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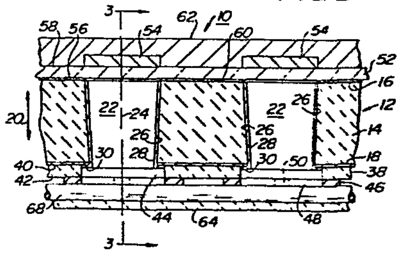
(54) **Display system and method of operating same.**

(57) A display system and operating method in which ultraviolet radiation is produced and made to impinge on fluorescent phosphors (54) and visible through translucent protective layer (62). The ultraviolet radiation is generated by application of a potential between the cathode cells and annular anodes (46) spaced therefrom by a dielectric film (38) having apertures (44) therein aligned with the cathode cells. The assembly is hermetically sealed by a reflective backing panel (64) which defines a chamber (66) communicating with the cathode cells (22) and containing an inert gas. Display is initiated by application of a first potential across the anodes and cathodes. Ions produced in the gaseous medium impinge on the metallic coating (28) and sputter metal atoms therefrom which ionize under a second applied potential thereby to produce the ultraviolet radiation for conversion into visible radiation by the fluorescent phosphors (54).

FIG 2



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DISPLAY SYSTEM AND METHOD OF OPERATING SAME

This invention relates to monochromatic and polychromatic display systems and a method of operating same. In particular, this invention relates to the construction and operation of display systems which provide matrix displays resulting from the conversion of long wave ultraviolet photons into visible light energy through the fluorescent excitation of fluorescent material compositions, such as synthetic Phosphors.

Gas discharge display systems are known in the art and although the present display systems cannot truly be classified as gas discharge displays, such gas discharge systems are believed to be the closest prior art. In prior art gas discharge systems, a plurality of plasma displays may be attained either as alpha-numeric displays having generally linearly or arcuately segmented cathodes, or dot matrix displays. Such prior art systems are generally based on the ionization of a noble gas or gas mixtures. In such prior art systems, the ionization occurs between two flat and parallel electrodes with generally the anode electrode being transparent to light generated in the neighbourhood of the cathode electrode.

Numerous disadvantages are apparent when such prior art gas discharge display systems are utilized. In such prior art gas discharge systems, the visible glow from the cathode surface is visibly stable only if the whole of the surface area of the cathode is uniformly covered by the glow and the cathode surface has uniform properties. In the event that either of these two conditions is not present, the visible light will provide a flickering effect which is deleterious to the eye of an observer.

Another major disadvantage of such prior art gas discharge systems is that the operating life is dependent on the sputtering rate from the cathode electrode. This is due to the fact that the sputtering of the material from the cathode electrode generally deposits itself on the anode, thus obviously reducing the anode's transparency. The sputtering also reduces the gas pressure by physical adsorption of the filling gas. In order to provide an acceptable operating light in such prior art systems, they are generally operated at lower than maximum current density thereby resulting in less than optimum light output.

Some prior art work has investigated the generation of polychromatic systems based on the conversion of ultraviolet photons into visible light with Phosphor compositions. One such prior work is reported by V. Van Gelder, Proc. IEEE, Vol. 61, No. 7, July 1973, and is directed to the utilization of ultraviolet photons emitted by recombinations in a positive column. In such prior work, the positive column is obtained through the well-known Principle of Similarity. In that system, the gaseous discharge occurs in a tubular structure for the ion/electron recombination on the walls of the tubular structure. Additionally, such prior work based on the Principle of Similarity dictates a particular relationship between the length, diameter and pressure of the tubular structure which is extremely difficult to produce. In normal tubes, the length/diameter ratio approximates 30.0 and such prior work dictates that such ratio should be preserved. Where the length in the tube in such prior work is two orders of magnitude smaller than an available fluorescent tube, in order to maintain the prescribed ratio, the diameter correspondingly must be two orders of magnitude less and the pressure two orders of magnitude larger than that found in an available fluorescent tubular structure. Such conditions would be extremely difficult to produce with the known technology, and at the present time are not capable of being manufactured. Another disadvantage of such theoretical prior art is the directionality of the system. In such prior art, the eye of the observer must be aligned with the axis of the tube in order to observe an optimized light intensity. A still further disadvantage is that as the resolution is increased, resulting in the tube diameter decreasing, it is extremely difficult to coat the inner wall of the tube uniformly with the Phosphor composition.

Other attempts to generate polychromatic displays based on the conversion of ultraviolet photons into visible light relies on the negative glow of the cathode. Such prior art work in this field has been published by M. Fukushiwa, Digest SID, P.120, 1975. However, just as in the case of the positive column type prior work, the Phosphor composition in this prior art using the negative glow is also immersed in the gas plasma and this results in similar disadvantages to those previously described for the positive column approach. Additionally, there is a lower efficiency in generating ultraviolet light in the plasma with flat parallel cathode-anode electrodes since the spectrum of the light released by the gas ionization does not consist solely of ultraviolet light, but includes spectral lines in the visible spectrum which prevent colour saturation due to colour mixing with the Phosphorspectrum.

Other prior art gas discharge type displays using hollow cathodes are represented in U.S. Patents Nos. 3,882,342 and 4,021,695. As in the case of other types of work, such references use the back filling gas to produce ultraviolet radiation in the positive column. This type of approach suffers the same disadvantages as hereinbefore described.

In contrast, the present invention does not require the gaseous medium to produce a measurable amount of ultraviolet energy but relies on the sputtering of atoms of metal from the cathode and the ionization thereof under an applied electric field ionizes to produce an intense ultraviolet glow. The ultraviolet glow thus produced is of a much greater intensity than that of the ultraviolet glow produced solely from a gaseous medium. Such a display system allows for a wide dynamic range of light intensity with an optimization of the reproducibility of physical characteristics. More importantly, the display system of the invention provides a visual display substantially devoid of any flicker within the visible bandwidth of the electromagnetic spectrum.

Broadly speaking the display system of the present invention comprises

a) a cathode assembly comprising a plate having a plurality of apertures therethrough lined with a metallic lining and forming a plurality of cathode cells;

b) a dielectric film applied to one surface of said plate and having a plurality of apertures therein aligned with the apertures in the cathode plate;

c) an anode assembly disposed on the side of said dielectric film remote from the cathode plate and comprising a plurality of anode elements with apertures therein aligned with the apertures and in the cathode plate and dielectric film;

d) a display panel transparent to ultraviolet radiation overlying the face of the cathode plate opposite the dielectric film and supporting on its surface opposite the cathode plate a plurality of patches of fluorescent material aligned with the apertures in the cathode plate so as to be impinged by ultraviolet radiation emitted from said apertures upon energization of the device; and

e) a backing panel spaced from said dielectric film in the direction away from the cathode plate and defining with the dielectric film a chamber in communication with the cathode apertures, said chamber containing a gaseous medium ionizable by an electrical field applied to the cathode and anode assemblies, thereby providing gaseous ions which impinge on the metallic lining of the cathode cells to cause ionization of metal atoms therein and the consequential generation of said ultraviolet radiation;

said cathode and anode assemblies, said dielectric film and said display and backing panels together forming a hermetically sealed display unit.

Also in accordance with this invention there is provided a method of obtaining a visual display which comprises generating radiation in the ultraviolet bandwidth by ionization of a gaseous medium in the region of a cathode by application of a potential to adjacent cathode and anode assemblies and impinging that radiation on a layer of fluorescent material thereby to convert that radiation into radiation in the visible region of the spectrum, wherein the ultraviolet radiation is generated within the confines of a hollow cathode cell, the side walls of which are lined with a metallic coating, by application of a first potential between said cathode cell and an anode spaced therefrom a predetermined distance and having said gaseous medium contained therebetween, said first potential being effective to obtain ionization of said gaseous medium, and applying a second potential between said cathode cell and anode, whereby gaseous ions are caused to bombard the metallic lining of said cathode cell and to extract therefrom metal atoms which undergo ionization in the gaseous medium with consequential emission of the said ultraviolet radiation from said ionized metal atoms for impingement on said layer of fluorescent material.

In its overall concept, display system of the present invention converts energy within the ultraviolet bandwidth of the electromagnetic spectrum into energy within the visible bandwidth of the electromagnetic spectrum through excitation of fluorescent materials, the ultraviolet radiation being generated by a gaseous plasma which originates in the negative glow captured in a cylindrically shaped cathode. More particularly, the energy produced comes from ionized atoms of metal which is sputtered from the cathode surface and generally consists of the ionized metals largest spectral lines which are generally found in the ultraviolet bandwidth of the electromagnetic radiation spectrum.

In the concept of this invention a noble gas is ionized by application of a voltage potential between an anode and a generally cylindrical cathode. Application of the potential ionizes the gas producing electrons and gaseous ions. The electrons are displaced toward the anode and the ions are displaced toward the cathode for impingement thereon. The cathode is formed of a metallic coating layer which when impinged by the ion, displaces an electron and subsequently an atom of the metal which is ionized. The atom of metal may be termed to be in a gaseous state and emits ultraviolet energy along its strongest spectral line.

The negative glow on the cathode thus provides the origination of the gaseous plasma which is confined within the cylindrical envelope of the cathode structure. The gaseous plasma includes the atoms of metal which are ionized and the particulates of metal sputtered from the cathode surface provides for the ultraviolet spectral radiation lines. When impinged by ionized or metastable atoms of a noble gas such as argon, neon, krypton, or some like gas, a nickel coated cathode would provide an intense radiation at approximately 2300 A^{o} (0.23 μm). The element mercury would emit at a level of approximately 2500A^{o} (0.25 μm) however, such would have approximately twice the intensity of the nickel spectral line. A copper coated cathode would emit energy approximately four times as intense as the nickel coated cathode; but at a spectral line of approximately 3200 A^{o} (0.32 μm). Additionally, other metals such as aluminum would emit at approximately 3900 A^{o} (0.39μm) and lead at 2200 A^{o} (0.22 μm) however, having different intensity levels.

Referring to the basic theory of operation of the display system of this invention in a preferred form this comprises a hollow cavity cathode having a metallic coating layer formed on the side walls thereof. An annular extension of the metallic coating lies in a plane substantially parallel to an anode element displaced from the cathode. Upon application of a potential between the anode and the cathode, there is applied a predetermined voltage corresponding to the breakdown which is described in Paschen's Law, which essentially states that the breakdown potential between two terminals in a gas is proportional to the pressure times the gap length. Thus, the gap length is inversely proportional to the pressure of the gas. The current that flows is limited by the resistance provided in the circuit and if the current is limited to a low value, the glow that occurs is provided on the annular extension of the cathode mechanism.

In this phase, the gas is being ionized and generates electrons, metastables, and ions. Metastables as well as photons are neutral particles and the field has substantially no effect on them and their path direction is generally random. Thus, in flat parallel electrode systems, only a small number of metastables and photons are able to intercept the cathode and contribute to secondary emissions of electrons.

In contrast, in the present invention, the ions attracted to the cathode and the electrons produced in the gaseous medium are attracted to the anode. Ions intercept the surface of the cathode metallic coating, and if the ions have a sufficient energy they extract an electron from the cathode surface which initially must neutralize the ion. In the event that more than one electron is released during this operation phase, the extra electron is accelerated by the field in a displacement path toward the anode.

As the electron is displaced, it collides with gas atoms and additional ions are produced which progressively increases the current. The positive ions satisfying this process, therefore, have an energy at least twice the work function of the metal coating of the cathode. Photons of energy equal to or greater than the work function of the metal coating also extract electrons from the metal by photoelectric effect.

The work function for most clean surface metals is between 4.0 and 5.0 electron volts. This energy corresponds to ultraviolet radiation in the approximate bandwidth of 2500 to 3100 Angstroms (0.25 to 0.31 μm). However, noble gases have low intensity of ultraviolet radiation compared to their radiation intensity in the visible portion of the electromagnetic spectrum. Such photons contribute minutely in producing secondary electrons from the radiative emission of the gases.

Subsequent to this phase of the operation, the series resistance placed between one of the electrodes, either the anode or the cathode and the supply energy is decreased. This secondary phase of the operation may be attained through well-known scanning mechanisms or in general, by modulation well-known in the art. When the resistance is decreased, the current that flows is greater than the current attained in the initial phase of the operation between the annular cathode section and the anode.

The glow now penetrates internal to the cavity of the cathode mechanism and the efficiency of producing secondary electrons is increased due to the fact that the fraction of metastable atoms and photons reaching the cathodic surface is in the neighbourhood of unity as compared to a fraction much less than 0.5 for flat parallel electrodes. Additionally, each electron will effect more collisions both ionizing and exciting prior to reaching the anode. Thus, the efficiency of the gas discharge is further increased and more electrons are produced. In this manner, there is provided more current as well as light energy.

It must be remembered that when system is initially fired, there is a low current flowing between the annular section of the cathode and the anode elements. Thus, there is a small potential drop across the load resistance which is subtracted from the total voltage that is supplied from the source of energy. This represents the voltage that appears between the anode and cathode elements and corresponds to the striking voltage which is dependent on the pressure and the anode to cathode gap distance.

In the second phase of the operation, when a greater current flows through the system, then the voltage drop across the series resistance increases since there is a current that may be orders of magnitude greater than previously achieved in the first phase. Obviously, the drop of potential corresponds to the increase of the current. The voltage that now appears between the anode and the cathode would be smaller than the normal sustaining voltage that would be used between a parallel anode and cathode of the prior art. The glow between the annulus and the anode thus goes off, since it cannot be sustained, however, such is sustained within the cathode cavity. It is to be remembered that when a low current produces a glow between the annulus of the cathode and the anode, it is only the spectrum of the gas that is produced, there is little sputtering since the current is too low for that condition to occur. As soon as the glow penetrates the cathode and the density of sputtering increases, atoms of metal are ionized which emit the ultraviolet radiation. It is thus the spectrum of the metal that is radiated and not the spectrum of the gas, as is generally provided in prior art systems.

The invention will now be further described with reference to the accompanying drawings, in which:-

Fig. 1 is an exploded perspective view of a cut-away section of the display system;

Fig. 2 is a cross-sectional view of a cut-away portion of the display system taken along the section lines 2-2 of Fig. 1;

Fig. 3 is a cross-sectional view of the display system cut-away portion taken along the section lines 3-3 of Fig. 2;

Fig. 4 is a plane view of the display system showing the vertical layers of the system; and

Fig. 5 is a structural schematic plane view of the display system showing alignment of fluorescent material with the anode and cathode elements of the display system.

Referring now to Figs. 1-4, there is shown the overall structure of a display system 10 in accordance with this invention which may be a monochromatic or a polychromatic system. In Fig. 1 the parts are shown in exploded relationship for clarity and ease of understanding although it will be understood that in actuality the display system 10 is formed into a hermetically sealed housing structure as is shown in Figs. 2 and 3 in order to maintain the internal gases at a predetermined pressure, the concept of which is well known in the art. Thus, display system 10 is generally formed into a monolithic type structure which greatly aids in optimizing display system 10, due to the high path accuracies of the energy, as well as the close tolerances needed in the overall construction as will be discussed in following paragraphs. Display system 10 includes a cathode assembly 12 which is used for producing energy in the ultraviolet bandwidth of the electro magnetic spectrum from ionization of metallic atoms. Cathode assembly 12 comprises a cathode plate 14 having opposing first and second surfaces 16 and 18 shown in Figs. 2-4. The first and second surfaces 16 and 18 generally are planar in contour and form a plane substantially normal to a vertical direction defined by arrow 20 shown in Figs 2 and 3. Cathode plate 14 is formed of a generally electrically insulating material such as glass, ceramic, or some like material not important to the inventive concept as is herein described. The thickness of cathode plate 14 may be .060 - .170 inches (1.52 to 4.32 mm) with a typical thickness of .080 inches (2.03 mm). Various dimensional characteristics of display system 10 will be elucidated in following paragraphs to generally show scaling and relative dimensions between elements of the display system 10 due to the fact that Figures 1-4 are greatly enlarged.

Each cathode plate 14 includes a plurality of cathode openings 22 formed therethrough extending in vertical direction 20, as is clearly seen in Figs. 1-3. Each of cathode openings 22 includes cathode opening axis lines 24, each of which extend in vertical direction 20. In general, cathode openings 22 define a substantially circular contour in a plane normal to axis line 24 of each of cathode plate member openings 22.

As is clearly seen in Figs. 2 and 3, cathode openings 22 generally provide a cross-sectional area at the first surface 16 of the cathode plate which is larger than the cross-sectional area at the second surface 18. In this manner, cathode openings 22 are seen to be frustoconical in contour. Each of cathode openings 22 is defined by side walls 26 which are inclined. The inclination in upward vertical direction 20 provides an angle with respect to axis lines 24 within the approximate range of 1.0^{o} - 5.0^{o} with a preferred angle of inclination approximating 3.0^{o}. Although cathode openings 22 may be formed in a non-inclined cylindrical contour it has been found that inclination of cathode opening sidewalls 26, as herein described, optimizes the directional displacement of the ultraviolet energy formed from the ionization of metallic atoms in an upward vertical direction 20 to impinge on fluorescent material to be described in following paragraphs.

The side walls 26 of each cathode opening 22 includes a metallic coating 28 formed thereon. Metallic coating 28 may be formed of aluminum, nickel, or some like metallic coating which would allow ionization of metallic atoms displaced from the surface during the operation of system 10. Metallic coating 28 forms a metallic film on side walls 26 having a thickness of about .001 -.005 inches (0.025 to 0.127 mm) with a preferred thickness of about .002 inches (0.05 mm).

Cathode assembly 12 includes a further metallic coating 30 formed in an annular contour, as is seen in Figs. 1-3 around the cathode opening and bonded to cathode plate member 14 on the second surface 18. Metallic coating annular portions 30 may be and generally are in the preferred embodiment, formed of the same composition as metallic coating 28. Annular portions 30 are generally planar in contour and extend to a predetermined external diameter. Annular portions 30 and side wall metallic coatings 28 may be formed in one-piece formation, or bonded each to the other separately, such not being important to the inventive concept as herein described with the exception that metallic coatings 28 and metallic coating annular portions 30 be electrically conductive and electrically coupled to each other. Thus, metallic coating annular portions 30 include an internal diameter substantially equal to the diameter of the cathode opening 22 adjacent the second surface 18 of the cathode plate 14. Metallic coating annular portion 30 has a predetermined external diameter larger than plate member opening 22, with the external diameter to be discussed in following paragraphs in relation to other elements of system 10.

Metallic coatings 28 and metallic coating annular portion 30 may be defined as the cathode elements of the overall cathode assembly 12. Additionally, the plurality of openings 22 are seen to be formed in a matrix pattern within cathode plate 14 defining rows and columns of openings 22 which are common in the display system art. For purposes of ease of description, column direction 32 is shown in Fig. 4. Additionally, row direction 34 passes normal to column direction 32 and is also provided in Fig. 4.

In order to couple the cathode elements in column direction 32, metallic coatings 28 and 30 of each cathode opening 22 are electrically coupled to the adjacent coatings 28 and 30 in a particular column. To couple consecutive cathode elements, recess 36 shown in Fig. 3 and 4, is formed within second surface 18 of cathode plate 14 and extends in column direction 32. Recess 36 extends between successive plate member openings 22 formed in a predetermined column. Recesses 36 are filled with a continuous metallic film which is electrically conductive and may be formed of aluminum, or some like electrically conductive composition. In this manner, metallic coatings 28 and 30 of particular openings 22 in a predetermined column are electrically coupled each to the other.

Referring to the dimensions of cavities or openings 22 shown in Figs. 1-4, such may typically range from 0.10 - 0.005 inches (2.54 to 0.127 mm) in diameter, with a separation distance of about 0.004 inches (0.1mm) between peripheral side walls 26. Typically, an opening 22 having a 0.010 inch (0.25 mm) diameter would be separated from a next consecutive or adjacent opening 22 by approximately 0.014 inches (0.356 mm) to provide a resolution of 70.0 display areas or dots per inch (2.75 dots per mm).

Display system 10 further includes dielectric film member 38 having first and second opposing surfaces 40 and 42 formed in a planar contour. As can be seen in Figs. 2 and 3, dielectric film member first surface 40 is bonded or otherwise securely fastened to second surface 18 of cathode plate 14. Further, dielectric film member 38 includes a plurality of openings 44 formed therethrough with each opening 44 having an axis line substantially aligned with axis lines 24 of each opening 22 in the cathode plate. Dielectric film member openings 44 are substantially aligned with metallic coating annular portions 30 and include a diameter substantially equal to the external diameter of annular portions 30. In this manner, openings 44 are insertable around each of annular portions 30, as is clearly evident in Figs. 2 and 3. In general, dielectric film member first surface 40 is fused to cathode plate member second surface 18 or otherwise bonded in fixed securement thereto. Dielectric film member 38 is used as an electrical insulator and may be formed of a glass film or some like composition.

Display system 10 further includes a plurality of anode elements 46 bonded to second surface 42 of dielectric film member 38. As can clearly be seen in Fig. 1, anode elements 46 are generally annular in contour and are coupled each to the other in row direction 34. Anode elements 46 include openings 48 defining a vertically directed axis line coincident with the axis lines 24 of the cathode openings. Additionally, anode elements 46 have an internal diameter substantially equal to the external diameter of metallic coating annular portions 30 of cathode elements 12. Thus, the diameter of anode openings 48 are substantially equal to the diameter of the dielectric film member openings 44 as is clearly seen in Fig. 2. In this manner, a shoulder section is formed between metallic coating annular portion 30 and the internal surfaces of dielectric film member openings 44 and anode openings 48.

Anode elements 46 further include anode coupling elements 50 for electrically coupling a plurality of anode elements 46 in row direction 34 to each other. The purpose of anode coupling elements 50 is to electrically couple consecutively positioned rows of anode elements 46 each with respect to the other, as is shown.

Anode elements 46 and corresponding anode coupling elements 50 are formed of an electrically conducting material such as aluminum, or some like metal which may be applied to dielectric film member second surface 42. In one form, anodes 46 and coupling elements 50 may be silk-screened to second surface 42 of dielectric film member 38. However, the basic mechanism of securing anode elements 46 and coupling elements 50 to dielectric film member 38 is not important to the inventive concept, with the exception that the method utilized provides for the fixed positional location of the elements, as has hereinbefore been described.

Display panel member 52 is secured to first surface 16 of cathode plate member 14. Display panel member 52, as will be described in following paragraphs, is substantially transparent to a bandwidth of the electromagnetic spectrum substantially comprising the ultraviolet bandwidth. Additionally, display panel member 52 has formed thereon a plurality of fluorescent material patches or coatings 54 for intercepting ultraviolet energy from the ionization of metal atoms from metallic coating 28 within the cathode cavity.

Display panel member 52 includes opposing first and second surfaces 56 and 58, as is shown in Figs. 2 and 3. Display panel member 52 is bonded or secured to cathode plate member 14 through sealing black glass frit film 60, shown in Figs.2 and 3. Film 60 provides a vacuum seal between display panel member 52 and cathode plate member 14 and further provides for substantial optical isolation of each cathode cavity when taken with respect to other cathode cavities formed adjacent thereto. Glass frit film 60 may have a thickness within the range of about 0.0005 - 0.001 inches (0.013 to 0.025 mm). In order to apply frit film 60 to cathode plate member first surface 16, a printing screen may be used having openings corresponding to all but cathode openings 22. In this manner, panel member first surface 56 is bonded to cathode plate member first surface 16 in secured fashion.

Display panel member 52 is formed of an ultraviolet transparent glass having a thickness of about 0.004 inches (0.1 mm). Fluorescent material 54 is secured to panel member second surface 58 in registration above cathode openings 22. Thus, fluorescent material 54 includes a diameter substantially equal to cathode openings 22 and having axis lines coincident with cathode opening axis line 24. Fluorescent material 54 may be one of a number of compositions such as various Phosphor compositions which radiate responsive to ultraviolet energy impinging thereon. A wide range of Phosphor compositions well-known in the art may be used as fluorescent material 54. Fluorescent material Phosphor elements 54 may be protected against abrasion by protective layer element 62. Layer element 62 may be a microsheet of glass, or such may be a metallo organic solution to form a coating of low refractive index and high abrasion resistance. Thus, protective layer element 62, as is seen in Figs. 2 and 3, contacts both fluorescent material elements 54 and display panel member second surface 58.

Display system 10 further includes back panel member 64 displaced from the anode element 46 and the dielectric film member 38. Back panel member 64 is in fixed displacement with respect to element 30 and 46 forming internal chamber 66, as is shown in Fig.3. In order to maintain structural integrity of back panel member 64, frame rod members 68 extend in column direction 32, as is shown in Figs. 2-4.

Frame rod members 68 maintain a fixed spaced relation of back panel member 64 with respect to the structure of cathode plate member 14. Frame rod members 68 may be formed of glass having an approximate diameter of 0.010 inches (0.25 mm). Frame rod members 68 are secured to back panel member 64 by adhesive means such as a frame paste, or some like material.

Back panel member 64 may be formed of a glass composition having a thickness within the range of about 0.060 - .120 inches (1.5 to 3 mm). Back panel member 64 includes internal surface 70 which is coated with a film of aluminum or like metallic coating which is reflective for ultraviolet radiation. The metallic coating over back panel member internal surface 70 is continuous in nature and is used for providing an equipotential electrode as well as providing an ion collection element for ions escaping from cathode mechanism 12.

In order to ensure a hermetic seal of the generally monolithic display system 10, as has herein been described, a frame of sealing glass frit may be screen printed around a common peripheral boundary in order to form a gas tight enclosure. One of frame rod member 68 may be formed in the overall peripheral contour of display system 10 and inserted between back panel member 64 and cathode mechanism 12.

Internal chamber 66 has a gaseous medium inserted therein to essentially fill the volume provided by the internal chamber 66, as well as cathode cavities. The gaseous medium is ionized by an electrical field applied to anode elements 46 and cathode mechanism 12.

Gaseous ions impinging on metallic coating 28 sputter the metal atoms to produce ultraviolet energy, as has hereinbefore been described. The gaseous medium inserted internal to display system 10 is formed of a substantially inert gaseous composition and may be formed from the group consisting of neon, argon, krypton, xenon or combinations thereof.

Back panel member 64 serves as a common or equipotential electrode. Due to the cylindrical contour of cathode mechanism 12, a minimum of sputtering exits from cathode openings 22. As is well-known, prior art plasma display sputtering forms deposits on the anode surfaces. However, with the electrode configuration as provided by metallic coating 28 and annular portion 30 of the subject display system, an electric field is established between common electrode or back panel member 64 and cathode annular portion 30. An electric field is also established between anode 46 and cathode annular portion 30. The field gradient which exists between back panel internal surface 70 and annular portion 30 is sufficient to attract metal atoms passing from cathode metallic coating 30 and such are deposited on internal surface 70 of back panel member 64 rather than on anode elements 46. However, the electrical field between back panel member internal surface 70 and annular portion 30 is not sufficient to initiate any discharge between the displaced but parallel electrodes defined by metallic coating annular portion 30 and internal surface 70 of back panel member 64. Due to the fact that internal surface 70 is reflecting and opaque in composition, surface 70 continues to reflect light which may escape from cathode cavities defined by the cathode openings 22.

Referring to the method of manufacturing discharge display system 10, as has hereinbefore been described, the initial step is in providing cathode mechanism 12 for producing energy in the ultraviolet bandwidth of the electromagnetic spectrum from ionization of metal atoms. A matrix of through or cathode openings 22 are formed in cathode plate member 14 which has opposing first and second surfaces 16 and 18, respectively. Through cathode openings 22 define cathode opening side walls 28 within plate member 14, as is clearly shown in Figs. 2 and 3. As has been described, cathode plate member 14 is formed of an insulating material such as a glass or ceramic composition. A number of fabrication techniques may be used in forming cathode plate member 14 having appropriate cathode openings 22. In one method of fabrication, a moulded plate of ceramic or glass having the appropriate matrix cathode openings 22 corresponding to a predetermined resolution may be formed. In such a moulding type method, cathode plate member 14 may be produced by using a ceramic coating such as No. 528 ceramic from Aremco Products, Inc., or a fritted glass commonly referred to as No. EE 10 from Owens-Illinois Company, have been successfully utilized. Another method of fabrication can easily be seen in providing cathode plate member 14 in continuous form and establishing a plurality of drill heads positionally located in the appropriate matrix alignment necessary to produce a predetermined resolution. In this type of fabrication, the drill heads would be tapered within the approximating range of $1^{\circ} - 5^{\circ}$ with a preferred taper of 3^o. Actuation of the drill heads in unison and contact as well as passage through cathode plate member 14 may be accomplished in one step, and provide the necessary through or cathode openings 22.

Subsequent to either the moulding operation, the drilling operation, photoetching, or some like step to form cathode openings 22, the step of providing cathode mechanism 22 further will include the step of coating through opening side walls 26 with a metallic coating such as aluminum, or some like metal. The step of coating side walls 26 with metallic coating 28 may be provided in a plurality of method steps. One step is by applying a metallic fluid paste on cathode plate member first surface 16 and compressively forcing the metallic paste through the through openings 22. This may be done by application of a squeegee, a roller mechanism, or some like device which would provide displacement characteristics to the metallic paste being used. The metallic paste would then be forcibly actuated or displaced within openings 22.

Another way in which coating of side walls 26 may be accomplished is by positioning a screen member over plate member first surface 16 wherein the screen member has a multiplicity of openings formed therethrough in axial alignment with cathode opening axis lines 24. As in the previous case, a metallic fluid paste is then inserted on an upper surface of the screen member and compressively displaced through the openings formed in the screen member. Whether the metallic paste is placed in direct contact with cathode plate member first surface 16 or applied to an upper surface of a screen member having the appropriate aligned openings, the metallic paste is then forced or displaced through the plate member openings 22.

The step of displacing the metallic paste through the openings 22 includes the step of applying a pressure differential between first and second surfaces 16 and 18 respectively of cathode plate member 14. A lower pressure is established at plate member second surface 18 when taken with respect to plate member first surface 16. In this manner, the metallic fluid paste is drawn through plate member openings 22 to form a metallic coating of predetermined thickness on side walls 26. The step of drawing the metallic paste through openings 22 may be accomplished in a variety of ways, one of which being to apply a low pressure vacuum pump suction surface at plate member second surface 18.

The printing screen previously described is commercially well-known in the art and would include a plurality of matrix openings aligned with cathode openings 22 in plate member 14. The openings within the printing screen would be positionally located in alignment with openings 22 and opaque throughout the remainder of the surface of the printing screen. A number of metallic fluid pastes may be utilized, one of which being a metallic fluid paste formed of an aluminum composition, such as No. 6110 manufactured by Electro-Oxide Corporation, or another paste formed of nickel such as No. 9531 Nycil, produced by Dupont Corporation may be used. Although the metallic paste or ink passing through openings 22 may be produced by gravity assist, as has been stated, a moderate suction may be applied on second surface 18 of plate member 14, which would leave a film of metallic paste approximating 0.002 inches (0.05 mm) in thickness on side walls 26. It is to be understood that the film thickness may be controlled by adjusting the viscosity of the metallic ink in well-known manners.

The basic step of providing cathode mechanism 12 further includes the step of establishing metallic coating annular portions 30 on cathode plate member second surface 18. As may be seen, the formation of metallic coating 28 on side walls 26 may include the formation of annular portions 30, however, a number of fabrication techniques may be utilized in providing annular portion 30. The important concept being that annular portion 30 is coupled to coating 28 on side walls 26. Additionally, annular portions 30 are electrically coupled each to the other in row direction 34 by the inclusion of linearly directed recesses 36 formed within second surface 18 of cathode plate member 14. Recesses 36 may be formed by moulding, milling, or some like technique not important to the inventive concept as herein described. Recesses 36 may then be filled with a metallic ink or paste to provide appropriate coupling between row directed annular portions 30.

The step of establishing annularly contoured metallic extension layers or annular portions 30 may include the step of masking plate member second surface 18 with a screen having screen openings formed therethrough. The screen openings are axially aligned with plate member openings 22 and the screen openings having a predetermined diameter greater than plate member through opening diameters at plate member second surface 18. A metallic coating layer may be applied to the masking screen and compressively interfaced in order to force the metallic coating paste through the openings formed in the masking screen.

Dielectric film member 38 is bonded to second surface 18 of cathode plate member 14. Dielectric film member 38 has a plurality of openings of predetermined diameter substantially equal to the external diameter of annular portions 30. Dielectric film member openings have an axis line which is aligned with axis lines 24 of each of the matrix of two openings 22 of plate member 14. Bonding of dielectric film member 38 may be provided by fusing, adhesive coupling, or some like technique not important to the inventive concept as is herein described. A masking screen having a negative type pattern in relation to openings 22 may be used for forming dielectric film member 38 on second surface 18 in a manner similar to that previously provided for application of metallic paste for metallic coatings 28.

Anode elements 46 are secured to dielectric film member second surface 42. Anode elements 46 include a plurality of annularly contoured configurations having an internal diameter which is substantially equal to the predetermined diameter of the openings formed in dielectric film member 38. Anode elements 46 are electrically coupled each to the other through anode coupling elements 50, as is clearly seen in the Figures. Once again, application of anode elements 46 and their associated coupling elements 50 may be applied through a masking screen type technique, well-known in the art.

The method of manufacturing or fabricating discharge display system 10 further includes the step of establishing display panel member 52 in bonded relation to first surface 16 of cathode plate member 14. Display panel member 52 includes a plurality of fluorescent material coatings 54 secured thereto. Coatings 54 are positionally located in registration with plate member through openings 22. A printing screen having formed thereon a negative pattern of the screen used to fill through openings 22 is used to deposit a film of sealing black glass frit 60 to a thickness in the range 0.0005 - 0.001 inches (0.013 to 0.025 mm). Black glass frit film 60 provides a vacuum tight seal between cathode plate member 14 and display panel member 52.

Display panel member 52 is composed of substantially an ultraviolet transparent glass having a thickness approximating 0.004 inches (0.1 mm). Display panel member 52 is commercially available and may be No.75183A manufactured by Owens-Illinois Corp., or Microsheet No. 9741 manufactured by Corning Glass Work, Inc. The combination of display panel member 52, frit film 60, and cathode plate member 14 is fired with a uniform pressure maintained in a compressive state on panel member 52 in order to provide uniformity of sealing.

Prior to the registration of fluorescent material 54 in alignment with cathode openings 22, a frame of sealing glass frit may be screen printed on dielectric film member second surface 42 around the periphery of display system 10. The sealing glass frit which is printed may have a thickness within the range 0.0015 - 0.002 inches

(0.038 - 0.051 mm) with a width of about 0.1 - 0.2 inches (2.5 to 5 mm). A glass rod member similar to the cylindrical contour of frame rod members 68 is deformed to assume the periphery of the sealing glass frit and is positionally located over the printed peripherally directed frit. The deformed glass rod may be maintained in place by frame paste being applied between surface 42 and the rod itself. A plurality of frame rod members 68 having a diameter within the approximate range of 0.005 - 0.010 inches (0.13 - 0.26 mm) are then positionally located and fixedly secured by the aforementioned frame paste. The entire panel system is then fired in a nitrogen environment with a compressive pressure appied to the frame rod, as well as frame rod members 68 until the glass forms a glaze.

Back panel member 64 formed of a standard glass composition and having a substantially equal cross-sectional area to that of cathode plate member 14 is coated on internal surface 70 with a film of aluminum, or some like metallic coating which is reflective to ultraviolet light. The overall thickness of back panel member 64 may be within the range 0.060 - 0.120 inches (1.5 to 3 mm). A peripheral frame of glass frit substantially identical to the frame glass frit secured to second surface 42 is deposited or otherwise coated on the metallic coating of internal surface 70. Cathode plate member 14 and back panel member 64 are placed in contiguous relation each to the other between a pair of flat carbon susceptors with the aforementioned panels being aligned each with respect to the other. The entire system is then placed in a vacuum environment to achieve a residual pressure approximating 10^{-7} mm Hg where the system is then heated to a temperature approximating 450°C. for a predetermined time to eliminate various residual gases from the glass compositions.

At the time that pressure/temperature equilibrium is achieved, the vacuum environment is isolated from a pumping station and an inert gas or mixture of gas which may comprise approximately 98.0% argon and 2.0% krypton is inserted into internal chamber 66 to establish a pressure approximating 24.0 - 25.0 mm Hg. At the time that equilibrium in temperature is achieved with the particular gas being introduced, the temperature of the susceptors is raised to the softening point of the glass frit which makes up the sealing frame. Referring to the glass frit produced by Owens-Illinois Corp., the temperature is in the neighbourhood of 530°C. When this limiting temperature is achieved by display system 10, the temperature is then lowered at a rate compatible with residual stress constraints.

The panel system now has applied to panel member second surface 58, a photographic emulsion composition layer which may be one or a number of photographic emulsion compositions, one of such being commercially available is referred to as Kodak Photo Resist. Anode elements 46 and predetermined cathode elements of cathode mechanism 12 are energised by voltage pulses in order to sensitize corresponding areas of the photographic emulsion composition above predetermined cathode openings 22. The energization is provided for positionally locating rows of the same colour. In this manner, the photographic emulsion composition is formed into a tacky composition in an area intercepted by ultraviolet energy emitted from cathode openings 22. Of important consequence is that the area being energized is substantially axially in alignment with plate member openings 22 being energized defining the sensitized region.

The photographic emulsion composition is then removed from the unsensitized region of display panel member 52 by washing away the unsensitized photographic emulsion composition. Thus, there remains on surface 58 the predetermined areas which are aligned with openings 22. A fluorescent material composition is then appied to display panel 52 and the fluorescent material composition is adhesively captured by the sensitized photographic emulsion composition. The entire structure is then heated to permanently fix or secure the fluorescent material composition to the sensitized emulsion composition. The method steps are the repeated for each colour in order to finally form a polychromatic display panel 52.

The step of heating is then followed by the step of applying a protective layer over the now fixed fluorescent material composition. The protective layer 62 may be a microsheet of glass or a metallo organic composition such as No. GR650 produced by Owens-Illinois Corp., which forms a coating of low refractive index and high abrasion resistance.

Fig. 5 is presented to provide clarification of the alignment and coupling of cathode mechanism 12 and anode elements 46. It is to be understood, that this figure is not structurally drawn, but is used as a pictorial schematic to show alignment of the various elements when used in a polychromatic display system 10. As can be seen, there appears a pair of anode lines 72 and 74 directed orthogonal to cathode couplings 36 with appropriate fluorescent material compositions 54 applied at the intersection positional location. The various fluorescent material dots 54 are provided to produce the visible colours of red, blue, and green to achieve appropriate polychromatic visual displays.

CLAIMS

1. A display system comprising means for generating radiation in the ultraviolet bandwidth and converting that radiation into radiation in the visible region of the spectrum by impingement on a fluorescent surface, characterised in that it comprises

a) a cathode assembly comprising a plate (12) having a plurality of apertures (22) therethrough lined with a metallic lining (28) and forming a plurality of cathode cells;

b) a dielectric film (38) applied to one surface of said plate and having a plurality of apertures (44) therein aligned with the apertures (22) in the cathode plate (14);

c) an anode assembly disposed on the side of said dielectric film remote from the cathode plate and comprising a plurality of anode elements (46) with apertures (48) therein aligned with the apertures (22) and (44) in the cathode plate and dielectric film;

d) a display panel (52) transparent to ultraviolet radiation overlying the face of the cathode plate (14) opposite the dielectric film and supporting on its surface opposite the cathode plate a plurality of patches (54) of fluorescent material aligned with the apertures in the cathode plate so as to be impinged by ultraviolet radiation emitted from said apertures upon energization of the device; and

e) a backing panel (64) spaced from said dielectric film

(38) in the direction away from the cathode plate (14) and defining with the dielectric film a chamber (66) in communication with the cathode apertures (22), said chamber containing a gaseous medium ionizable by an electrical field appied to the cathode and anode assemblies, thereby providing gaseous ions which impinge on the metallic lining (28) of the cathode cells to cause ionization of metal atoms therein and the consequential generation of said ultraviolet radiation;

said cathode and anode assemblies, said dielectric film and said display and backing panels together forming a hermetically sealed display unit.

2. A display system according to claim 1, characterised in that the apertures (22) in the cathode plate (14) are of circular cross-section.

3. A display system according to claim 2, characterised in that the apertures (22) in the cathode plate (14) are frustoconical in contour and inverted with relation to the display panel (52).

4. A display system according to claim 3, characterised in that the side walls of said apertures (22) in the cathode plate (14) are inclined at an angle of from 1-5^{o} to the axis of the aperture.

5. A display system according to any one of claims 1-4, characterised in that metallic lining (28) of the apertures (22) in the

cathode plate (14) extend into a flange (30) surrounding those apertures on the face of the cathode plate directed towards said dielectric film.

6. A display system according to any one of claims 1-5, characterised in that the face of the backing panel (64) directed toward the dielectric film (36) is coated with a continuous metal layer capable of reflecting radiation in the ultraviolet bandwidth.

7. A display system according to any one of claims 1-6, characterised by spacer elements (68) located in said chamber (66) between the dielectric film (38) and the backing panel (64).

8. A display system according to any one of claims 1-7, characterised by an optically transparent abrasion resistant film or layer (62) covering said fluorescent patches (54).

9. A display system according to any one of the preceding claims, characterised in that the said gaseous medium is argon, neon, krypton, xenon, hydrogen or helium.

10. A display system according to any one of claims 1-9, characterised in that the cathode plate (12), the dielectric film (38), the anode elements (46) and the display panel (52) are bonded one to the other in face-to-face relation.

11. A method of obtaining a visual display which comprises generating radiation in the ultraviolet bandwidth by ionization of a gaseous medium in the region of a cathode by application of a potential to adjacent cathode and anode assemblies and impinging that radiation on a layer of fluorescent material thereby to convert that radiation into radiation in the visible region of the spectrum, characterised in that the ultraviolet radiation is generated within the confines of a hollow cathode cell, the side walls of which are lined with a metallic coating, by application of a first potential between said cathode cell and an anode spaced therefrom a predetermined distance and having said gaseous medium contained therebetween, said first potential being effective to obtain ionization of said gaseous medium, and applying a second potential between said cathode cell and anode, whereby gaseous ions are caused to bombard the metallic lining of said cathode cell and to extract therefrom metal atoms which undergo ionization in the gaseous medium with consequential emission of the said ultraviolet radiation from said ionized metal atoms for impingement on said layer of fluorescent material.

12. A method according to claim 11, characterised in that said first potential corresponds to the breakdown voltage of the gaseous medium.

13. A method according to claim 11 or 12, characterised in

that said cathode cell comprises a further layer of metallic material external to said side walls and opposed to the anode, and said first potential is effective to establish a negative cathode glow between the anode and said external metallic layer.

14. A method according to claim 13, characterised in that second potential is effective to extinguish said cathode glow.

FIG. 1

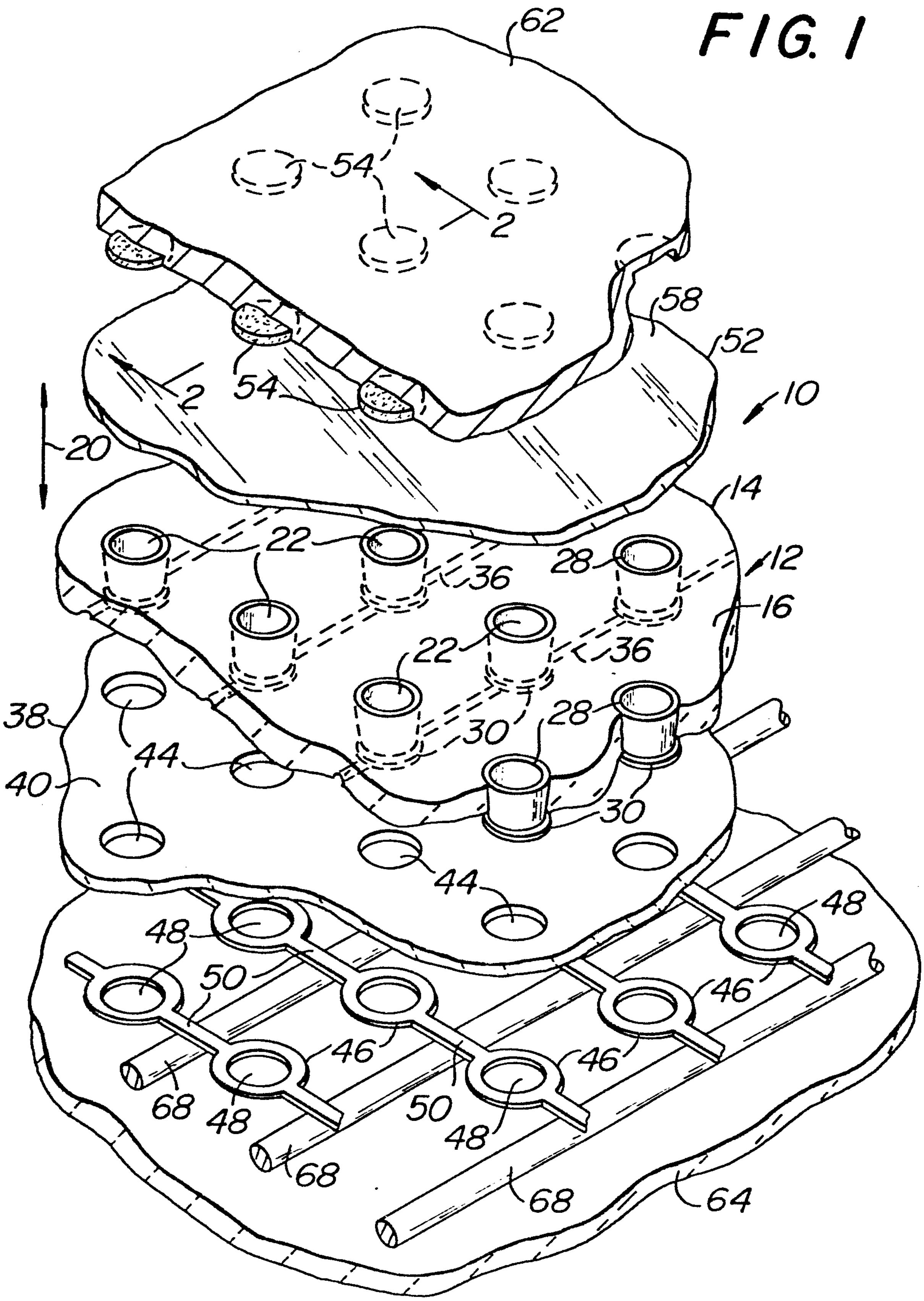
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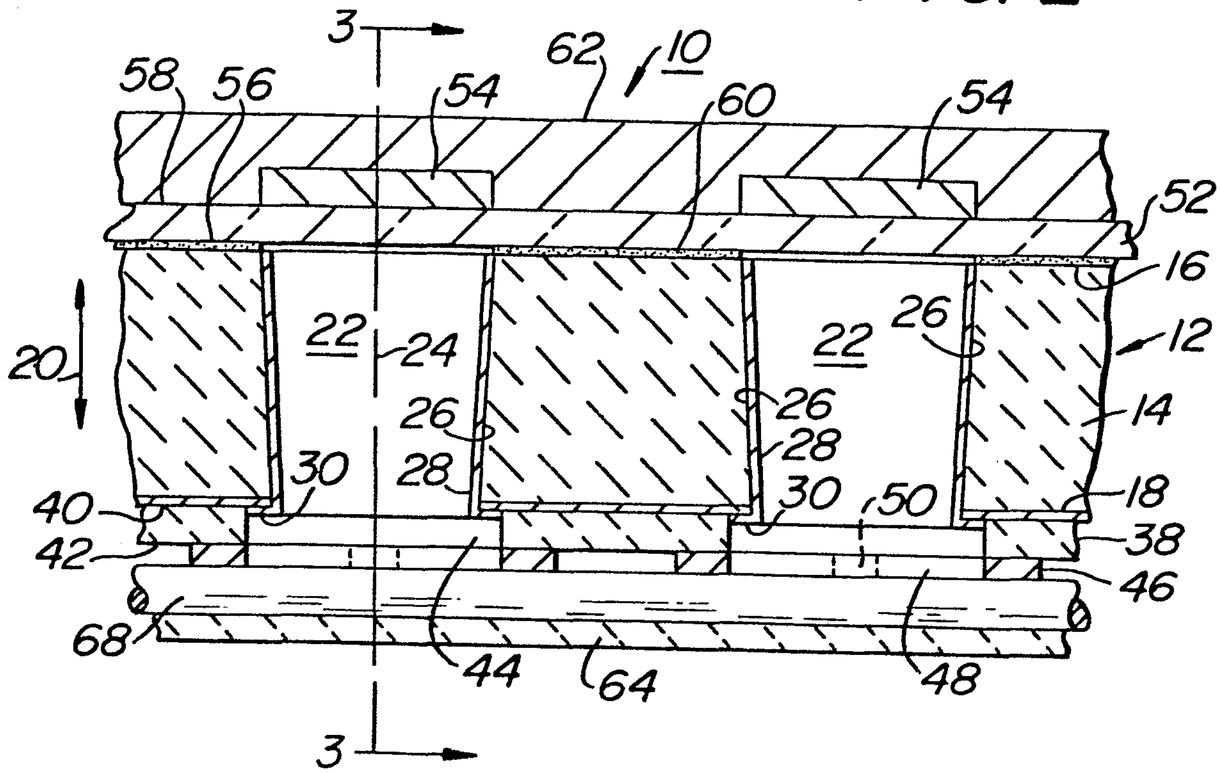
FIG. 2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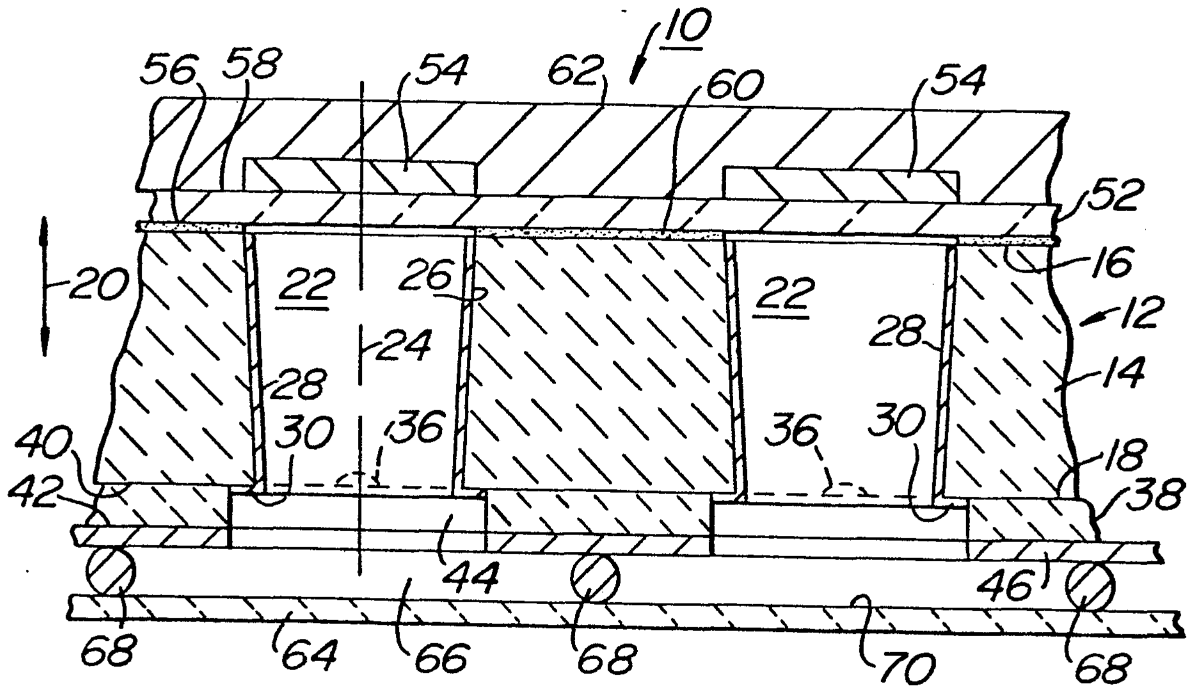
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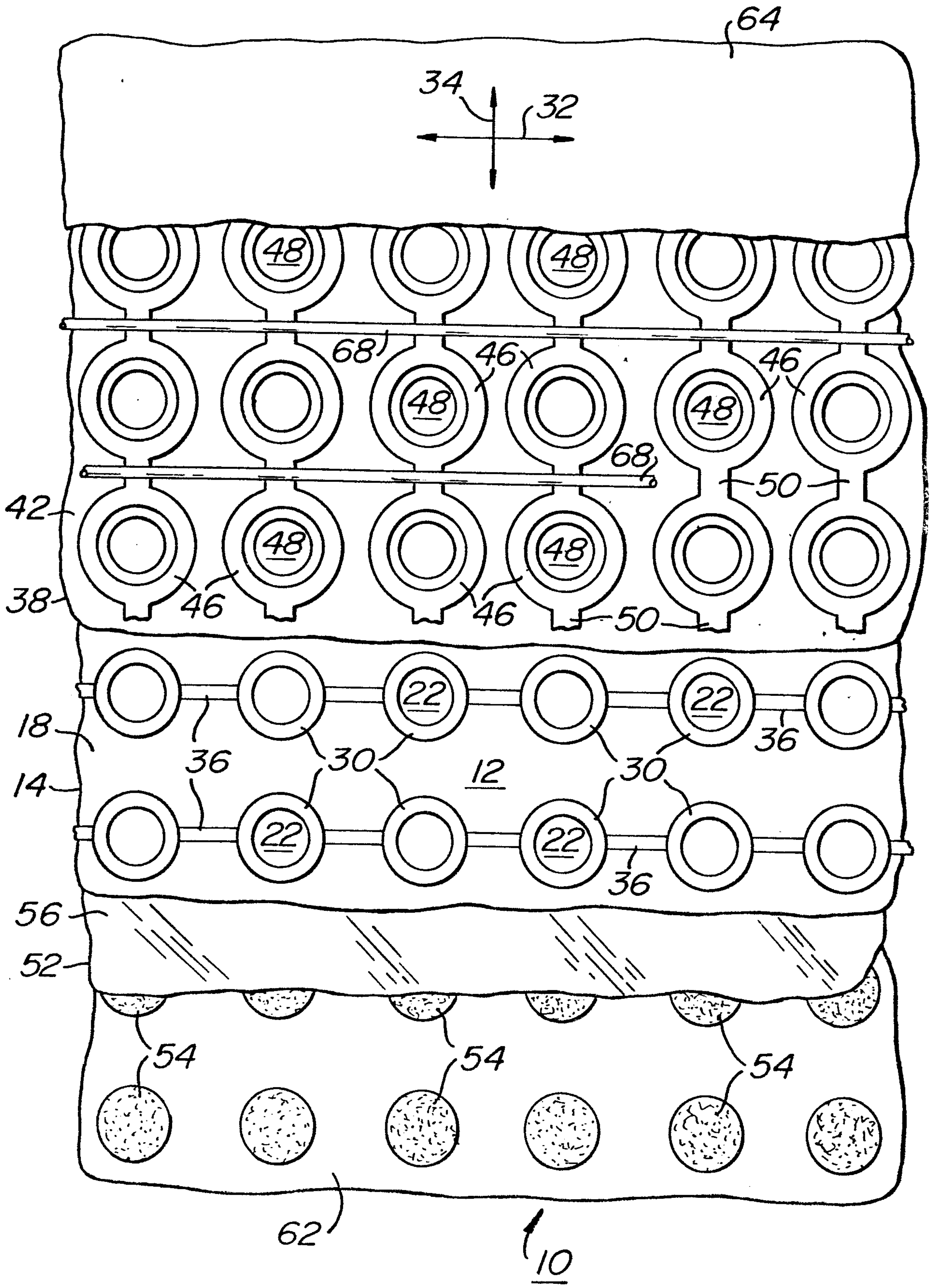
FIG. 3

FIG. 4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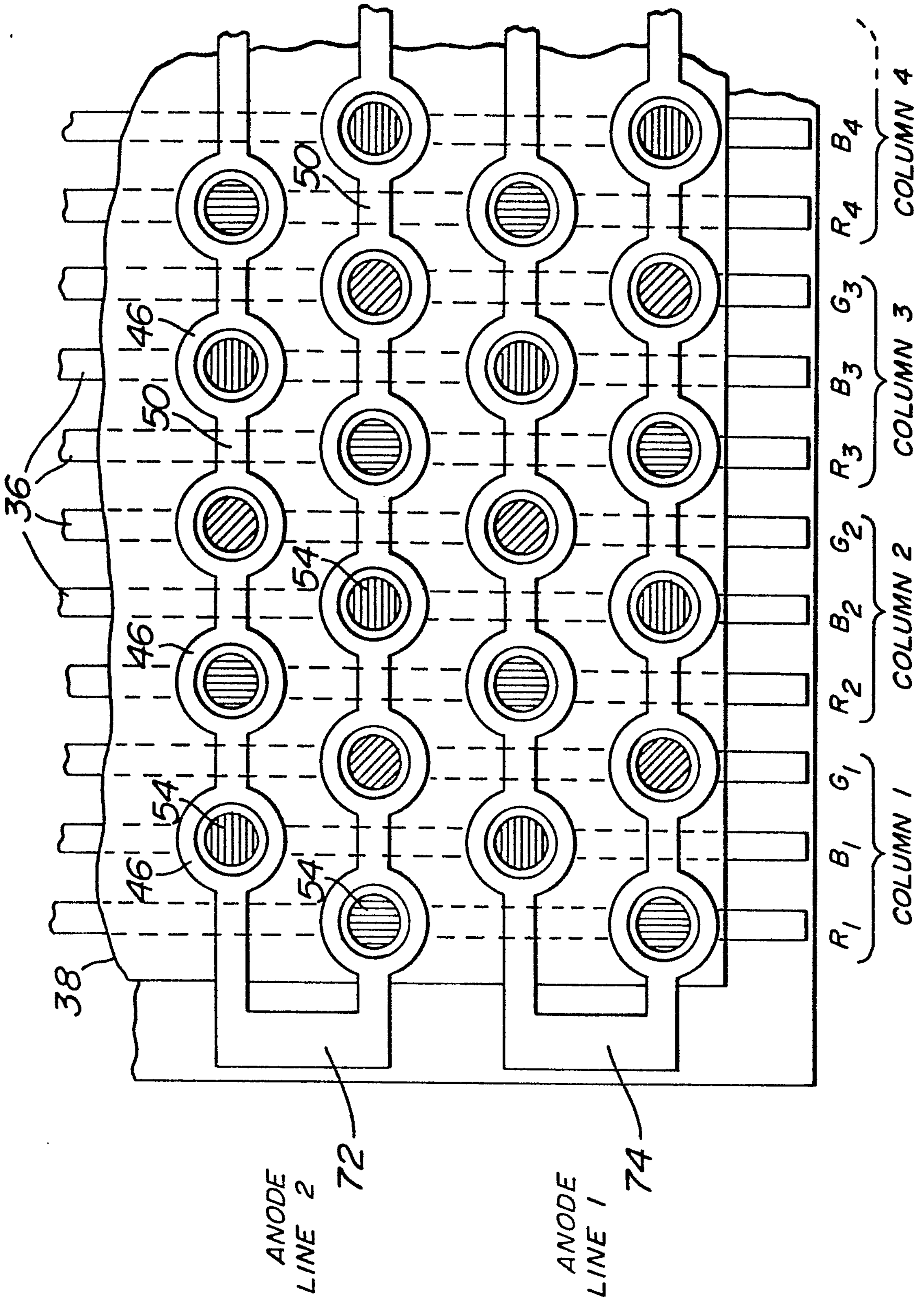
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38
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50
54
72
74
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R2 B2 G2
R3 B3 G3
R4 B4
COLUMN 1
COLUMN 2
COLUMN 3
COLUMN 4

FIG. 5

European Patent Office

0074440
Application number
EP 81304149.8

EUROPEAN SEARCH REPORT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	US - A - 4 047 077 (VEITH) * Fig.; abstract; column 7, claims 1-3; column 8, claim 18; columns 9,10, claims 19,20 * --	1,2,10, 11	H 01 J 17/49
A	US - A - 4 176 297 (THISTLE et al.) * Abstract; fig. 1,2; column 2, lines 4-29; columns 3,4, claims 1,9-13 * --	1,2,8, 11	
			TECHNICAL FIELDS SEARCHED (Int.Cl. 3)
A	US - A - 3 956 667 (VEITH) * Abstract; fig. 1; column 3, lines 54-66 * --	1,2,11	H 01 J 17/00 H 05 B 41/00 H 01 J 61/00
A	US - A - 3 984 720 (WATANABE) * Columns 6,7; claims 1-2 * --	1,7	H 04 N 3/00 H 05 B 37/00 H 01 J 63/00
A	US - A - 3 986 074 (WATANABE et al.) * Column 8, claims 1-3 * --	1	H 01 J 11/00
			CATEGORY OF CITED DOCUMENTS
A	US - A - 3 803 439 (SASAKI et al.) * Abstract; column 2, lines 54-68; column 3, lines 1-46; column 6, claims 1,3 * --	1,2,9-12	X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons
A	US - A - 3 873 870 (FUKUSHIMA et al.) * Abstract; column 2, lines 17-23; column 11, claims 1, 5 * --	1,11	
X	The present search report has been drawn up for all claims		&: member of the same patent family, corresponding document

Place of search	Date of completion of the search	Examiner
VIENNA	03-05-1982	VAKIL

EPO Form 1503.1 06.78

European Patent Office

EUROPEAN SEARCH REPORT

0074440

Application number

EP 81304149.8

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int Cl ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	US - A - 3 886 389 (OGLE) * Abstract; column 6, claims 1,6 * --	1,2,7, 11	
A	US - A - 3 886 390 (MALONEY et al.) * Abstract; columns 3,4; claim 1 * --	1,2,11	
A	US - A - 3 886 395 (EUKUSHIMA) * Abstract; column 3, lines 34-60; columns 5-8, claims 1-7 * --	1,2,9, 11,13	TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
A	US - A - 3 890 609 (SASAKI et al.) * Abstract; column 4, claims 1-5 * --	1,2,11	
A	US - A - 3 896 327 (SCHERMERHORN) * Column 2, lines 40-45; column 10, claims 1-7 * --	1,11	
D,A	US - A - 3 882 342 (KAMEGAYA et al.) * Totality * ----	1	