the window 50 after masking a portion of the window 50 by laying straight wires in the grooves 53. Any metal coating of a low secondary electron emission coefficient can also be used in this arrangement since the material is placed in spaced regions with the material in each region disconnected from that in the other regions thereby preventing the formation of a conductive layer in the dielectric window. It is not necessary to coat the grooves 53 since the electrons have amplitudes larger than the widths of the grooves 53 and will strike the crests 54. This arrangement substantially reduces electron multipactor on dielectric windows.

The dielectric materials forming the dielectric windows discussed in this application can be any one of the materials selected from the group consisting of alumina, alumina-silicate glass, beryllia, fused silica, steatite, and forsterite. The invention can also be practiced with other dielectric materials.

FIGURE 6 shows another embodiment of this invention wherein a titanium suboxide coating 61 is applied to one half of dielectric window 60. The coating 61 is applied to the crests 64 of the window 60. It was discovered that the coating 61 spreads to the remainder of the window 60 when electromagnetic wave energy is passed through the window 60 and this results in reduction of electron multipactor.

An alternative technique in reducing electron multipactor from that shown in the figures of this drawing depicting grooves formed along a dielectric surface is the use of metal members in the form of thin metal strips, i.e. Venetian blinds along the dielectric surface. The metal strips can be mounted on the surface of a flat dielectric window perpendicular to the direction of the electric lines of force of the electric field in the vicinity of the window. The metal members will reduce electron multipactor if the distance between the metal members is smaller than the distance required for the lowest order two-surface multipactor. The metal members are not transparent to electrons in the presence of a high frequency field, whereas the electromagnetic wave passes almost undisturbed. The secondary electrons emitted from the surface of the dielectric window will strike the thin metal members before they can strike the window surface after reaching high energy levels thereby causing the release of more secondary electrons.

A brief description of the effect that apparently takes place when an electron bombards a dielectric window is necessary to provide an understanding of the principles involved in electron multipactor. Electrons striking a dielectric body will become imbedded at a distance below the surface of the dielectric body. During the motion through the surface of the dielectric body, they will be striking other electrons until they lose enough energy to

become stuck in the dielectric material. Consequently, the electrons that were struck by the incoming bombarding electrons will be scattered around and kicked out of the dielectric material. The resultant effect is that an electric field will exist between the negatively charged electrons which have become imbedded in the dielectric material thereby creating a net negative region and the positive charge on the surface of the dielectric material created by the secondary electrons being emitted therefrom. The electric field will move free electrons in the direction of the surface of the dielectric material because of the positive charge there. Thus, the free electrons created by electron bombardment of the dielectric material will move toward the surface and if they have sufficient energy they will move out of the dielectric material.

In dielectric materials, such as silica, which have a high induced conductance, the electrons have greater movement. This high induced conductance in silica results in draining the electric field that is created by bombarding a dielectric material with electrons. Consequently, electrons bombarding silica will not kick out as many secondary electrons as occurs in other dielectric materials. Therefore, the grooves in a silica window in accordance with this invention substantially reduce electron multiplier.

In the embodiments utilizing strips of titanium suboxide on a dielectric window, fairly thick coatings of titanium suboxide can be used because of the inherent high electrical resistance of the dielectric surface, however, very thick strips of titanium suboxide will cause arcing between the titanium suboxide regions.

It is to be understood that the above-described arrangements are simply illustrative of the application of the principles of the invention. Numerous other arrangements may be readily devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof.

I claim:

1. A dielectric window transparent to incident high radio-frequency electromagnetic wave energy in a vacuum and in the presence of incident-free electrons which electromagnetic wave includes an electric field component comprising a body of dielectric material having a surface to be exposed to free electrons in vacuum and high radio-frequency electric fields, a plurality of spaced peaked ridges located along the said surface to define grooves therebetween transparent to the electromagnetic waves, the distance between adjacent ridges maintained constant; and titanium suboxide deposited solely at the peaks of said ridges, said dielectric window having the titanium suboxide deposited thereon being transparent to the electromagnetic waves.

2. The dielectric window according to claim 1 wherein said dielectric body is of material selected from the group consisting of alumina, alumina-silicate glass, beryllia, fused silica, steatite, and forsterites.

3. The dielectric window according to claim 1 wherein said deposited titanium suboxide is located solely at the peaks of said ridges in one-half of the area of said dielectric surface.

4. The dielectric window according to claim 1 wherein said grooves defined between said ridges are V-shaped defining a groove angle in the range of 60° to 120°.

5. The dielectric window according to claim 1 wherein said ridges are of dielectric material and form part of said dielectric surface of said window.

6. A high power radio-frequency tube comprising an electron gun section, a radio-frequency interaction section and a collector section joined to define an evacuated envelope; said radio-frequency interaction section including, input and output coupling arrangements, said input coupling arrangement including means for coupling to a radio-frequency generator for receiving therefrom an electromagnetic wave including an electric field; said output coupling arrangement including a dielectric radio-frequency window transparent to and having a surface upon which the electromagnetic wave is incident for coupling the wave therethrough, said electromagnetic wave having an electric field including a component in the plane of the dielectric surface; a plurality of spaced peaked ridges located along said dielectric surface to define grooves therebetween transparent to the incident electromagnetic wave, the distance between adjacent ridges being constant, said ridges located at an angle with respect to the direction of the electric field of said electromagnetic wave in the vicinity of said surface of said window; and titanium suboxide deposited solely at the peaks of said ridges, said dielectric window having the titanium suboxide deposited thereon being transparent to the electromagnetic waves.

7. The radio-frequency device according to claim 6 wherein said dielectric material is selected from the group consisting of alumina, alumina-silicate glass, beryllia, fused silica, steatite, and forsterite.

8. The radio-frequency device according to claim 6 wherein said deposited titanium suboxide is located solely at the peaks of said ridges in one-half of the area of said dielectric surface.

9. The radio-frequency device according to claim 6 wherein said ridges are of dielectric material and form part of said dielectric surface.

10. The tube according to claim 6 wherein said angle is 90°, and said grooves defined between said ridges are V-shaped.

11. The tube according to claim 10 wherein said grooves define a groove angle in the range of 60° to 120°, and said peaks of said ridges spaced at a distance in the range of 0.015 to 0.060 inch.

12. The tube according to claim 6 wherein said dielectric window is comprised of silica.

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ROBERT SEGAL, *Primary Examiner*.

U.S. Cl. X.R.

313—106; 315—39; 333—98