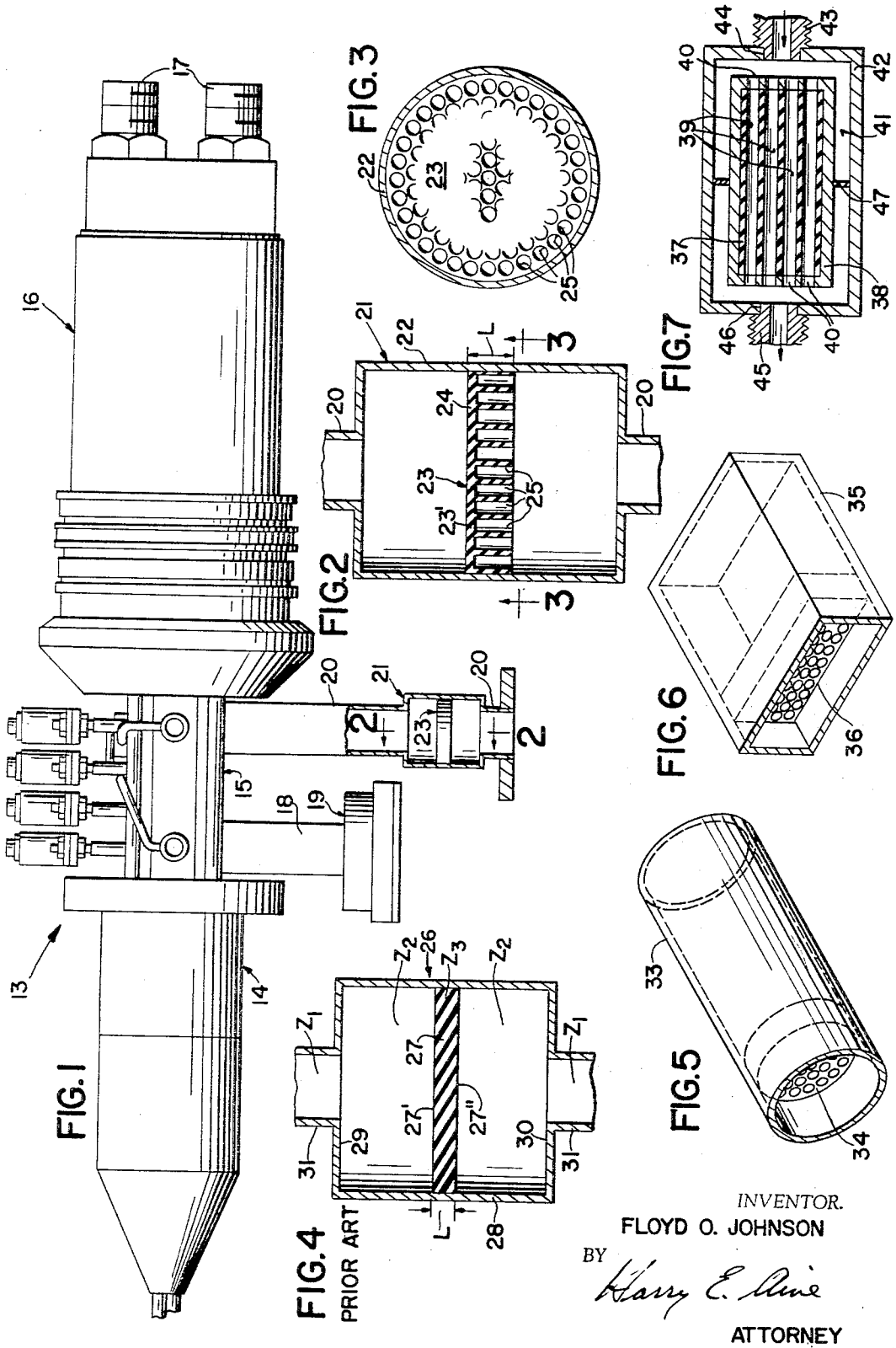
Aug. 29, 1967 F. O. JOHNSON 3,339,102

HIGH FREQUENCY ELECTRON DISCHARGE DEVICES AND WAVE PERMEABLE WINDOWS

Filed Feb. 27, 1964 2 Sheets-Sheet 1



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HIGH FREQUENCY ELECTRON DISCHARGE DEVICES AND WAVE PERMEABLE WINDOWS

Filed Feb. 27, 1964 2 Sheets-Sheet 2

FIG. 9

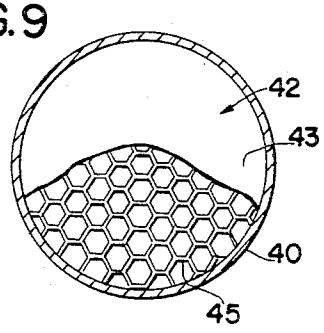


FIG. 10

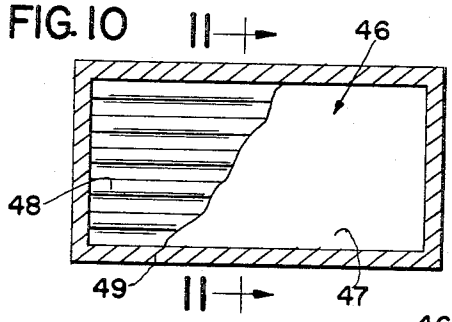


FIG. 8

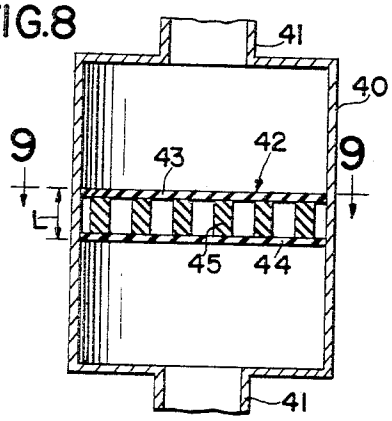


FIG. 13

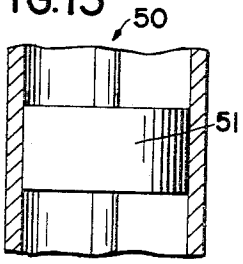


FIG. 11

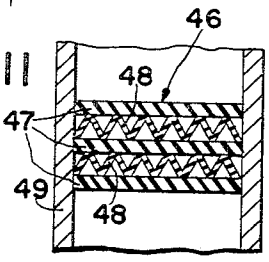


FIG. 14

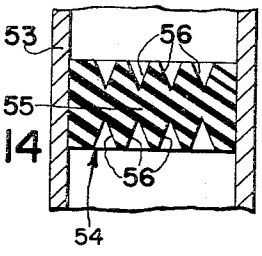
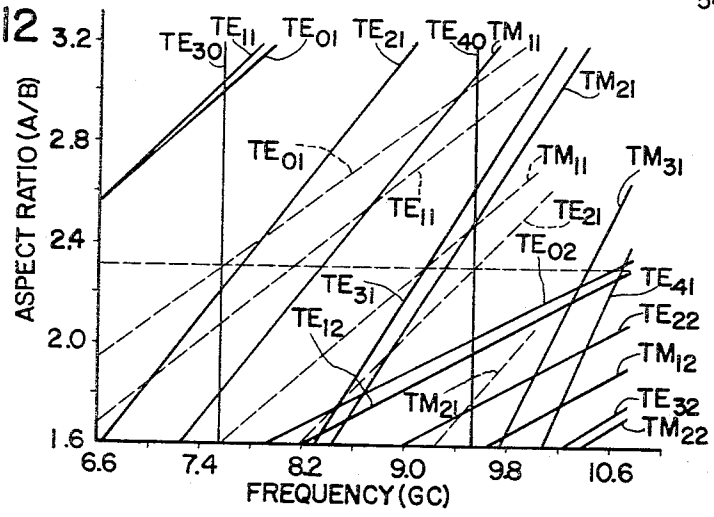


FIG. 12



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United States Patent Office 3,339,102
Patented Aug. 29, 1967

3,339,102

HIGH FREQUENCY ELECTRON DISCHARGE DEVICES AND WAVE PERMEABLE WINDOWS

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Filed Feb. 27, 1964, Ser. No. 347,911
4 Claims. (Cl. 315—3)

ABSTRACT OF THE DISCLOSURE

Improvements in both high power electromagnetic wave permeable self-resonant window structures with respect to improved freedom from ghost modes inducing undesirable thermal expansions and contractions and improved electrical breakdown characteristics are achieved by constructing the self-resonant window as a honeycomb (a window having a plurality of voids, bores, substantially blanketing a cross-sectional portion of the window taken along a plane through the window transverse to the longitudinal or thickness dimension of the window) window of either a singlar or composite type.

This invention relates in general to high frequency electron discharge devices and more particularly to improved high frequency electron discharge devices and improved wave permeable window assemblies.

High frequency electron discharge devices such as klystrons, traveling wave tubes, magnetrons, linear accelerators and so forth, are constantly being improved in relation to their power output capabilities. At the present time, extensive research and development is underway in an attempt to generate average microwave powers in the regions of hundreds of kilowatts and above and peak mircowave powers in the regions of one megawatt and above. Such investigations have shown that a severe limitation on such high power devices is the vacuum-sealed wave permeable window assembly of said devices. Window failures have constantly been observed due to a variety of causes such as the following: mechanical breakage due to such factors as differential thermal expansions occurring within the wave-permeable window itself under high power operating conditions; electrical breakdown within the window itself or in the surrounding waveguide regions which are adjacent thereto which is essentially caused by excessively high local electric fields; breakdown and erosion due to electron bombardments by high velocity electrons impacting on the window surfaces due to the localized electromagnetic fields in the region of the window; thermal expansions and contractions due to localized spurious resonances such as ghost modes occurring within the vicinity of the window itself and building up to extremely high power levels only within the vicinity of the window. Other adverse conditions occurring in microwave windows are electromagnetic reflections due to abrupt impedance discontinuities and multipactor effects.

Typical examples of relatively high and high power wave-permeable vacuum-tight windows for electron discharge devices are to be found in U.S. Patent 2,958,834, by R. S. Symons et al.; U.S. Patent 2,698,421, by J. Kline et al.; U.S. Patent 2,929,035, by L. M. Winslow et al.; U.S. Patent 2,786,185, by T. D. Sege et al.; U.S. Patent 3,058,074, by J. F. Kane; U.S. Patent 2,930,008, by A. S. Walsh; U. S. Patent 2,990,526, by E. J. Shelton, Jr.; U.S. Patent 2,869,086, by T. P. Curtin et al. The aforementioned U.S. patents are cited as illustrative of typical microwave wave-permeable windows for electron discharge devices. In each case, the aforementioned wave-permeable windows depicted in the above cited patents are susceptible when operated at high power to breakdown for the reasons set forth herein above. The aforementioned waveguide windows set forth in the U.S. patents are thought to represent a wide spectrum of windows suitable for variable applications, bandwidths, power outputs and so forth. My copending application, U.S. Ser. No. 316,865, filed Oct. 17, 1963, entitled, "Waveguide Window and Devices using Same," and assigned to the same assignee as the present invention is illustrative of other typical high power waveguide window configurations. It is thought that in each of the above illustrative examples that the waveguide windows set forth therein may advantageously benefit from the teachings of the present invention as will be set forth in detail hereinafter.

The present invention, through the utilization of a novel honeycomb, of either a singular or composite nature, wave-permeable window technique provides an overall improvement in high power window strength while simultaneously rendering said wave-permeable windows less susceptible to breakdown and consequent destruction due to spurious resonant modes otherwise termed ghost modes therein and due to other casual factors such as set forth herein. A honeycombed structure is herein defined as one having a plurality of voids, bores, etc., substantially blanketing a cross-sectional portion of said structure taken along a plane through said structure transverse to the longitudinal or thickness dimension of said structure. The present invention furthermore provides means for cooling the aforementioned novel electromagnetic wave-permeable windows. The present invention, through the utilization of a singular or composite wave-permeable window assembly (of honeycomb nature), further provides improved breakdown characteristics due to electron bombardment in certain specific configurations or embodiments as well as improved properties with regard to electric field breakdown. The utilization of a honeycomb singular or composite window according to the teaching of the present invention reduces the dielectric constant of the window and at the same time permits an increase in the thickness of the window which results in increased strength while simultaneously shifting resonant ghost modes up in frequency to thereby reduce the probability of window breakdown due to excitation of said resonant ghost modes in the passband of the particular window design under consideration. The present invention further provides means for providing built-in impedance transformation within the window itself as well as means for reducing multipactor effects.

It is therefore an object of the present invention to provide high frequency electron discharge devices with means for improving the power transmission capabilities therefore while simultaneously providing more spurious mode free transmission characteristics.

A feature of the present invention is the provision of a high frequency electron discharge device with an improved wave-permeable vacuum-sealed window assembly.

Another feature of the present invention is the provision of a high frequency electron discharge device having improved wave-permeable vacuum-sealed window assembly.

Another feature of the present invention is the provision of a high-frequency electron discharge device having improved wave-permeable vacuum-sealed transmission means therefore, wherein said improved wave-permeable vacuum-sealed transmission means comprise a honey-comb wave-permeable window of a singular or composite nature.

Another feature of the present invention is the provision of a rectangular waveguide having secured therein in a vacuum-sealed relationship, a rectangular electromagnetic wave-permeable honeycomb window, said window of a composite or singular structure.

Other features and advantages of the present invention will become more apparent upon perusal of the following

specification taken in conjunction with the accompanying drawings wherein:

FIG. 1 depicts a plan view partially in cross-section showing an improved electron discharge device utilizing the features of the present invention;

FIG. 2 is an enlarged cross-sectional view of a preferred embodiment of the present invention taken along the lines 2—2 of FIG. 1 in the direction of the arrows;

FIG. 3 is a cross-sectional view of the coupler depicted in FIG. 2 taken along the lines 3—3 in the direction of the arrows;

FIG. 4 is a cross-sectional view of a typical prior art waveguide window assembly such as shown in U.S. Patent 2,958,834;

FIG. 5 is a fragmentary isometric view of a circular waveguide having a circular wave-permeable vacuum-sealed window disposed therein wherein said wave-permeable vacuum-sealed window is made of a honeycomb structure;

FIG. 6 is a fragmentary isometric view of a rectangular waveguide having a wave-permeable honeycomb window disposed in vacuum-sealed relationship therein;

FIG. 7 is a cross-sectional view of another wave-permeable vacuum-sealed window disposed within a waveguide section, said wave-permeable vacuum-sealed window being made from a honeycomb structure and having cooling provisions therefore;

FIG. 8 is a fragmentary cross-sectional view of a circular waveguide section such as depicted in FIG. 4, having a wave-permeable vacuum-sealed window disposed therein wherein said wave-permeable vacuum-sealed window is formed from a composite honeycomb structure;

FIG. 9 is a fragmentary cross-sectional view partially in elevation of the wave-permeable window depicted in FIG. 8 take along the lines 9—9 in the direction of the arrows;

FIG. 10 is a cross-sectional view partly in elevation of a rectangular waveguide having a composite honeycomb laminated wave-permeable vacuum-sealed window structure disposed therein;

FIG. 11 is a fragmentary cross-sectional view taken along lines 11—11 in the direction of the arrows of the embodiment depicted in FIG. 10, rotated 90° counterclockwise;

FIG. 12 is a graphical portrayal of aspect ratio versus frequency depicting the resonant ghost modes found in two typical solid or non-honeycomb wave-permeable windows cut for resonance at 8 gc. (8000 megacycles);

FIG. 13 is a fragmentary cross-sectional view of a coaxial waveguide having a honeycomb wave-permeable window vacuum-sealed therein;

FIG. 14 is a fragmentary cross-sectional view of another embodiment of the present invention.

Referring now to the drawings and in particular to FIG. 1, there is shown an electron discharge device employing novel features of the present invention. A multicavity klystron amplifier tube **13** of the type shown and described in more detail in U.S. patent application Ser. No. 148,520, filed Oct. 30, 1961, now U.S. Patent No. 3,281,616, issued Oct. 25, 1966, and assigned to the same assignee as the present invention, comprises three main portions: A beam producing section **14** on one end which serves to form and project a beam of electrons over a predetermined path directed axially and longitudinally of the tube **13**; a central beam interaction section **15** where interaction takes place between the projected electron beam and an applied electromagnetic wave to produce amplification of the wave; and collector structure **16** at the terminating end of the tube **13** where the electrons of the spent beam are collected. A suitable coolant fluid such as water is applied to the collector structure **16** via fluid fittings **17** and circulates through ducts (not shown) in the collector structure **16**.

The tube **13** is evacuated to a suitable low-pressure, for example, 10^{-9} torr. Input energy to be amplified is coupled to the upstream end of the beam interaction section **15** via the intermediary of a rectangular waveguide **18** and through a vacuum-sealed waveguide structure **19** which supports a window sealed therein (not shown) transparent to electromagnetic waves. Amplified output wave energy is extracted in conventional manner at the downstream end of the beam interaction section **15** via the intermediary of a rectangular waveguide **20** and through an output waveguide window assembly **21** to be described in more detail below.

Referring now to FIGS. 2 and 3, there is shown an enlarged view of the output waveguide assembly **21**. A section of circular waveguide **22** carries transversely therein a gas-tight wave-permeable window **23** as of, for example, an alumina type ceramic or any other suitable dielectric material which is both transparent to electromagnetic waves and capable of being sealed in vacuum-sealed communication to the inner wall of the circular guide section **22** such as, for example, Al_2O_3, BeO, fused quartz, single crystal sapphire, boron nitrate, etc. Sealing of the wave-permeable window **23** to the inner wall of circular waveguide **22** may be made by any of the well-known sealing techniques, such as, for example, by brazing.

In a preferred embodiment, the abrupt transition between rectangular waveguides **20** and circular waveguide **22** are made electrically on the order of $n/2$ wavelengths apart at the center frequency of the passband, where n can be any positive integer. A structure which is electrically one wavelength long is defined as one which causes a phase shift of 2π radians in a wave propagating therethrough.

The wave-permeable window **23** disclosed in circular waveguide **22** is preferably maintained at a minimal thickness in order to prevent electrical breakdown at the window faces due to trapped modes therein.

Referring now to FIG. 4, a typical prior art waveguide window coupler design as more thoroughly discussed in U.S. Patent 2,958,834 is shown. The window assembly **26** depicted in FIG. 4 contains a solid wave-permeable window **27** disposed in a circular waveguide section **28** in the same fashion as shown in FIGS. 2 and 3. Reference to the aforementioned U.S. Patent 2,958,834 indicates and further analytical studies have shown that it is desirable to minimize the thickness of the window **27** in the direction of propagation or to express it another way, maximize the distance between the window faces **27'**, **27''** of the wave-permeable window **27** and the capacitive discontinuities **29** and **30** formed by the junction between the circular waveguide **28** and rectangular waveguide **31** in order to minimize the chances of window failure due to high electric field gradients or trapped modes therein. It is known that the passband properties of a window such as depicted in FIG. 4 as well as in FIGS. 2 and 3 is dependent upon the physical thickness of the window to a certain degree as well as the dielectric constant of the material used in making the window.

The present invention provides an improvement over the prior art configuration depicted in FIG. 4 through the utilization of a singular or composite honeycomb type window. Examination of FIGS. 2 and 3 shows a plurality of bores **25** extending partially through the thickness dimension of window **23** and blanketing the entire cross-sectional area of the window. The bores **25** can be made such as by drilling, molding, or any other suitable technique for preparing ceramics and dielectrics of the aforementioned types. It is to be noted that the distance or axial extent of the bores as taken in the direction of wave propagation is much greater than the thickness of the face slab portion **23'** which is necessary to preserve vacuum integrity. It is also to be noted from a comparison of FIGS. 2 and 4 that the thickness L of the composite or honeycomb structure in FIG. 2 is much greater than the thickness L of the solid wave-permeable window depicted in the prior art as shown in FIG. 3. Similarly, the

distance between the face of the slab 23' and the capacitive discontinuity formed at the junction of the circular and rectangular guides is greater in the embodiment depicted in FIG. 2 than a comparable distance between the faces 27', 27'' of the window 27 and the capacitive discontinuities in the embodiment of FIG. 4. Thus, it is evident that the chances for electrical breakdown between the capacitive discontinuities in the embodiment of FIG. 2 is much less than in the embodiment of FIG. 4, due to the increased physical separation therebetween. Furthermore, the field gradients existing in the embodiment of FIG. 2 should be considerably reduced along the length L of the window in comparison to that of FIG. 4 along the length L of the window. Additionally, the window depicted in FIG. 2 being greater in thickness L is obviously of superior strength to the window depicted in FIG. 4. Furthermore, the relationship between the number of bores, the diameter of the bores, spacing between bores and the longitudinal extent of the bores within the window assembly of FIG. 2 can be so varied and interrelated that the dielectric constant is less in the configuration of FIG. 2 than a window of equivalent strength or even less strength which is solid in nature such as that depicted in FIG. 4. Therefore, it is evident that a stronger window can be made which has a dielectric constant equivalent to or less than its solid body counterpart such as shown in FIG. 4 through the use of the teachings of the present invention.

Theoretical studies have been made of what is termed ghost modes which are defined as resonant electromagnetic field configurations existing in the vicinity of certain waveguide obstacles such as dielectric windows by various people. These modes have been shown to be both of the propagating and the non-propagating or trapped type. Reference is made to the following articles: "Ghost Modes in Imperfect Waveguides," by E. T. Jaynes, Proceeding of the I.R.E., February 1958, vol. 46, pages 415–418. "Resonant Modes in Waveguide Windows," by M. P. Forrer and E. T. Jaynes, in I.R.E. Transactions on Microwave Theory and Technique, vol. MTT–8, No. 2, March 1960.

Theoretical and experimental studies have been made on various dielectric materials and plots of the ghost modes therein have been made. Referring to FIG. 12, there is depicted a calculated study showing the presence of multiple ghost modes in two types of rectangular block-type windows cut for self-resonance at 8 gc. The characteristics in FIG. 12 depict aspect ratio (A/B) (width/height) versus frequency. The solid lines are indicative of ghost modes found in a ½ wavelength thick resonant block window made from beryllia having a relative dielectric constant of approximately 6.8 and an aspect ratio of approximately 2.3. The dotted lines are indicative of the ghost modes found in a quartz block window cut for self-resonance at 8 gc. having a relative dielectric constant of approximately 3.75 and an aspect ratio of 2.3. The physical thickness of the beryllia window was .2925 inch and the physical thickness of the quartz window was .4050 inch. Examination of the ghost modes found in the calculated characteristics depicted in FIG. 12 shows that a considerable spreading and shifting of the ghost modes is found when a lower dielectric constant material is employed, even though the physical thickness of the window is greater for the lower dielectric constant material than for the higher dielectric constant material. Thus, it is rather self-evident on examination of FIG. 12 that a window of equal strength but lower dielectric constant than another window will have characteristics which are considerably more free of ghost mode resonances than the window of higher dielectric constant. The present invention provides a novel solution to such a problem wherein ghost mode resonances are deleterious to effective microwave transmission. Examination in FIG. 12 of the TE_{01} mode for the beryllia and for the quartz windows shows that indeed a definite shift does take place in resonant ghost modes regardless of window thickness. Thus, for an alumina, beryllia or any other dielectric constant material, if the dielectric constant can be reduced while simultaneously increasing the physical thickness of the window then with that particular dielectric constant material the ghost modes will be shifted up in frequency and spread apart, and a window can easily be constructed to be comparatively mode-free for the passband of interest. Thus, the designer through the utilization of the present invention is given extreme flexibility in picking mode-free bandwidths and designing windows therefore which prior art techniques did not make available. In addition, a window of increased strength which has improved thermal and electrical breakdown properties, thus capable of handling high multi-megawatt powers such as on the order of hundreds of kilowatts average power output or better, can easily be constructed utilizing the techniques of the present invention. Quite obviously the techniques of the present invention with regard to reducing dielectric constant while simultaneously strengthening a vacuum-sealed wave-permeable window are applicable to the low energy coupling devices suitable for use in low power tubes as well as in high power tubes.

The present invention is obviously very broad in nature and applicable to any electromagnetic vacuum-sealed wave transmission system such as, for example, those depicted in FIGS. 5 and 6. In FIG. 5 a circular waveguide 33 having a circular wave-permeable vacuum-sealed window 34 therein is shown. The wave-permeable window 34 has a singular type of honeycomb structure. FIG. 6 depicts a rectangular waveguide 35 having a honeycomb type wave-permeable window disposed in vacuum-sealed relationship therein according to the teachings of the present invention. Obviously, the techniques of the present invention with regard to reduction in dielectric constant while simultaneously increasing strength through the use of the honeycomb singular or composite window are applicable to coaxial as well as waveguide configurations.

In FIG. 7, there is depicted another embodiment of a honeycomb type of waveguide window structure. A rectangular half-wave length block 37 of dielectric material as, for example, alumina ceramic is mounted within a rectangular waveguide 38. A series of holes 39 are drilled through block 37 to form fluid ducts. Waveguide 38 also contains apertures 40 which are in alignment with holes 39. The space 41 between housing 42 and waveguide 38 is adapted to receive a moderately lossy dielectric coolant which flows through nozzle 43 in opening 44 through ducts 39 and blocks 37, and out through nozzle 45 and opening 46. The fluid is prevented from flowing just through the space 41 by means of a pair of diametrically opposed septums or fins 47. For a more thorough explanation of the cooling techniques see U.S. patent application Ser. No. 316,865, by Floyd A. Johnson, and assigned to the same assignee as the present invention, filed Oct. 17, 1963, and copending herewith. This copending application describes cooling techniques which can be used in the present invention. The holes or bores 39 depicted in the embodiment of FIG. 7 substantially entirely blanket the cross-sectional areas of the block window in much the same fashion as depicted in FIGS. 2 and 3, as well as FIGS. 5 and 6. The external fluid circulating means such as for example, that depicted in my copending U.S. patent application Ser. No. 316,865 may be utilized to circulate fluid in the embodiments depicted in the present invention.

Directing your attention to FIGS. 8 and 9, there is depicted an alternative embodiment of the present invention wherein is shown a circular waveguide section 40 fed by a pair of rectangular waveguides 41 in much the same fashion as depicted in prior art FIG. 4 and the embodiments of FIGS. 2 and 3. Disposed within and vacuum-sealed in the circular waveguide portion 40 is a wave-permeable composite honeycomb type of waveguide win-

dow 42. The wave-permeable window 42 is formed from a composite structure comprising a pair of discs 43 and 44 which have a honeycomb structure 45 sandwiched therebetween. The honeycomb structure 45 is characterized by being made from a plurality of hexagonal bores extending completely through the central honeycomb section 45. Any suitable techniques such as molding or drilling may be utilized to form the honeycomb section. The composite assembly including the face plates of discs 43 and 44 is preferably sintered together utilizing known techniques to form a, practically speaking, integral structure having a dielectric constant which is lower than a window made of solid material which is equivalent in thickness. With regard to FIGS. 8 and 9, all the advantages set forth previously with regard to lowering of the dielectric constant and simultaneously strengthening the window while physically increasing the size thereof in order to shift the ghost mode resonances, increase the strength and lessen the chances of thermal stresses rupturing the window as well as reducing the field gradients therein are applicable to the windows shown in FIGS. 8 and 9.

In FIGS. 10 and 11, an alternative embodiment of the present invention employing a laminated composite honeycomb window assembly is depicted. In the embodiments of FIGS. 10 and 11, a honeycomb composite laminated wave-permeable vacuum-sealed window 46 is depicted in vacuum-sealed relationship within a rectangular waveguide 49 as shown. The laminated composite honeycomb wave-permeable window is made from a plurality of flat ceramic slabs, discs or plates 47 preferably thin in nature on the order of less than ⅛ of an electrical wavelength and which have sandwiched therebetween sinuous or corrugated central portions 48 forming a honeycomb section between the flat plates 47. Techniques described in U.S. Patent 3,112,184, by R. Z. Hollenbach, may advantageously be utilized to form the composite honeycomb window laminated structure depicted in FIGS. 10 and 11. The advantages set forth previously with regard to lowering of dielectric constant while simultaneously increasing window strength with all the resultant benefits are equally applicable to the embodiment set forth in FIGS. 10 and 11.

FIG. 13 depicts a coaxial line 50 having a honeycomb coaxial window 51 disposed therein in vacuum sealed relationship. All of the previously mentioned advantages with regard to the utilization of honeycomb windows with respect to rectangular and circular waveguides are equally applicable to the coaxial embodiment depicted in FIG. 13. The window 51 can be of any of the previously recited types, composite or singular in nature and all of the aforementioned types are equally advantageously incorporated in the coaxial embodiments.

The embodiment depicted in FIG. 14 depicts a honeycomb window assembly 52 wherein a rectangular waveguide 53 has a honeycomb dielectric window 54 disposed therein in vacuum-sealed relationship. The window 54 has a central solid slab portion 55 as shown and a plurality of bores 56 extending inwardly from both faces as shown. The bores may be of the type described previously with regard to the embodiments depicted in FIGS. 2 and 9, and could even advantageously be formed from the laminated structure depicted in FIG. 11 with the end slabs 47 removed. The bores 56 are shown as being tapered from the faces of the window inwardly to the central slab portion 55. This taper concept provides a built-in impedance transformation within the window itself to therefore substantially reduce reflections of wave energy from the transition planes of the window faces and the air or vacuum sides of the window. Quite obviously any known impedance transformation techniques may be advantageously employed to provide a smooth transition. The embodiments depicted in FIGS. 2, 5 and 6 are obviously amendable to the utilization of the built-in impedance transformation shown in the embodiment of FIG. 14. Furthermore, the embodiments depicted in FIGS. 2, 5, 6 and 14 also enhance the suppression of multipactor effects by capturing and/or dispersion of electrons on the apertured window surfaces.

With regard to the percentage of voids for a given volume of window, the present invention teaches a preferred void/vol. ratio of $50\% \pm 15\%$ in all of the embodiments, although void/vol. ratios of $\geq 10\%$ can be advantageously employed without departing from the scope of the present invention. With regard to the block window embodiments depicted in FIGS. 5, 6 and 7, an electrical thickness of $\frac{1}{2}\lambda$ and integral multiples thereof, where λ is defined as a 2π radians phase shift of the propagating energy at the center of the passband of the window, is preferred although obviously the present invention includes windows of any dimensions where the honeycomb concept can advantageously be utilized. If air of reduced or atmospheric pressure is trapped within the bores, voids, etc., of the honeycomb sections and becomes a problem, pin holes may be drilled or otherwise made interconnecting the voids to a suitable exhaust system for evacuation.

Since, quite obviously, the present invention is broad in nature and the particular sizes, shapes, orientations, etc., of the voids or bores in the various embodiments can take innumerable forms, a recitation of same would be inappropriate. However, the present invention does teach a preferential blanketing of the cross-section area of the window in a given honeycomb volume with voids, bores, etc., in a more or less symmetrical manner. Although obviously differential sized voids, bores, etc., may be utilized as well as random distribution thereof in a given honeycomb volume.

Since many changes can be made in the above construction and many apparently widely different embodiments could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A high frequency electromagnetic wave-permeable window assembly comprising: wave transmission means made of conductive material having an electromagnetic wave-permeable dielectric self-resonant window vacuum-sealed therein, said wave permeable vacuum-sealed window having a honeycomb structure, said wave transmission means and said honeycomb window defining a passband with the center frequency determined at the self-resonant frequency of the window, said window having a thickness dimension disposed parallel to the direction of wave energy propagation through said wave transmission means, said honeycomb structure including a plurality of bores extending partially through the thickness dimension of the wave-permeable window.

2. A high frequency electromagnetic wave-permeable window assembly comprising: wave transmission means made of conductive material having an electromagnetic wave-permeable dielectric self-resonant window vacuum-sealed therein, said wave-permeable vacuum-sealed window having a honeycomb structure, said wave transmission means and said honeycomb window defining a passband with the center frequency determined at the self-resonant frequency of the window, said window having a thickness dimension disposed parallel to the direction of wave energy propagation through said wave transmission means, said wave permeable honeycomb window having a plurality of bores extending in the direction of wave propagation through the window, said plurality of bores extending partially through the thickness dimension of said window taken along the direction of wave propagation therethrough, said honeycomb window being singular in nature.

3. A high frequency electron discharge device having a predetermined operating band in the microwave spectrum including: a vacuum envelope, means for forming and projecting a beam of electrons over an elongated pre-

determined beam path in said envelope, means for collecting the beam at the terminal end of said beam path; electromagnetic interaction means disposed within said envelope arranged along said beam path between said beam forming and said beam collecting means for electromagnetic interaction with said beam; wave transmission means coupled to said device, said wave transmission means including a dielectric electromagnetic wave-permeable window vacuum-sealed therein, said dielectric wave-permeable window having a honeycomb structure, said honeycomb dielectric window being self-resonant at a frequency within the operating band of said device and having a thickness dimension disposed parallel to the direction of wave energy propagation through said wave transmission means, said honeycomb structure including a plurality of bores extending partially through the thickness dimension of the wave-permeable window.

4. A high frequency electron discharge device having a predetermined operating band in the microwave spectrum including: a vacuum envelope, means for forming and projecting a beam of electrons over an elongated predetermined beam path in said envelope, means for collecting the beam at the terminal end of said beam path; electromagnetic interaction means disposed within said envelope arranged along said beam path between said beam forming and said beam collecting means for electromagnetic interaction with said beam; wave transmission means coupled to said device, said wave transmission means including a dielectric electromagnetic wave-

permeable window vacuum-sealed therein, said dielectric wave-permeable window having a honeycomb structure, said honeycomb dielectric window being self-resonant at a frequency within the operating band of said device and having a thickness dimension disposed parallel to the direction of wave energy propagation through said wave transmission means, said wave-permeable honeycomb window having a plurality of bores therein extending in the direction of wave propagation through the window, said plurality of bores extending partially through the thickness dimension of said honeycomb window taken along the direction of wave propagation through the window, said honeycomb window being single in nature.

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