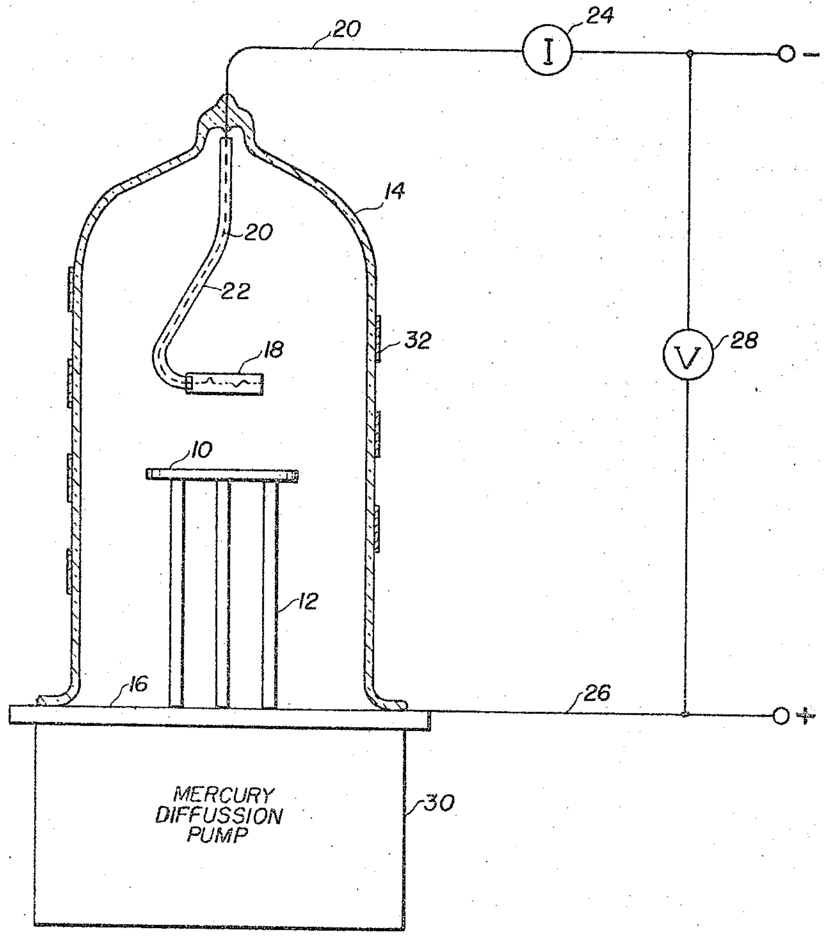
March 14, 1967 O. HEIL 3,309,302

METHOD OF PREPARING AN ELECTRON TUBE INCLUDING SPUTTERING A SUBOXIDE OF TITANIUM ON DIELECTRIC COMPONENTS THEREOF

Filed Oct. 7, 1963




INVENTOR.
OSKAR HEIL

BY Robert W. Dilts

ATTORNEY

United States Patent Office

3,309,302

Patented Mar. 14, 1967

1

3,309,302

# METHOD OF PREPARING AN ELECTRON TUBE INCLUDING SPUTTERING A SUBOXIDE OF TITANIUM ON DIELECTRIC COMPONENTS THEREOF

Oskar Heil, San Mateo, Calif., assignor, by mesne assignments, to Varian Associates, a corporation of California

Filed Oct. 7, 1963, Ser. No. 314,182
7 Claims. (Cl. 204—192)

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 frenquency 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 suscepitible 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 method for reducing secondary electron emission on the surface of a 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.

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 material having a secondary electron emission coefficient whose maximum value is less than unity is sputtered onto a surface of the dielectric body. The sputtered layer on the dielectric body has a high resistance, preferably, greater than $10^8$ ohms per square and is firmly bonded to the surface of the dielectric body.

This invention also relates to a method for reducing electron multipactor on a dielectric window transparent

2

to electromagnetic wave energy which is to be used in the presence of free electrons and a high frequency electromagnetic field. A layer of a material whose secondary electron emission coefficient is less than unity is sputtered onto a surface of the window. The sputtered layer has a resistance greater than $10^8$ ohms per square and a thickness sufficient to reduce electron multipactor on the surface of the dielectric window.

In the drawing:

The sole figure is a cross-sectional view of the sputtering apparatus used in connection with the method of the subject invention.

Referring to the sole figure, a dielectric body **10** is mounted on three equally spaced dielectric support rods **12**, preferably, of fused silica within a chanmber **14**, such as, for example, a bell jar. A metal plate **16** serves as a base support for the three equally spaced support rods **12**. The metal plate **16** is provided with a circular opening located within and defined by the three support rods **12**. A target **18** is suspended at a distance from the dielectric body **10** by a lead **20** that is provided with rigid insulation **22** within the chamber **14**. The lead **20** is connected through an ammeter **24** to an appropriate source of negative D.C. voltage, for example, 1200 to 1500 volts, thus making the target **18** a negative electrode. A lead **26** is connected to the metal base plate **16** and to the positive side of the voltage source thus making the base plate **16** a positive electrode. A volt meter **28** is connected across the voltage source for the purpose of monitoring the applied potential.

The chamber **14** contains a gas suitable for creating a plasma in the chamber **14** when the D.C. voltage source is electrically connected to the leads **20** and **26**. The positive ions of the plasma created in the chamber **14** are attracted to the target **18** and strike the target with sufficient energy to cause the material of the target **18** to sputter off and onto the dielectric body **10**.

In one example, the target **18** consisted of an elongated cylindrically shaped body of titanium monoxide that was 1.5 inches long and 3 inches in diameter and was spaced 1.5 inches from the dielectric body **10**. The dielectric body **10** was used as a circular dielectric window in an output coupling arrangement of a klystron and had a 3 inch diameter and a thickness of .15 inch. A mercury diffusion pump **30** was connected to the bottom of metal plate **16** for the purpose of maintaining a mercury atmosphere at a pressure of $10^{-3}$ torr at a temperature of 25° C.

A trap was mounted below the circular opening in the base plate **16** to maintain the mercury pressure at a constant value and at an exact temperature of about 18° C. The trap used was simply a circular or elliptical shaped cylinder filled with water at room temperature.

A helical copper R.F. coil **32** is wound around the bell jar **14** and energized by an oscillator operating at a frequency of 27 megacycles and providing several hundred watts of power for the purpose of exciting or concentrating the mercury plasma in the region about the target **18** and the window **10**. The copper coil **32** used in the example was approximately 1 inch wide.

The coating or layer which was sputtered onto the dielectric window **10** has, preferably, a thickness of 1000 angstrom units. This thickness provides a visible film of titanium monoxide. The mercury ion current was, preferably, held at 4 milliamperes for about a 60 minute period in order to constantly reproduce coatings having the same thickness on the dielectric window **10**.

The thicknesses of the coatings produced in accordance with the sputtering operation described above are easily reproduced and the sputtering technique that is used in producing coatings of low secondary electron emissive material on the dielectric window **10** is temperature insensitive since the energy of the impinging ions is in the range of 1200 to 1500 electron volts which is far above and unaffected by thermal energies. The sputtered molecules of titanium monoxide have energies in the neighborhood of several electron volts which is also above thermal energies and hence, uneffected thereby. The sputtering operation provides coatings that are firmly bonded to the dielectric window **10** without the necessity of heating the dielectric window **10**.

The dielectric window **10** was selected from any one of the materials of the group consisting of alumina, beryllia, and silica.

In another example, thicker coatings of titanium monoxide were deposited on the dielectric window **10** to suppress electron multipactor without lowering the resistance of the surface of the dieelectric window **10** which should be, preferably, greater than $10^8$ ohms per square. A flattened nickel wire mesh was placed on the surface of the dielectric window **10** prior to the sputtering operation. A network of dots of titanium monoxide was thus sputtered onto the dielectric window **10** covering 20% of the area of the window **10**. The dots were .75 mm. apart and provided an inherently large electrical resistance thereby permitting the thicker coatings, if desired. It was discovered that the sputtered dot coating reduced electron multipactor on the surface of the dielectric window **10**.

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.** In the manufacture of an electron tube having a dielectric body and in which operation of the tube causes the surface of the dielectric body to be bombarded by electrons, the improvement comprising the steps of sputtering onto said surface a dotted coating of a suboxide of titanium.

**2.** A method as claimed in claim **1** in which the dots of said dotted coating of the suboxide of titanium are spaced .75 millimeters apart and cover 20% of said surface of the dielectric.

**3.** In the manufacture of an electron tube having a dielectric body and in which operation of the tube causes the surface of the dielectric body to be bombarded by electrons, the improvement comprising the step of sputtering a suboxide of titanium onto said surface from a target electrode made of said suboxide material, said suboxide material having a secondary electron emission coefficient of less than unity, and said suboxide material being sputtered onto said surface to form a film which is thick enough to reduce the secondary emission coefficient of said surface and thin enough to have a high electrical resistance.

**4.** In the manufacture of an electron tube having a dielectric body and in which operation of the tube causes the surface of the dielectric body to be bombarded by electrons, the improvement comprising the step of sputtering onto said surface a suboxide of titanium whose secondary electron emission coefficient has a maximum value less than unity for a time sufficient to form a film having a resistance greater than $10^8$ ohms per square and a thickness on the order of about 1000 angstrom units, said sputtering being performed with a target electrode made of said suboxide of titanium.

**5.** In the manufacture of an electron tube having a dielectric body and in which operation of the tube causes the surface of the dielectric body to be bombarded by electrons, the improvement comprising the step of sputtering onto said surface titanium monoxide for a time sufficient to form a film of said titanium monoxide having a resistance greater than $10^8$ ohms per square on said surface, said sputtering being performed with a target electrode made of titanium monoxide.

**6.** In the manufacture of an electron tube having a dielectric body and in which operation of the tube causes the surface of the dielectric body to be bombarded by electrons, the improvement comprising the steps of placing the dielectric body within a gas filled chamber having two spaced electrodes, one of said electrodes being of a material consisting essentially of sub-oxides of titanium connecting a D.C. voltage across said electrodes to create a plasma in said chamber, said one electrode being operated at a negative potential in said plasma so that positive ions in the plasma bombard said one electrode knocking off particles of the electrode which deposit on the surface of said dielectric body, and forming a coating of said low secondary electron emissive material on said surface of said dielectric body having a resistance greater than $10^8$ ohms per square and a thickness sufficient to reduce the secondary electron emission of said dielectric body to a value less than unity.

**7.** In the manufacture of an electron tube having a dielectric body and in which operation of the tube causes the surface of the dielectric body to be bombarded by electrons, the improvement comprising the steps of placing the dielectric body within a chamber having two spaced electrodes and containing a mercury atmosphere which is at a pressure of $10^{-3}$ torr at a temperature of 25° C., one of said electrodes being of titanium monoxide material which has a coefficient of secondary electron emission less than unity, connecting a D.C. voltage having a value in the range of between 1200 and 1500 volts across said electrodes to create a mercury plasma in said chamber, applying an R.F. potential across said chamber to concentrate the mercury plasma in the region between said dielectric body and said one electrode, said one electrode being operated at a negative potential in said mercury plasma so that the positive mercury ions in the plasma bombard said one electrode knocking off particles of the electrode which deposit on the surface of said dielectric body, and forming a coating of said titanium monoxide material on said surface of said dielectric body having a resistance greater than $10^8$ ohms per square and a thickness on the order of about 1000 angstrom units.


**References Cited by the Examiner**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,233,917 | 3/1941 | De Borer et al. | 313—107 |
| 2,513,241 | 6/1950 | Holst et al. | 313—107 |
| 2,883,305 | 4/1959 | Auwarter | 204—192 X |
| 3,021,271 | 2/1962 | Wehner | 204—192 |
| 3,050,651 | 8/1962 | Beggs | 313—107 |
| 3,057,795 | 10/1962 | Frohlich | 204—156 |
| 3,259,558 | 7/1966 | Hagiwara et al. | 117—212 |

OTHER REFERENCES

Boot et al., J. of Electronics and Control, vol. 4, pp. 434, 435 and 449-452.

Preist et al., I.R.E. Transactions On Electron Devices, July 1961, pp. 243-251.

Wehner, Advances in Electronics and Electron Physics, (Edited by Morton), vol. VII, pp. 249-254, 267 and 268, 1955.


HOWARD S. WILLIAMS, *Primary Examiner.*

JOHN H. MACK, *Examiner.*

R. K. MIHALEK, *Assistant Examiner.*

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,309,302 March 14, 1967

Oskar Heil

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 24, for "frenquency" read -- frequency --; column 2, line 15, for "chanmber" read -- chamber --; column 3, line 16, for "dieelectric" read -- dielectric --; column 3, line 38, for "steps" read -- step --.

Signed and sealed this 26th day of December 1967.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents