July 11, 1967 L. REED 3,330,707

METHOD FOR REDUCING ELECTRON MULTIPACTOR ON A DIELECTRIC WINDOW SURFACE

Filed Oct. 7, 1963

2 Sheets-Sheet 1

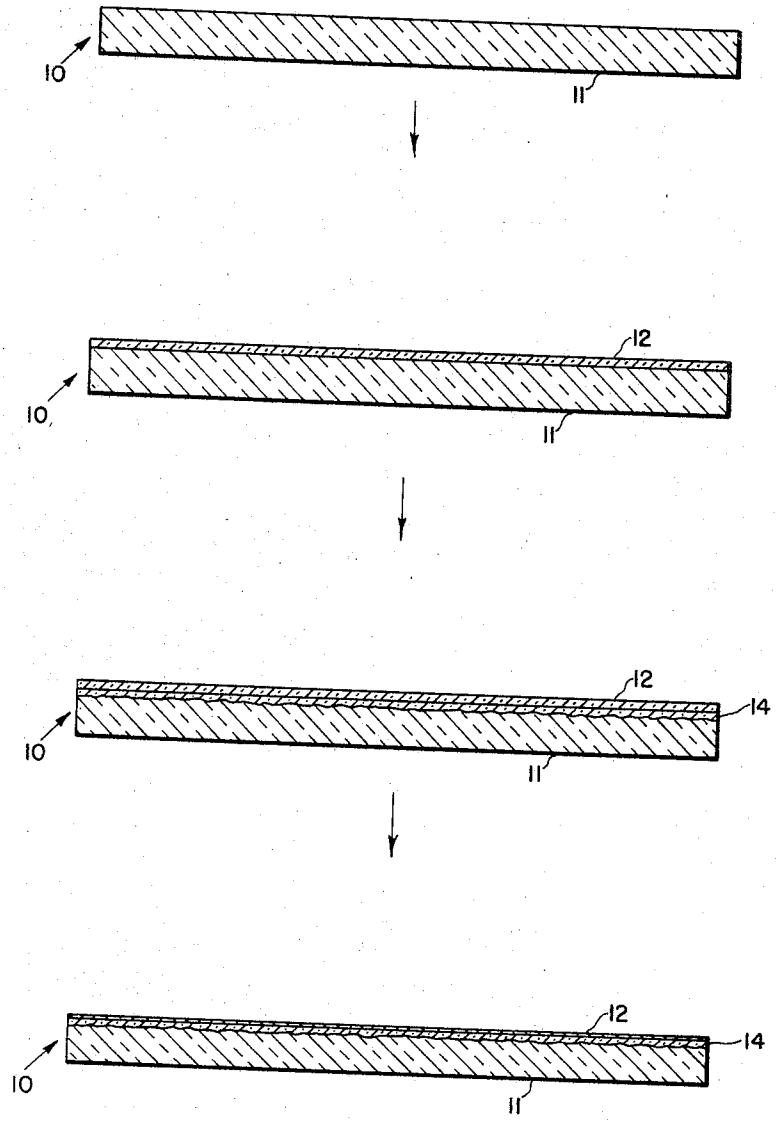


Fig. 1

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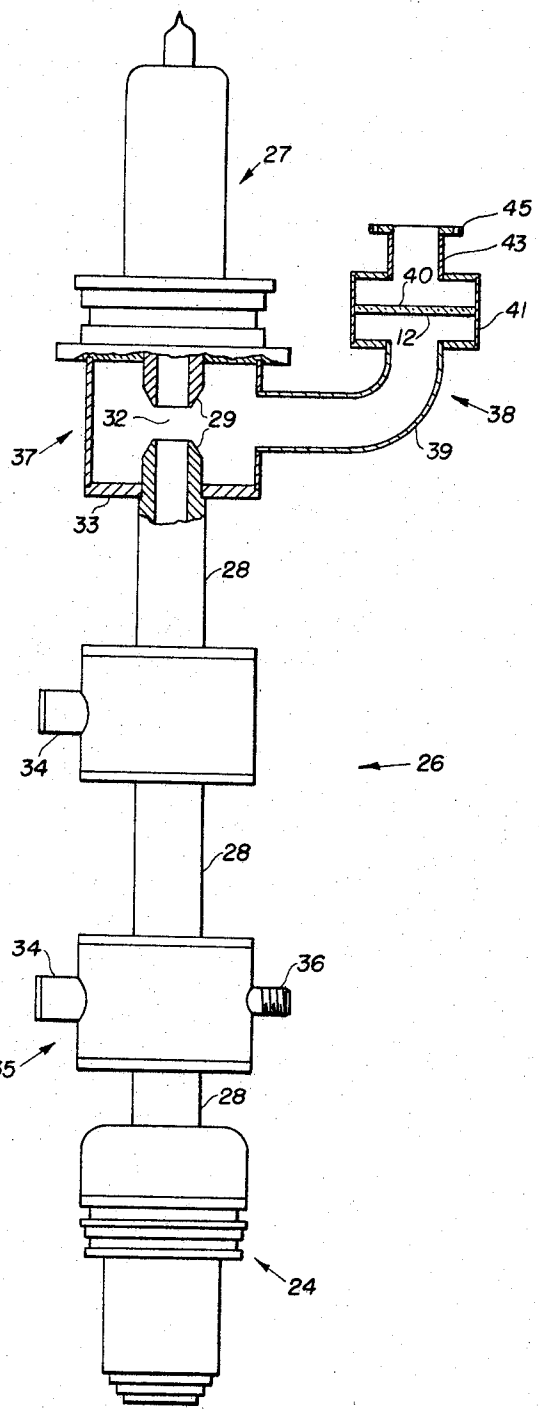


Fig. 2

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METHOD FOR REDUCING ELECTRON MULTIPACTOR ON A DIELECTRIC WINDOW SURFACE

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2 Claims. (Cl. 156—3)

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 Prefessional Group of Electron Devices, volume ED–8, No. 4, dated July 1961.

It is an object of this invention to provide a method for reducing secondary electron emission on the surface of a dielectric body and also to provide a dielectric body composed of dielectric material and low secondary electron emissive material which reduces secondary electron emission on the surface of the dielectric body.

It is a further object of this invention to provide a method for reducing electron multipactor on the surface of a dielectric window exposed to large amounts of high frequency electromagnetic wave energy and also to provide a dielectric window composed of dielectric material and low secondary electron emissive material which reduces electron multipactor on the surface of the dielectric window.

Briefly described, this invention relates to a method for reducing secondary electron emission on the surface of a dielectric body. A layer consisting of a suboxide of a material having a secondary electron emission coefficient whose maximum value is less than unity is formed on the surface of the dielectric body. A portion of the low secondary emission coefficient suboxide material which was formed on the surface of the dielectric body is diffused into the dielectric body. A portion of the suboxide material remaining on the surface of the dielectric body is removed to increase the resistance of the surface of the dielectric body to a value greater than 10^8 ohms per square unit.

This invention also relates to a dielectric body made by the above described method. The dielectric body is composed of dielectric material and material whose coefficient of secondary electron emission is less than unity. The dielectric body comprises a dielectric base portion and a layer of the material whose coefficient of secondary electron emission is less than unity located on at least one surface of the dielectric base portion. The dielectric base portion is also doped with a material whose secondary electron emission coefficient is less than unity.

In the drawing:

FIGURE 1 contains four illustrations in cross-section of a dielectric body having a surface portion thereof being treated in order to reduce secondary electron emission in accordance with the method of this invention; and

FIGURE 2 is an elevational view of a klystron tube incorporating a radio-frequency output window treated in accordance with the method of FIGURE 1 wherein the last resonant cavity together with a portion of the output waveguide coupling arrangement is shown in vertical section.

Referring to FIGURE 1, a dielectric body **10** is shown in the first of the four illustrations. In the second illustration, the dielectric body **10** is shown as comprising a dielectric base portion **11** provided with a surface coating or layer **12** of a material having a coefficient of secondary electron emission less than unity. The low secondary electron emission layer **12** preferably consists of a suboxide of a material, such as titanium. The dielectric base portion **11** is composed of a dielectric material selected from the group consisting of alumina and beryllia.

The third illustration in FIGURE 1 depicts the dielectric body **10** after the diffusion of a portion of the layer **12** of low secondary electron emission material into the dielectric base portion **11**. A portion **14** of the dielectric base portion **11** contains substantially all of the low secondary electron emission material that is diffused within the dielectric base portion **11**. The depth of the diffused material in the dielectric base portion **11** should, desirably, reach a level at least substantially equal to the main distance of penetration by electrons bombarding the surface of the dielectric body **10** until they lose enough energy to become imbedded within the dielectric body **10**. The microfield that is created in the dielectric base portion **11** of dielectric body **10** by bombarding electrons is discussed in more detail in the application Ser. No. 314,181 of Oskar Heil filed the same day as this application.

The fourth and last illustration in FIGURE 1 depicts the dielectric base portion **11** of the dielectric body **10** with its layer **12** of low secondary electron emission material reduced in thickness to indicate the removal of a portion of the layer **12** for the purpose of increasing the resistance across the surface of the dielectric body **10** to a value greater than 10^8 ohms per square unit and preferably greater than 10^{12} ohms per square unit which is a value of resistance approaching infinity.

With regard to the second illustration of FIGURE 1, the coating or layer **12** is applied preferably by spraying a liquid suspension containing the low secondary electron emission material onto the surface of the dielectric base portion **11** of the dielectric body **10**. An example of one such low secondary electron emission liquid mixture is prepared as follows: a quantity of 100 grams of titanium dioxide with 50 cubic centimeters of 20A lacquer is

mixed. The 20A lacquer consists of 4.2 grams of nitrocellulose, 150 cubic centimeters of methyl ethyl ketone and 150 cubic centimeters of ethylene glycol ethyl ether, such as Dowanol EE. The titanium dioxide suspension is ball milled for a period of 24 hours. The final mixture is removed from the ball mill and placed in a conventional spray bottle and sprayed to a thickness of approximately 1 mil onto a surface of the dielectric body **10** after the body **10** is cleaned by conventional means and metalized in accordance with a desired pattern. Metalizing of the dielectric body can take place at the same time or follow the diffusion step described below.

If it is desired to place a dot coating of low secondary electron emissive material onto the surface of the dielectric body **10** in accordance with the teachings of the afore-mentioned application of Oskar Heil, then the titanium dioxide mixture is sprayed onto the clean surface of the dielectric body **10** through a mask consisting of expanded nickel sheet and having, preferably, apertures whose diameters are $\frac{1}{32}$ of an inch long. A dotted coating having a thickness of approximately 1 mil is thus formed onto the surface of the dielectric body **10** and allowed to dry.

The coated dielectric body **10** is then placed into a furnace and heated at a temperature between 1300 and 1600° C. for a time sufficient to diffuse a portion of the resulting titanium suboxide dioxide layer **12** located on the surface of the dielectric base portion **11** of the dielectric body **10** into the dielectric base portion **11**. Preferably the depth of diffusion of the titanium Ti^{3+}; Ti^{2+} ions is substantially 50 microns with traces of the titanium ions reaching a depth of 300 microns within the dielectric base portion **11** of the dielectric body **10**. The coated dielectric body **10** is, preferably, heated at a temperature of 1425° C. for a period of 30 minutes in a reducing atmosphere, such as 75% nitrogen and 25% hydrogen at a dew point of +60° F. The resistance of the surface of the dielectric body **10** after firing is in the range of from 10^4 to 10^6 ohms per square unit.

After the coated dielectric body **10** is removed from the furnace, the surface containing the titanium suboxide layer **12** is etched, preferably, with a 5% hydrofluoric acid solution for a period of approximately 30 minutes until the resistance of the coated surface **12** of the dielectric body **10** reaches a value greater than 10^8 ohms per square unit. As an alternative to etching, polishing, sand blasting, etc. can be used to reduce the thickness of the titanium suboxide layer **12** so as to increase the resistance of the surface of the dielectric body **10** to a value greater than 10^8 ohms per square unit.

After the etching step, the coated dielectric body **10** is rinsed with deionized water and dried with acetone. In the situation where the coated dielectric body **10** is a coated dielectric window, the window is now ready to be mounted into a waveguide. The window is connected to the waveguide by a normal brazing operation which is carried out preferably in a dry hydrogen atmosphere at −80° F. dew point. (An intervening metalizing plating operation may also be carried out if desired.)

One significant advantage of the diffusion process is that there is no danger of having all or significant portions of the low secondary emission material powder or flake off the dielectric body **10** during multiple brazing or metalizing operations that are sometimes required during the assembly of the electromagnetic transmission system in which the dielectric window is mounted.

A spiral coating or any other type of desired coating can be applied to the surface of the dielectric body **10**. The coating **12** can consist of any compound of an element whose secondary electron emission coefficient has a maximum value less than unity. Compounds of titanium, such as titanium hydride (TiH_2), and titanium suboxides, such as TiO_x, and TiO_2, or other titanium compounds may also be used as the original coating material. However, during the heating process, the coating material

compound that was originally applied to the surface of the dielectric base portion **11** of the dielectric body **10** reduces to a suboxide form and a portion of the suboxide coating diffuses into the grain boundary phase of the dielectric base portion **11** of the dielectric body **10**. In the case of the titanium suboxides, the titanium ions react with the ceramic to produce alumina silicate titania glasses, primary crystalline titanium compounds or glassy phase devitrification products. The titanium ions also react with the alumina or beryllia crystals where the dielectric body **10** comprises aluminum or beryllium, respectively, to form aluminum or beryllium titanates. In the case of alumina the Ti^{3+} ions can form a limited solid solution in the Al_2O_3 phase.

An alternate method for producing a dotted or other type of spaced coating of a material having a secondary electron emission coefficient whose maximum value is less than unity on the surface of the dielectric base portion **11** of the dielectric body **10**, without spraying through a mask, can be achieved by starting with a continuous coating deposited on the surface of the dielectric base portion **11** of the dielectric body **10**. The continuous coating is covered with a material, such as Kodak Photoresist and a desired pattern is exposed. The portions of the low secondary electron emissive material can then be etched away from undesired areas.

The last step of the invention, which is the removal of a portion of the coating material remaining after firing of the dielectric body **10**, can be eliminated if it is not necessary to raise the resistance value of the surface of the dielectric body **10** to the high resistance values that can be reached by removing a portion of the coating **12**. It is also possible to continue the diffusion step until the material remaining on the surface has the desired final resistance (10^8–10^{12} ohms per square unit) at room temperature or the temperature of operation of the window in the tube.

Referring to FIGURE 2, a klystron is shown which includes an electron gun section **24**, a radio-frequency interaction section **26**, and a collector section **27**. 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 **28**, each terminating within a cavity in a conically tapered end portion **29** spaced from the associated end of an adjacent drift tube section to provide an interaction gap **32** therebetween. Drift tube sections **28** are supported in axially spaced alignment by relatively heavy transversely extending annular metallic plates **33**, preferably fabricated from oxygen-free high-conductivity copper.

Tuners **34** are provided in each of the first two cavities in the interaction section **26**. Input cavity **35** contains an input loop **36** part of which is shown in FIGURE 1. Output cavity **37** is provided with an output coupling arrangement **38** which comprises a rectangular waveguide section **39** coupled to the output cavity **37**.

A dielectric output window **40** capable of passing high frequency electromagnetic wave energy is mounted in a cylindrical waveguide section **39** connected between the rectangular waveguide section **41** and rectangular waveguide section **43**. The surface of the dielectric output window **40** that faces the vacuum side which is the same window surface that electrons from the output cavity **37** will bombard is diffusion treated in accordance with the method of this invention to reduce electron multipactor on the surface of the window **40**. The rectangular waveguide section **43** has a flange **45** 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 also treated in accordance with the teachings of this invention.

It is to be understood that the above described speci-

fication sets forth some of the ways of carrying out the present invention. Numerous other arrangements in accordance with the principles disclosed herein may be readily devised by those skilled in the art to which this invention pertains.

I claim:

1. A method for reducing electron multipactor on the surface of a dielectric window adaptable for passing electromagnetic waves of a material selected from the group consisting of alumina and beryllia comprising the steps of forming a coating on the surface of said dielectric window consisting of titanium suboxide which has a secondary electron emission coefficient whose maximum value is less than unity, heating said coated dielectric window to a temperature of 1425° C. for a period of thirty minutes in a reducing atmosphere, and etching away a portion of said titanium suboxide material remaining on the surface of said dielectric window with a 5% HF acid solution for a period of thirty minutes at room temperature to increase the resistance of the surface of said dielectric window to a value greater than 10^8 ohms per square.

2. A method for reducing electron multipactor on the surface of a dielectric window adaptable for passing electromagnetic waves of a material selected from the group consisting of alumina and beryllia comprising the steps of spraying a liquid mixture containing titanium dioxide through a mask onto a clean surface of said dielectric window to form a dotted coating having a thickness of approximately 1 mil, heating said titanium dioxide sprayed dielectric window to a temperature of 1425° C. for a period of thirty minutes in an atmosphere of 75% nitrogen and 25% hydrogen at a dew point of +60° F., and etching away a portion of said dotted titanium suboxide coating on the surface of said dielectric window with a 5% HF acid solution for a period of thirty minutes at room temperature to increase the resistance of the surface of said dielectric window to a value greater than 10^8 ohms per square.

References Cited

UNITED STATES PATENTS

2,985,548	5/1961	Blickwedel et al.	117—221
3,036,018	5/1962	Peras	117—221
3,094,436	6/1963	Schroder	117—215
3,165,430	1/1965	Hugle	156—17
3,252,034	5/1966	Priest et al.	313—107

FOREIGN PATENTS

639,638	4/1962	Canada.

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