

[54] **ELECTRON DISCHARGE DEVICE HAVING
ELECTRON MULTIPACTOR SUPPRESSION
COATING ON WINDOW BODY**

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abandoned.

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[58] Field of Search **333/98 P, 99 MP; 313/107**

[56] **References Cited**

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in High-Power Microwave Tubes," Microwave, Jr.,
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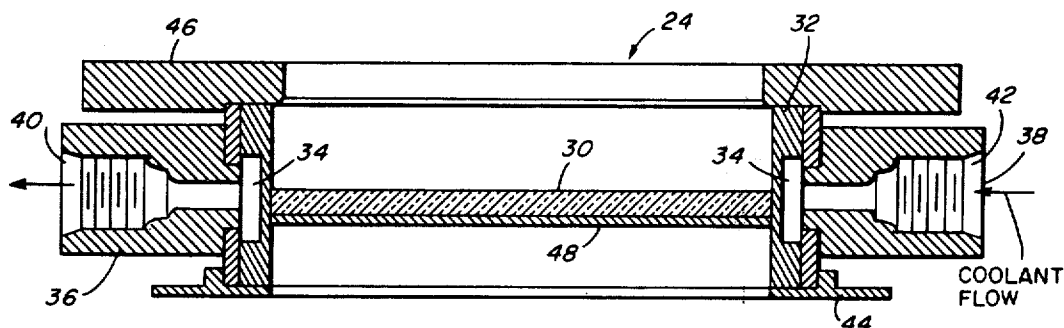
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ABSTRACT

A dielectric body which is permeable to electromagnetic wave energy of a material selected from the group consisting of alumina and beryllia ceramics is provided with a coating of a semiconducting oxide to substantially suppress electron multipactoring. The exemplary materials include semiconducting oxides of silicon and transition metals including copper, cobalt, chromium, iron, manganese and nickel. Thicknesses averaging 1,000 Angstrom units have resulted in substantial increases in the power handling ability of electromagnetic devices employing such dielectric bodies.

2 Claims, 3 Drawing Figures



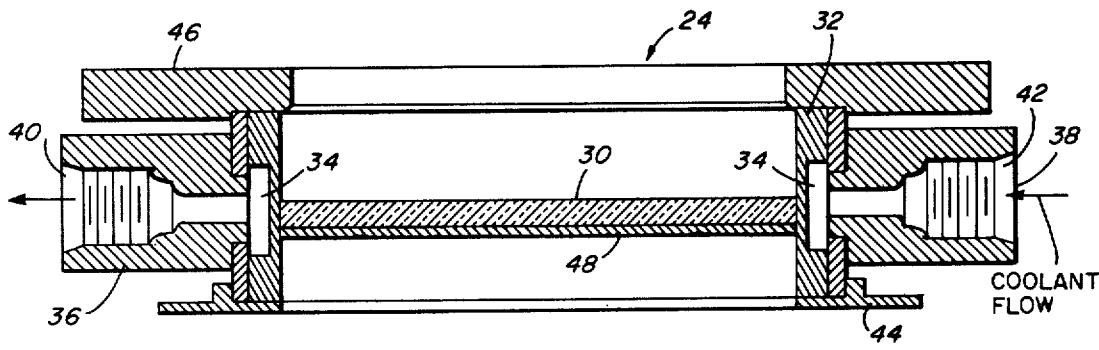


FIG. 1

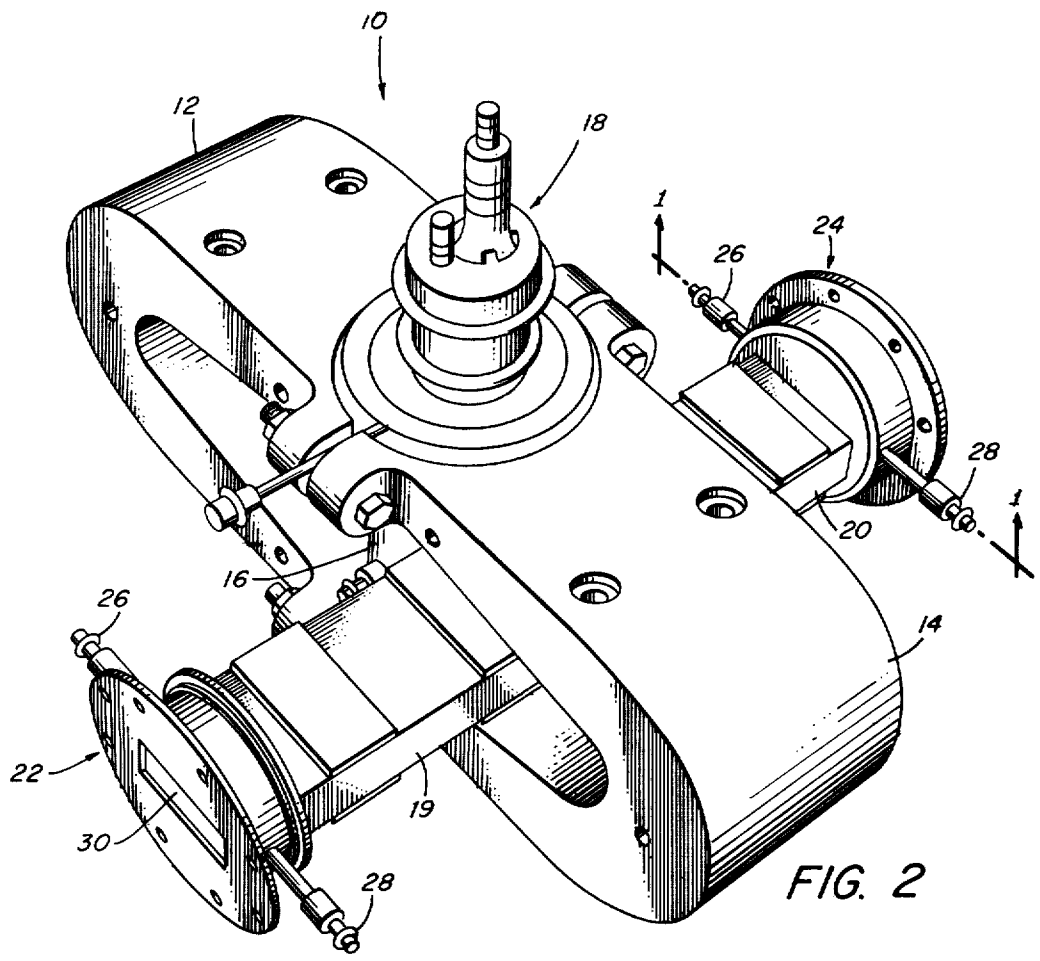


FIG. 2

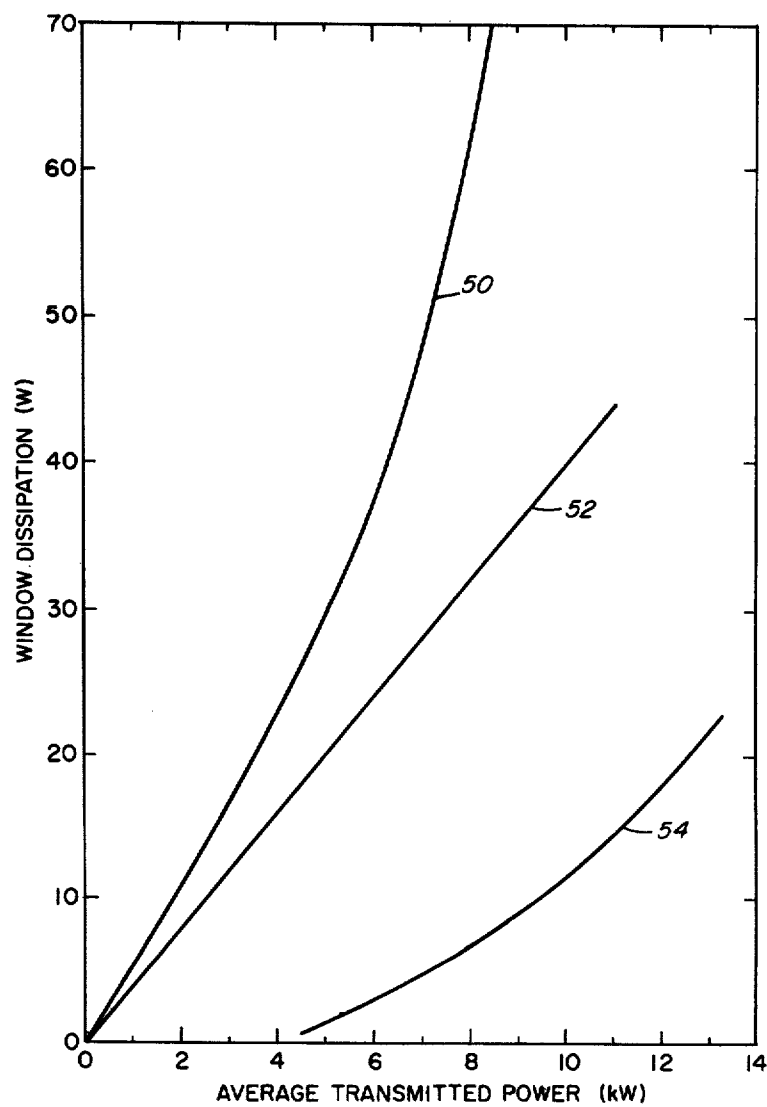


FIG. 3

ELECTRON DISCHARGE DEVICE HAVING ELECTRON MULTIPACTOR SUPPRESSION COATING ON WINDOW BODY

This is a division of application Ser. No. 266,020 filed June 26, 1972, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to means for suppressing electron multipactor on the surface of dielectric bodies.

2. Description of the Prior Art

Bodies of dielectric materials selected from the group including alumina and beryllia have been utilized as windows in the microwave art for the transmission of electromagnetic energy and to provide vacuum seals in high power electron discharge devices due to the ability to withstand thermal shock up to predetermined levels. Magnetrons, klystrons, crossed field amplifiers, as well as oscillators, are exemplary electron discharge devices employing such dielectric bodies. At high output power levels the dielectric windows dissipate substantial thermal energy with forced fluid cooling without puncture or fracture which destroys the vacuum condition. A limitation, however, has been imposed on the state-of-the-art with regard to such dielectric ceramic materials in that they typically have secondary electron emission coefficient values of 3 or higher and when bombardment by free electrons within the vacuum envelope, become subjected to destructive heating due to electron multipactoring and the build-up of electric fields on the surfaces. Electron multipactor phenomena and the resultant window failures during high power operation have been described in an article entitled "Some High-Power Window Failures" by J. R. M. Vaughan, IRE Transactions on Electron Devices, July 1961, pps. 302-308. Window failures due to cracking as well as punctures is stated to be a result of electrical arcs and thermal shock.

Attempts to solve the foregoing problem include the deposition of such materials as titanium, carbon, metal carbides and nitrides to provide a surface on the dielectric body having a secondary electron emission coefficient value of substantially unity. Such metallic type conduction materials deposited on the surface of the dielectric bodies typically decrease the resistivity to values less than 10^8 ohms per square unit area. Examples of such prior art efforts may be found in U.S. Pat. No. 3,252,034, issued May 17, 1966, to D. H. Preist et al and U.S. Pat. No. 3,330,707, issued July 11, 1967, to L. Reed. Typically, such layers must be discontinuous and are approximately 100 Angstrom units or less in thickness in order to avoid ohmic losses. The requirement for the extremely thin film due to the low electrical resistivity is at conflict with the need for a sufficient thickness to absorb the primary electrons and substantially suppress the escape of secondary electrons generated at the dielectric body surface. The method utilized in the deposition of the foregoing enumerated materials for such relatively thin films is difficult to control. With ever increasing power levels of applicable electron discharge devices operating in the electromagnetic wave energy spectrum, electron multipactoring is a continuing problem limiting advance of the art.

SUMMARY OF THE INVENTION

In accordance with the present invention, a dielectric body permeable to electromagnetic energy selected from a group including alumina and beryllia is coated with an oxide of a semiconducting material to effectively suppress secondary electron emission. The selected semiconducting oxides are principally of silicon or any of the transition metals including manganese, chromium, cobalt, copper, iron and nickel, which demonstrate stable characteristics after high bake-out temperature conditions of, for example, 600°C or higher utilized in the evacuating of applicable devices. The term "semiconducting" is interpreted for the purposes of the present invention to refer to a solid material whose electrical conductivity is between that of a conductor and that of an insulator. Further, the term "microwave" defines that portion of the electromagnetic energy spectrum having wavelengths in the order of 1 meter to 1 millimeter and frequencies in excess of 300 MHz. The coating of semiconducting oxide material may be deposited on the dielectric body material by one of the following techniques:

- a. evaporation of the metal in low pressure oxygen;
- b. evaporation of the metal in high vacuum followed by controlled oxidation of the film;
- c. reactive sputtering of the metal in an atmosphere containing oxygen;
- d. sputtering of the metal followed by controlled oxidation of the metal film;
- e. RF sputtering from a target composed of the desired oxide.

Coating thicknesses averaging 1,000 Angstrom units of the selected materials have been found to substantially suppress electron multipactoring and permit operation at much higher power levels, typically over one megawatt peak and above 10 kilowatts average. The secondary electron emission coefficient characteristics of the materials is typically lower than the titanium sub-oxide coatings utilized in the prior art. The utilization of the substantially thicker coatings also results in a visible evidence capability not permissible with coatings having thicknesses averaging only 100 Angstroms or less to simplify process control as well as quality assurance measurements. In exemplary embodiments of the invention to be hereinafter described a two-fold increase in power handling ability by substantial reduction of thermal energy generated in the dielectric body material by electron bombardment was observed for the semiconducting oxide coated windows as compared to the prior art coated windows. This has resulted in an increase of power handling capabilities of the applicable devices by at least a factor of two.

BRIEF DESCRIPTION OF THE DRAWINGS

Details of the invention will be readily understood after consideration of the following description of an illustrative embodiment and reference to the accompanying drawings, wherein:

FIG. 1 is a cross-sectional view of a microwave window assembly for high power microwave devices with the view taken along the line 1-1 in FIG. 2;

FIG. 2 is an isometric view of a high power crossed field amplifier embodying the invention; and

FIG. 3 is a graph of the results of thermal dissipation of dielectric bodies uncoated, coated in accordance

with the prior art and coated in accordance with the invention with relation to average power transmitted.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2 of the drawings, an exemplary device for the amplification of electromagnetic energy is shown. The crossed field amplifier 10 has typical operating characteristics for pulsed type operation of 3 megawatts peak power when driven by an RF signal of 550 kilowatts. Such devices are conventionally utilized in a frequency band of from 2,900 to 3,100 MHz. The average power output for such devices for operation at this band as well as L-band is typically 10 kilowatts or higher. The device shown is of the integral magnet type with the magnetic fields provided by substantially U-shaped magnet members 12 and 14. A vacuum sealed metallic envelope 16 houses the internal components including the slow wave anode structure and cold cathode. A metal-to-ceramic cathode assembly 18 provides for the application of anode-cathode electrical voltages, typically in the range of from 40 to 50 kilovolts. The electromagnetic energy is coupled to the anode structure by input and output rectangular access waveguide sections 19 and 20 which are sealed at the outer ends by energy permeable window assemblies 22 and 24. The high powers handled by such devices require forced fluid cooling coupled through conduit means 26 and 28 in each of the window assemblies.

A representative high power handling window assembly is shown in detail in FIG. 1. Such assemblies conventionally employ dielectric window members which are permeable to electromagnetic energy of a high thermal shock resistance material such as any of the materials in the group including alumina and beryllia ceramics. Such window members are typically of a circular configuration and dielectric window member 30 of the desired composition is shown sealed within a circular metallic waveguide section 32 by any of the known metallizing and brazing techniques. A hollow passageway 34 provides for circulation of a cooling fluid introduced through tubular adapters 36 and 38 internally threaded as at 40 and 42 to receive the threaded ends of the conduits 26 and 28. The circular waveguide 32 is provided at one end with a circular flange 44 for brazing the assembly to the rectangular waveguide sections or in many devices the window assembly is affixed directly to the metallic tube envelope to enclose an access opening. The opposing end of the circular waveguide body is provided with a thicker circular waveguide mounting flange 46 of the type conventionally used in electromagnetic transmission systems for coupling the energy to or from the device. In accordance with the teachings of the invention, a relatively thick film coating 48 having a thickness averaging about 1,000 Angstroms is deposited on at least one surface of the dielectric window body 30 of an oxide of a semiconducting material. Transition metals selected from the group including chromium, cobalt, copper, iron, manganese and nickel, (atomic numbers 24-29), as well as oxides of other semiconductor materials, such as silicon, have demonstrated successful performance in exemplary embodiments of the invention.

The semiconducting oxide coatings of manganese and chromium (MnO and Cr_2O_3) have shown in the results plotted in FIG. 3 a two-fold increase in the amount of thermal energy dissipation measured by conven-

tional calorimetric techniques. An uncoated dielectric body shown by curve 50 will dissipate only approximately 80 watts at 10 kilowatts which would be well off the graph shown. A prior art titanium oxide dielectric body is represented by curve 52 and thermal energy dissipation of 40 watts was measured at the 10 kw average power level. Dielectric bodies coated in accordance with a semiconducting oxide are represented by curve 54. Such coated dielectric bodies have demonstrated a thermal energy dissipation capability of approximately 22 watts at the average power level of 10 kw. This almost two-fold increase in the thermal energy dissipated permits substantially a two-fold increase in the energy handling capability of an applicable device. The thicker coatings of the semiconducting oxide materials have measured resistivities typically in the range of about 10^6 ohms per square unit area which has no adverse effects on the electromagnetic energy propagation characteristics or arcing. The thicker coating is believed to substantially prevent the penetration and bombardment by primary electrons in the presence of intense RF fields leading to high secondary electron emission with the accompanying rise in thermal energy.

A varied number of methods are possible in the practice of the invention for the provision of the multipactor suppressing coating on the surface of the dielectric body member. A number of these methods have previously been enumerated and only one exemplary embodiment will, therefore, be described. In the case of chromium semiconducting oxide and manganese oxide coating RF sputtering from target members provided the control necessary for the deposition of the coating thicknesses in accordance with the invention. The window assembly including waveguide 32 and window 30, after cleaning by conventional techniques, is then mounted in an RF sputtering system which is evacuated to a pressure of less than 2×10^{-6} torr. High purity argon is introduced into the system and the pressure adjusted to approximately 5-6 millitorr. Because of the size and shape of the dielectric bodies (3-5 inches) a screen at anode potential is disposed between the target source and dielectric body to provide a uniform RF field and insure uniform sputtering. An RF power level of 300 watts is employed for the chromium while a power level of 110 watts is employed for the manganese oxide. The sputtering times for the 1,000 Angstrom coatings is determined on the basis of interferometer measurement of the coating thickness in premanufacturing experiments.

With the RF sputtering process the material released from the target at cathode potential upon bombardment by the argon gas ions is deposited on the dielectric body (anode) forming the window member of the assembly. Due to the fact that the target material is electrically nonconductive, only RF fields can be utilized. In the case of a manganese oxide coating a secondary electron emission coefficient value of approximately 1.46 was measured which is lower than the prior art titanium suboxide coatings having higher values ranging between 1.54 and 1.88. The thicker coatings are less critical to produce in order to avoid conduction losses. The thicker coatings also reduce the overall cost of fabrication and have an ancillary benefit in that any errors resulting from confusion between coated and uncoated windows is substantially reduced by the visual evidence of the thicker coatings.

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In addition to the foregoing high power electron discharge devices, the multipactor suppressing coating may be applied to other dielectric bodies where high RF and DC electric fields are present. An example of such an additional application would be in the field of high voltage stand-off structures where the effective surface electric field strength leading to damaging arcs as well as multipactoring is reduced by the deposition of a semiconducting oxide coating on the surfaces where such fields are likely to occur. Other applications, variations and modifications will be evident to those skilled in the art. It is intended, therefore, that the foregoing description of the invention and illustrative embodiments be considered broadly and not in a limiting sense.

I claim:

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1. An electron discharge device comprising:
an evacuated envelope having an access opening for propagating electromagnetic energy;
a body of a dielectric material sealing said access opening;
a coating of a semiconducting oxide material of a transition metal having a thickness averaging about 1,000 Angstrom units on the surface of said dielectric body exposed to the vacuum to suppress electron multipactoring.
2. The device according to claim 1 wherein said dielectric material is selected from the group including alumina and beryllia and said coating material is selected from the group including silicon, chromium, cobalt, copper, iron, manganese and nickel.

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