



US005962968A

United States Patent [19]
van Os

[11] **Patent Number:** **5,962,968**
[45] **Date of Patent:** **Oct. 5, 1999**

[54] **VESSEL SHAPES AND COIL FORMS FOR ELECTRODELESS DISCHARGE LAMPS**

[75] Inventor: **Ron van Os**, Sunnyvale, Calif.

[73] Assignee: **Diablo Research Corporation**, Sunnyvale, Calif.

[21] Appl. No.: **08/924,218**

[22] Filed: **Sep. 5, 1997**

[51] **Int. Cl.**⁶ **H01J 1/62**; H01J 63/04; H01J 1/50; H01J 3/20

[52] **U.S. Cl.** **313/493**; 313/494; 313/161; 313/634; 315/248

[58] **Field of Search** 313/160, 161, 313/491-493, 634, 637, 638, 153, 573, 494; 315/246, 248, 39, 267, 344, 57, 70, 85, 283, 111.21

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,005,330	1/1977	Glascoek, Jr. et al.	315/57
4,119,889	10/1978	Hollister	315/248
4,240,010	12/1980	Buhrer	313/493
4,245,179	1/1981	Buhrer	315/248
4,266,167	5/1981	Proud et al.	315/248
4,675,577	6/1987	Hanlet	315/248
4,812,702	3/1989	Anderson	313/153
4,872,741	10/1989	Daki et al.	350/345
4,910,439	3/1990	El-Hamamsy et al.	313/638 X
4,950,059	8/1990	Roberts	350/345

5,013,975	5/1991	Ukegawa et al.	315/248
5,349,271	9/1994	Van Os et al.	313/161 X
5,500,574	3/1996	Popov et al.	313/161 X
5,619,103	4/1997	Tobin et al.	315/111.21

FOREIGN PATENT DOCUMENTS

26 01 664	1/1976	Germany .	
4-357661	of 1992	Japan	H01J 65/04
WO 94/22280	9/1994	WIPO	H05B 41/10

OTHER PUBLICATIONS

Donald D. Hollister et al.. "A Xenon Lamp with Two Less Electrodes", Feb. 1971, Electro-Optical Systems Design.

Primary Examiner—Nimeshkumar D. Patel

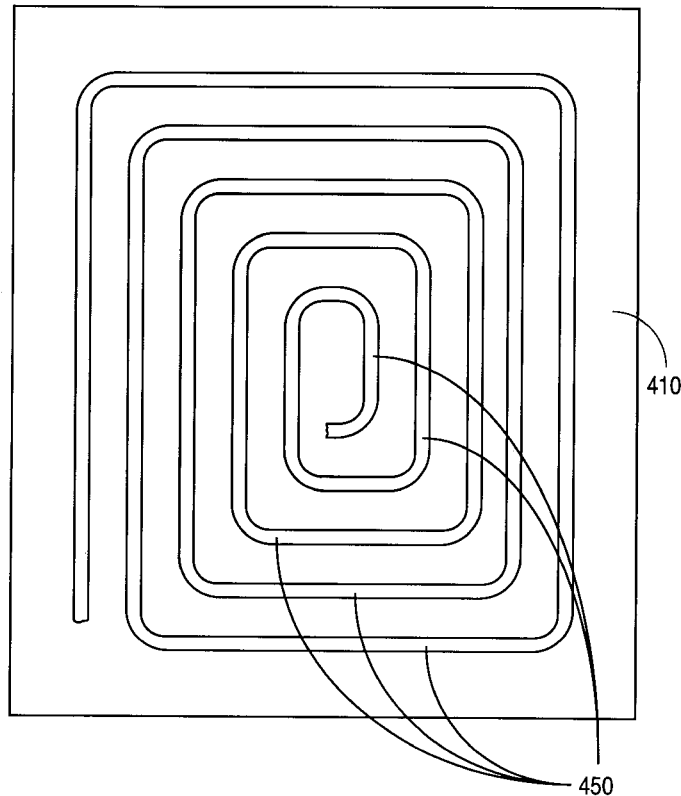
Assistant Examiner—Mack Haynes

Attorney, Agent, or Firm—Skjerven, Morrill, MacPherson, Franklin & Friel LLP; David E. Steuber

[57] **ABSTRACT**

A discharge vessel for an electrodeless lamp having a pair of substantially parallel front and back walls. In one implementation, the front wall of the discharge vessel has a collimating structure, e.g a fresnel lens, for directing the light in a preferential direction such as in a flood light. In another implementation, the flat discharge vessel is quadrilateral and together with one or more quadrilateral excitation coils can be used as a backlight for a flat panel display. In yet another implementation, a cup-shaped discharge vessel with a collimating structure on the front wall is used in an electrodeless lamp for a task lighting such as a spot light.

1 Claim, 8 Drawing Sheets



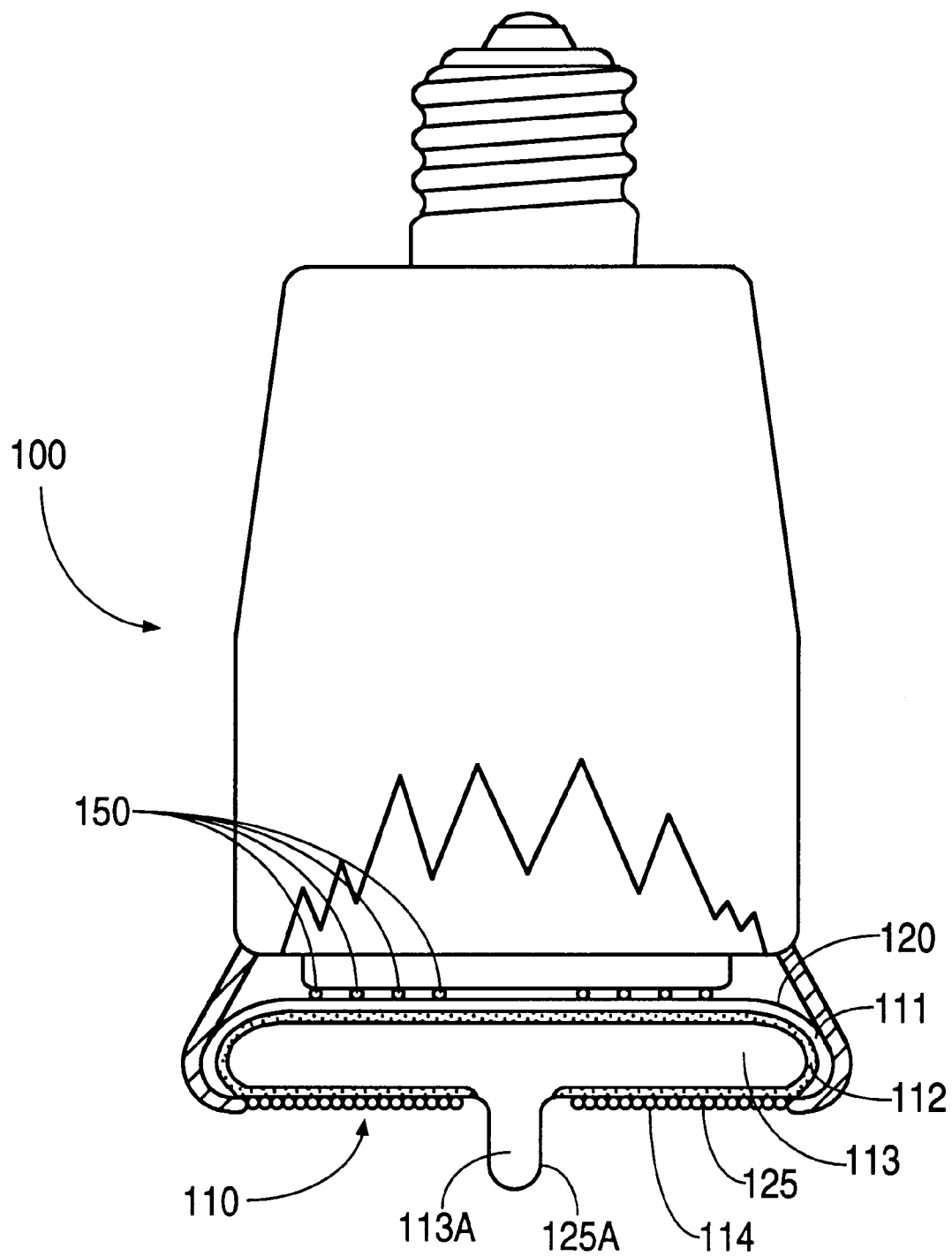


FIG. 1A

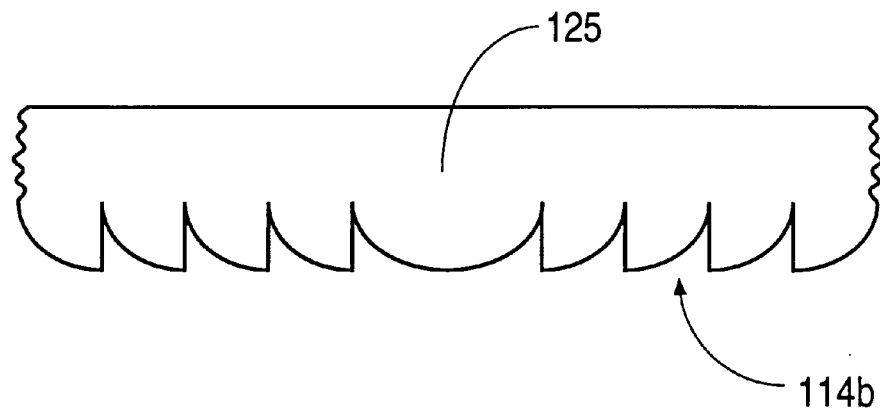


FIG. 1B

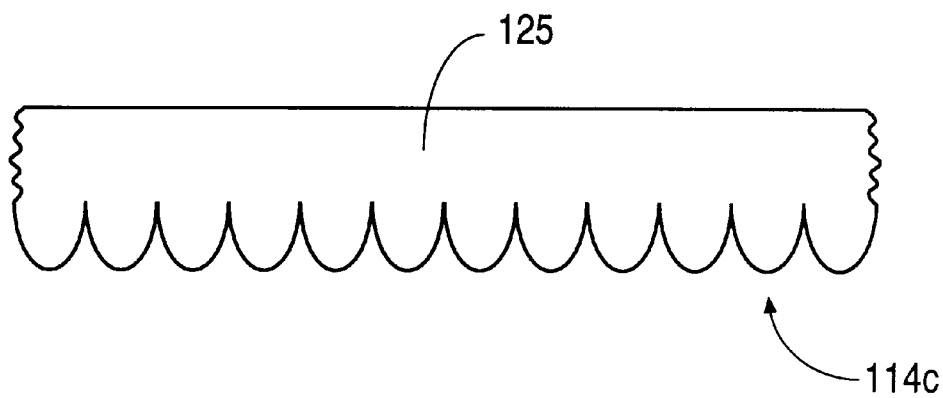


FIG. 1C

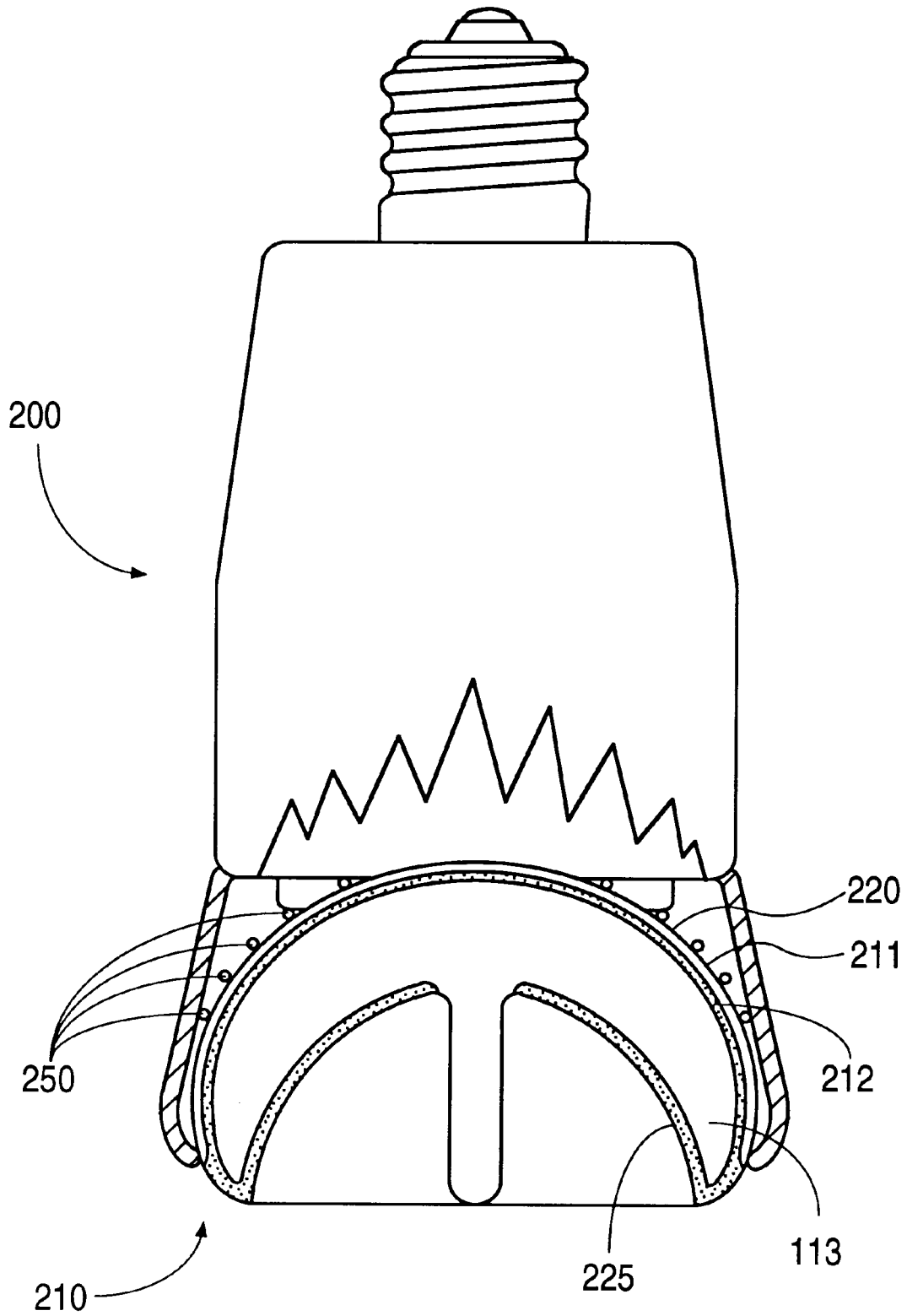


FIG. 2

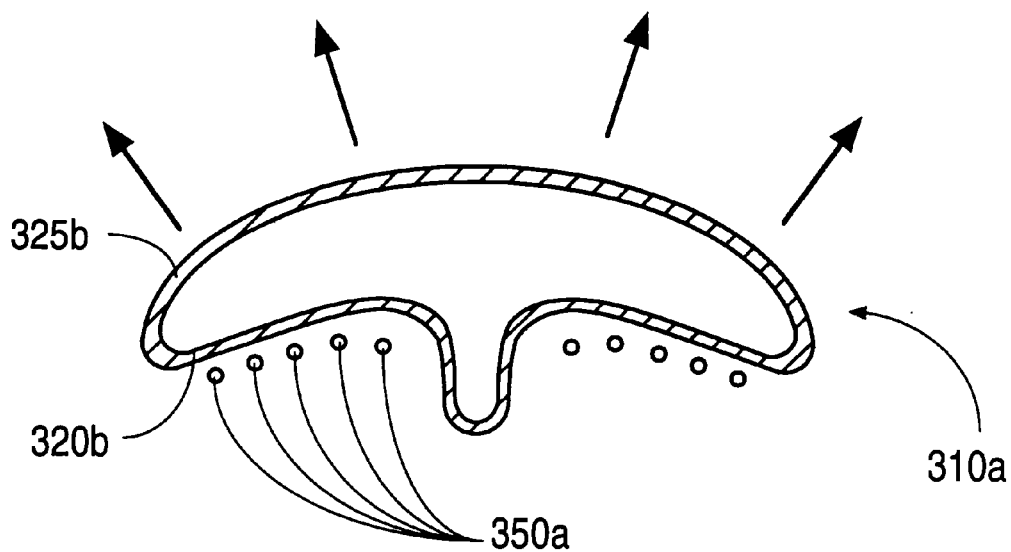


FIG. 3A

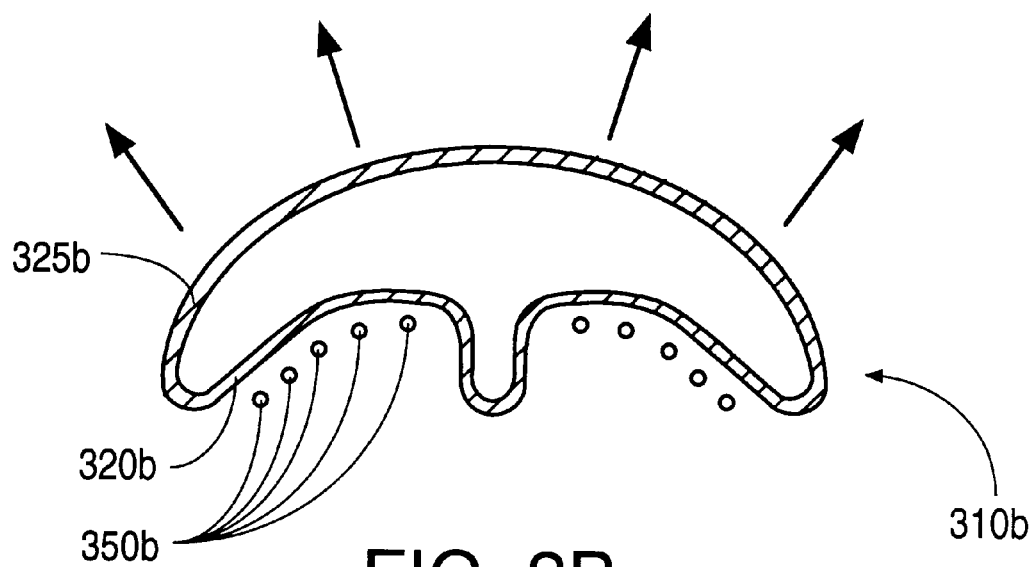
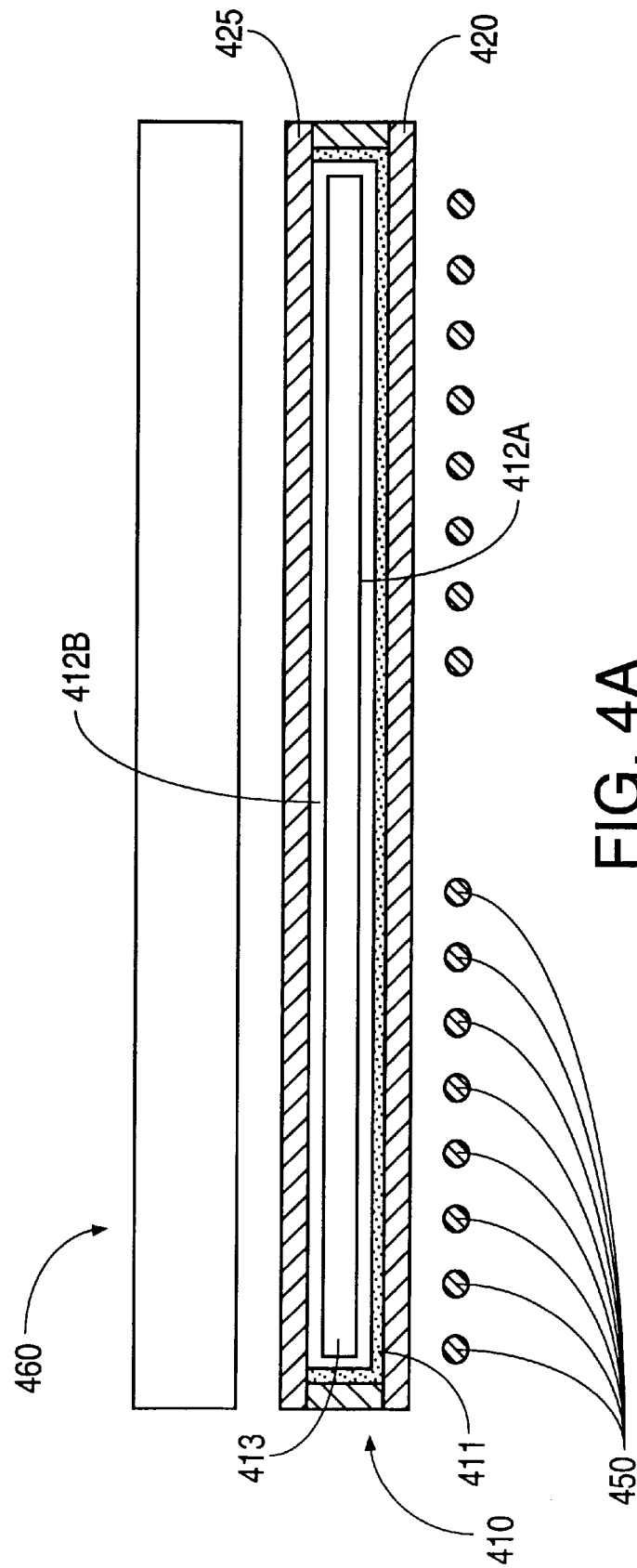


FIG. 3B



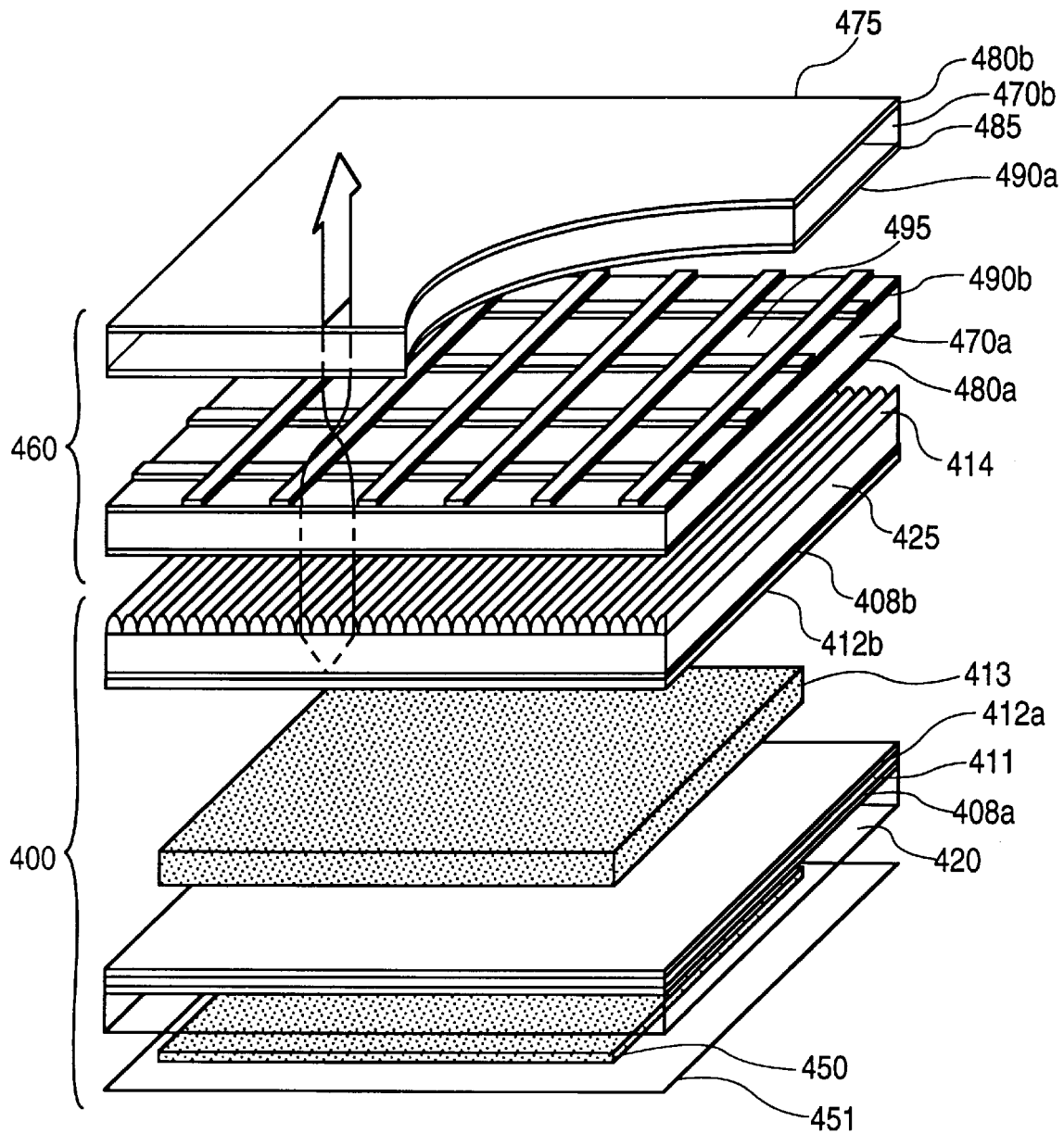


FIG. 4B

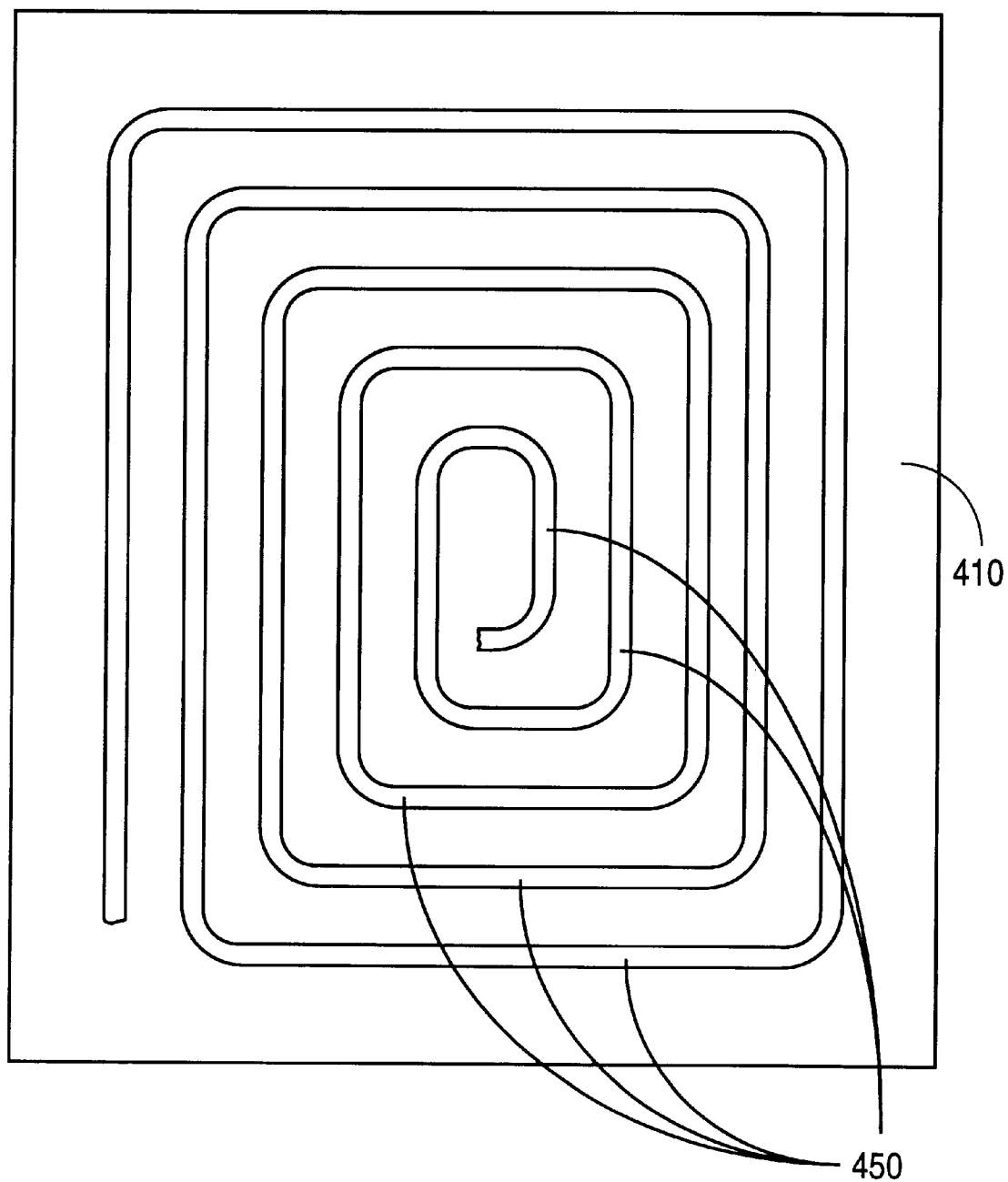


FIG. 4C

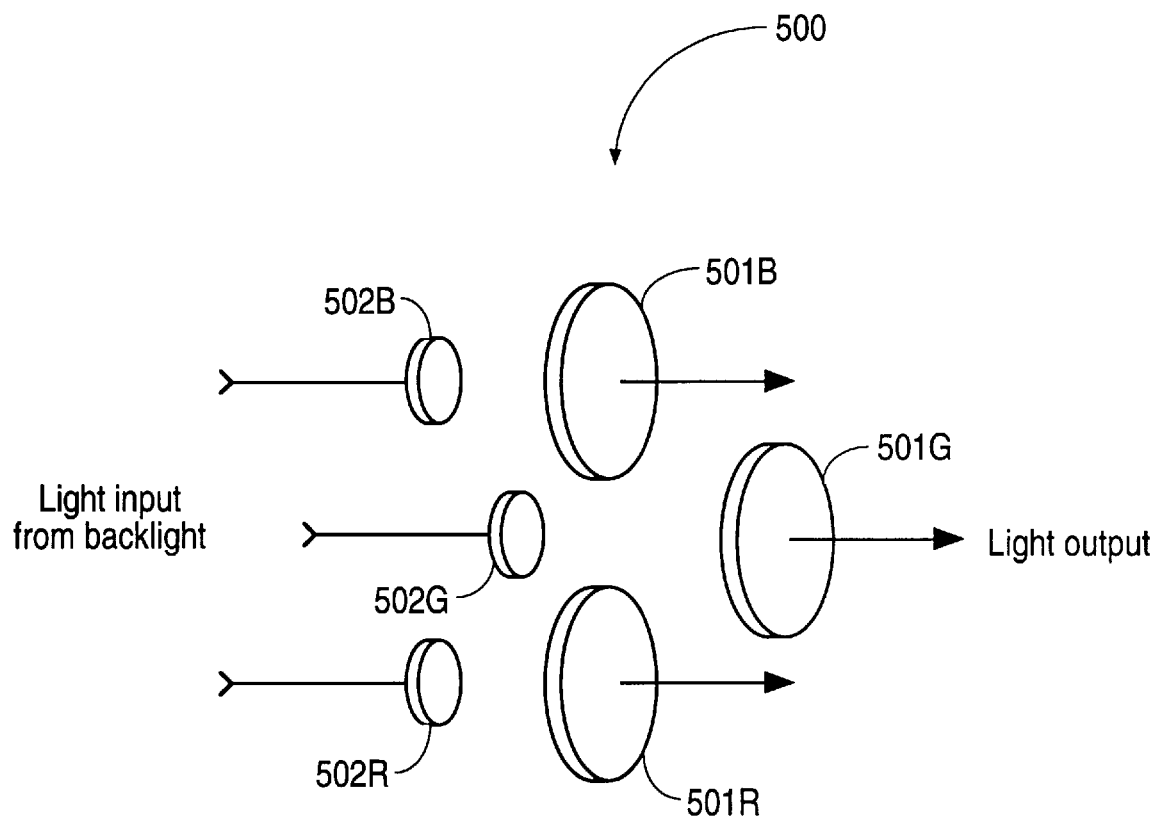


FIG. 5

VESSEL SHAPES AND COIL FORMS FOR ELECTRODELESS DISCHARGE LAMPS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is application is a continuation division of application Ser. No. 08/139,387, filed Oct. 19, 1993 now abandoned.

This application is related to, and incorporates by reference, the following U.S. patent applications: the application entitled "Electrodeless Discharge Lamp with Spectral Reflector and High Pass Filter" filed May 20, 1992, Ser. No. 07/887,165; the application entitled "Radio Frequency Interference Reduction Arrangements for Electrodeless Discharge Lamps" filed May 20, 1992, Ser. No. 07/883,850; the application entitled "Phosphor Protection Device for Electrodeless Discharge Lamp" filed May 20, 1992, Ser. No. 07/883,972; the application entitled "Base Mechanism to Attach an Electrodeless Discharge Light Bulb to a Socket in a Standard Lamp Harp Structure" filed May 20, 1992, Ser. No. 08/068,846; the application entitled "Discharge Lamps and Methods for Making Discharge Lamps", filed May 20, 1992, Ser. No. 07/883,971; the application entitled "Stable Power Supply Providing a High Power Factor and Low Harmonic Distortion" filed May 20, 1992, Ser. No. 07/886,718; the application entitled "Zero-Voltage Complementary Switching High Efficiency Class D Amplifier" filed May 20, 1992, Ser. No. 07/887,168, now U.S. Pat. No. 5,306,986; the application entitled "Electrodeless Discharge Lamp with Spiral Induction Coil" filed Mar. 24, 1993, Ser. No. 08/036,303; and the application entitled "Dimmer for Electrodeless Discharge Lamp" filed Oct. 14, 1992, Ser. No. 07/961,763.

FIELD OF THE INVENTION

This invention relates to vessel shapes and coil forms for electrodeless discharge lamps. More particularly, this invention relates to a self focusing and flatter vessel shape for an electrodeless discharge lamp.

BACKGROUND OF THE INVENTION

Electrodeless discharge lamps are described in sources such as U.S. Pat. No. 4,010,400 to Hollister, M.H. incorporated herein by reference, which describes an electrodeless discharge lamp including an induction coil positioned in a central cavity surrounded by a sealed discharge vessel. The discharge vessel contains a mixture of a metal vapor and an ionizable gas. Mercury vapor and argon are frequently used. The induction coil is connected in series with a capacitor. A radio frequency (RF) signal is generated by an oscillator, amplified and fed into a series L-C network. When the L-C network is energized by this RF signal, it resonates and the induction coil generates electromagnetic energy which is transferred to the gaseous mixture in the sealed discharge vessel.

Electrodeless discharge lamps operate in two stages. In the start-up electromagnetic discharge mode, i.e., as the lamp is being turned on, the electric field from the induction coil causes some of the atoms in the gaseous mixture to be ionized. The electrons which are freed in this process circulate around the induction coil within the sealed discharge vessel. Collisions between these electrons and the atoms release additional electrons until a plasma of circulating charged particles is formed. The induction coil and plasma behave in the manner similar to a transformer, i.e. with the coil acting as the primary winding and the discharge

current acting as the secondary winding. However, because of air gaps between the coil and the sealed discharge vessel, typically made of glass, the magnetic coupling between the coil and the gaseous mixture is normally quite poor.

Many of these collisions excite the mercury atoms to a higher energy state rather than ionizing them. As the mercury atoms fall back from the higher energy state, they emit radiation, primarily in the ultraviolet (UV) spectrum. This radiation impinges on phosphors which coat the inner surface of the discharge vessel. The phosphors are selected to be highly excitable by UV radiation and in turn emit visible light as they return from their excited state.

During the second stage of operation, i.e. after the electron flow in the gaseous mixture has been established, the magnetic field generated by the induction coil becomes of primary importance in maintaining the discharge.

The early introduction of the incandescent lamp caused a major revolution in the way light was delivered. Originally, the pear-shaped glass vessel was chosen as the enclosure of choice because it was strong, inexpensive, and was the easiest shape for a glass blower to achieve. The vessels were then produced manually by blowing air into a bit of molten glass at the end of a long pipe. Although glass vessels are mass produced today using modern machinery, the pear-shaped vessel has been retained since the configuration also lends itself to high speed machines. As a result, the pear shape has become the industry standard.

The incandescent lamp in a pear-shaped vessel has several drawbacks. Being a point source of light, it causes an unpleasant glare which requires the addition of shades, reflectors, and/or baffles to make the lighting system more acceptable to the user. Unfortunately, these techniques also reduce the energy efficiency of the light source. Various glass shapes have been used to deliver an improved quantity of usable light for particular applications. This includes the pressed glass reflector (known as a PAR lamp) which delivers light in a preferential direction, making it more efficient for task and display lighting applications.

Electrodeless discharge lamps have generally retained the original pear-shape because these newer light sources were intended to serve as energy efficient replacements for the standard incandescent lamp. Since the existing sockets had been designed around the standard industry bulb shape, it was important to retain compatibility with the existing physical shape.

Task lighting or directional applications present a challenge for electrodeless discharge lamps. Electrodeless discharge lamps have the characteristics of providing a uniform level of illumination over the surface area of the phosphor layer, i.e. they are not point sources of light. Therefore, reflectors are not particularly efficient in increasing the light level in any preferential direction.

Accordingly, there is a need for electrodeless discharge lamps which deliver useful quantities of light in a preferential manner to efficiently illuminate a task or specific area.

SUMMARY OF THE INVENTION

In accordance with the invention, a substantially flat vessel serves as a containment vessel for an ionizable gaseous mixture which includes a metal vapor and a rare gas. The front and back walls of the vessel are similar in shape and are generally parallel to each other. The gaseous mixture within the vessel is excited by an induction coil, which is disposed adjacent to one of the walls. The induction coil has a shape which approximates the shape of one wall of the vessel and is coupled to a high frequency source of RF energy.

In one embodiment, the discharge vessel is oval or round and is coupled with a substantially planar spiral coil. Such a lamp is well suited for use as a flood light.

In another embodiment the discharge vessel is rectangular and is coupled with a substantially planar, quadrilateral spiral coil. Such a rectangular and planar light source is well suited as a backlight for a flat panel display device.

In yet another embodiment, the discharge vessel comprises two parallel cup-shaped surfaces, either or both of which may be the light emissive surface. The lamp is driven by a conical spiral induction coil which may be disposed adjacent to either surface.

The discharge vessel may also be fitted with a fresnel lens or equivalent to enhance the quality of the light output in a preferential direction, and/or to diffuse the light, thereby increasing its uniformity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A shows a partial cutaway view of a first embodiment of an electrodeless discharge lamp with a substantially flat cylindrical discharge vessel.

FIGS. 1B and 1C are detailed cross-sectional views of two collimating structures for the discharge lamp of FIG. 1A, showing a fresnel lens and a "ridged" front with a series of concentric ridges, respectively.

FIG. 2 shows a partial cutaway view of a second embodiment of an electrodeless lamp with a curved cylindrical discharge vessel having a concave cup-shaped profile and a pair of substantially parallel front and back walls.

FIGS. 3A and 3B are cross-sectional views of two additional embodiments of convex cup-shaped discharge vessels with varying degrees of curvature.

FIG. 4A is a cross-sectional view of a flat panel display including a quadrilateral discharge vessel according to this invention.

FIG. 4B is an exploded view showing the structural layers in the flat panel display of FIG. 4A.

FIG. 4C is a plan view of a quadrilateral spiral excitation coil for the discharge vessel of FIG. 4A.

FIG. 5 illustrates schematically the basic structure of a single element in an active matrix display.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1A shows a partial cutaway view of a first embodiment of an electrodeless discharge lamp 100 with a substantially flat cylindrical discharge vessel 110. Discharge vessel 110 includes a pair of walls, a front wall 125 and a back wall 120, which are generally parallel to each other. Front wall 125 and back wall 120 of vessel 110 can be substantially flat, slightly concave or slightly convex. A slightly concave or convex wall profile adds to the mechanical strength of the low pressure discharge vessel 110 which is subjected to external atmospheric pressure. Other shapes for discharge vessel 110 are possible, including a substantially flat oval shape.

Vessel 110 contains an ionizable gaseous mixture 113, which includes a metal vapor, such as mercury, and a rare gas, such as argon. Front wall 125 has a protrusion 125a for condensing mercury vapor 113 thereby forming a "cold-spot" 113a. A substantially flat spiral coil 150 is disposed adjacent the outside surface of back wall 120. A reflective layer 111, such as titanium oxide, is formed on the inner surface of back wall 120. A phosphor layer 112 is disposed

on top of reflective layer 111 and also extends over the inner surface of front wall 125. Reflective layer 111 is designed to reflect both ultra violet light generated by the discharge and visible light generated by phosphor layer 112.

An induction coil 150 serves as the excitation energy source for gaseous mixture 113. UV radiation is produced as the atoms of metal in gaseous mixture 113 cycle between their excited and non-excited states. The UV radiation in turn causes phosphor layer 112 to produce visible light. Reflective layer 111 serves to reflect and hence intensify the resulting visible radiation.

A collimating structure 114 is disposed on front wall 125 of vessel 110. This collimating structure 114 causes light emitted by phosphor layer 112 and light reflected off reflective layer 111 to be directed in a preferential direction. In other words, such an electrodeless discharge lamp serves as a flood light. Collimating structure 114 can be produced integrally in front wall 125 using well known manufacturing methods such as stamping.

Collimating structure 114 can be any one of well known structures, e.g., a fresnel lens 114b or a "ridged" front 114c comprising a series of concentric rounded ridges, whose cross-sectional views are shown in FIGS. 1B and 1C, respectively. Collimating structure 114 can also help to diffuse light emitted by discharge lamp 100, thereby producing a more uniform beam of light.

FIG. 2 shows a cutaway view of a second embodiment of an electrodeless discharge lamp 200 with a concave discharge vessel 210. Vessel 210 has a cross section view which is somewhat banana-shaped, and has an overall profile of a shallow cup or a deep saucer, with a substantially parallel front wall 225 and back wall 220. Vessel 210 is evacuated and contains an ionizable gaseous mixture 113. A spiral coil 250 disposed adjacent to the outside surface of back wall 220 provides the excitation energy for gaseous mixture 113. Coil 250 is generally conical and follows the shape of back wall 220. A reflective layer 211 is formed on the inner surface of back wall 220. A phosphor layer 212 is deposited over reflective layer 211 and the inner surface of front wall 225. UV radiation is produced by excited gaseous mixture 113 and converted into visible light by phosphor layer 212 in the manner described in the first embodiment.

The cup-shaped or saucer-shaped discharge vessel 210 causes the emitted light to be directed in a more focused manner, i.e., for use as a spot light illuminating a specific area. A collimating structure similar to that of the first embodiment 100 can be incorporated on the outside surface of front wall 225 to further control the direction and/or diffuse the emitted light.

FIGS. 3A and 3B show embodiments of two additional discharge vessels 310a and 310b. Both vessels 310a and 310b are cup-shaped or saucer-shaped, as in the second embodiment, with varying degrees of curvature. The main difference is that vessels 310a, 310b have spiral coils 350a, 350b disposed on the concave side of back walls 320a, 320b, with light emitting from the convex side of front walls 325a, 325b, respectively.

Lamps according to the invention are particularly suitable for use as backlights for displays such as liquid crystal displays. In another embodiment as illustrated by cross-sectional and exploded views, FIGS. 4A and 4B, respectively, an electrodeless discharge lamp 400 includes a flat rectangular shaped discharge vessel 410 disposed adjacent to a spiral coil 450. Spiral coil 450 has a quadrilateral shape and is supported by a coil substrate 451, as illustrated in the plan view of FIG. 4C. Discharge vessel 410 has a flat

front wall 425 and a parallel flat back wall 420. A reflective layer 411, comprising barium sulfate or titanium oxide, is formed on the upper surface of back wall 420 and extends over the sidewalls of vessel 410. A phosphor layer 112, preferably made of a tristimulus phosphor, coats the inside of vessel 410, with planar sections 412a and 412b being formed over reflective layer 411 and below the lower surface of front wall 425, respectively. Front wall 425 and back wall 420 are joined together along their respective edges to seal vessel 410 for containing a gaseous mixture 413. Mixture 413 comprises a metal vapor, such as mercury, and a rare gas, such as argon. Adherence of phosphor layers 412a and 412b to front and back walls 425 and 420, respectively, is enhanced by the use of adhesion layers 408a and 408b as shown in FIG. 4B. Suitable materials for adhesion layers 408a and 408b include aluminum oxide and silicon oxide.

The rectangular electrodeless discharge lamp 400 serves as a back light for a flat panel liquid crystal display assembly 460, having an active or passive matrix liquid crystal display (PMLCD or AMLCD) capable of displaying a full color image. Visible light emitted by lamp 400 is directed towards liquid crystal display (LCD) assembly 460. The ability to produce high luminance at low power and the absence of electrodes makes electrodeless discharge lamp 400 a superior option for backlighting LCD assembly 460.

FIG. 4B illustrates in greater detail the exploded view of the structure of electrodeless discharge lamp 400 and LCD assembly 460. Lamp 400 uses the same technology used in lamps 100 and 200, discussed above, the major difference being the completely flat, rectangular shape of discharge vessel 410. An optional collimating diffusion layer 414 is disposed on the upper surface of front wall 425 of lamp 400 and below LCD assembly 460. Diffusion layer 414 comprises rows of parallel ridges. Other well-known collimating structures can also be used, such as a fresnel lens.

LCD assembly 460 comprises the following layers. Starting from the bottom of LCD assembly 460, a first polarizer 480a is formed on the lower surface of a lower glass wall 470a. Lower glass wall 470a and an upper glass wall 470b sandwich a matrix of X-Y electrodes 490b, liquid crystal molecules 495, a common electrode layer 490a, and a RGB color filter 485 disposed on the lower surface of upper glass wall 470b. Completing LCD assembly are a second polarizer 480b and an anti-reflective coating layer 475, both of which are disposed on the top surface of upper glass wall 470b.

Other shapes for LCD assembly 460 and backlight lamp 400 are possible, including a flat square shape or a flat rounded shape.

Referring back to lamp 400 of FIGS. 4A and 4B, RF energy is supplied to excitation coil 450, which is in close proximity to gaseous mixture 413 disposed between front wall 425 and back wall 420. Upon ionization of gaseous mixture 413, a current is induced inside discharge vessel 410 along the overall contours of excitation coil 450. The current in coil 450 generates a potential drop along the path of the current flow, providing the acceleration potential for the plasma electrons of mixture 413, thereby sustaining the discharge.

In this embodiment, excitation coil 450 is positioned in close proximity to plasma mixture 413, to produce an electric field for ignition and a magnetic field for sustaining the H-mode, respectively. Preferably, coil 450 is driven by a Class D or Class E type amplifier. In this manner efficiencies as high as 88% can be achieved.

The minimum spacing between front wall 425 and back wall 420 is approximately 0.6 inches to ensure reasonable

efficiency and good integrating characteristics. As a result, the minimum external thickness of discharge vessel 410 is about 0.75 inches. The width and height of backlight lamp 400 is limited by the resolution and driving capability of LCD assembly 460. For example, a 4" x4" backlight having a single excitation coil has been successfully fabricated. For larger backlights, multiple excitation coils may be combined with glass partitioning of discharge vessel 410 thereby maintaining high efficiency with light uniformity.

One advantage of electrodeless discharge backlight lamp 400 is the absence of electrodes inside discharge vessel 410. As a result, there is no deposit from the inevitable long term sputtering of the electrode materials in an electrode based lamp. This absence of an electrode or filament inside discharge vessel 410 also makes lamp 400 sturdy and highly resistant to shock and vibration. Further, with an all glass discharge vessel 410 lamp, the operating temperature range of backlight lamp 400 is very wide. The operating temperature range of the resulting flat panel display system is limited only by the limitations of LCD assembly 460.

Several additional considerations should be taken into account in the design and fabrication of an electrodeless discharge lamp used as a backlight.

1. Uniformity of Light Output. The uniformity of the emitted light across the face of the backlight can be controlled by careful design and placement of the excitation coil. The maximum amount of UV radiation is produced in the regions where the electron temperature (i.e., the average internal energy of the electrons) is on the order of 3.2eV. By selection of the gas fill pressure, these regions can be tailored to maximize uniformity. The UV radiation is emitted randomly, and due to the conformal phosphor coating on the inside of the glass enclosure, an integration takes place of all the produced visible light. The depth (i.e., the actual minimum dimension) of the plasma, affects the spatial distribution of the electron temperature profiles and the integrating properties of the glass envelope. The dominant UV production region will be around the perimeter of the plasma current.

2. Phosphor Characteristics. By controlling the mixture ratio of the three components of the tristimulus phosphor, taking into consideration the visible spectra of mercury lines, a wide range of color temperatures is achievable. Moreover, since the phosphors respond linearly with the incident UV flux, a constant color temperature is achievable during dimming of the display.

These factors make it possible to increase the brightness and color definition of the display. Each element of an active matrix display normally contains three individual pixels, each of which contains a color filter, typically a gel filter. The three color filters in the element are typically red, green and blue (RGB). A light valve (e.g., an LCD switch) is associated with each of the filters to control the amount of light passing through it. This structure is illustrated schematically in FIG. 5, where element 500 of an active matrix display contains light filters 501R, 501G and 501B positioned in front of light valves 502R, 502G and 502B, respectively.

Since the light emitted by conventional electroluminescent backlights is typically deficient in blue content, the transmissivity of the red and green filters is made somewhat lower in order to compensate for the lack of blue light and thereby produce a white light when all of the light valves are fully opened. Reducing the transmissivity of the red and green filters, however, reduces the overall efficiency of the active matrix display. Using an electrodeless dis-

charge lamp as a backlight, in accordance with this invention, permits one to adjust the spectrum of radiation emitted by the backlight and thereby avoid the necessity of intentionally lowering the transmissivity of the filters.

Accordingly, the phosphor mixture ratio can be proportioned to compensate for the difference in the transmission efficiencies of the RGB filters, with special consideration being given to the visible (blue) components of the mercury discharge. The efficiency of a color matrix display using an ordinary electro-luminescent backlight is on the order of 2%. Using the principles of this invention, it is believed that the efficiency can be increased to 4–5%.

3. Longevity of Phosphors. To increase the longevity of the phosphor layer, the use of an electro-static screen or an RF-driven shield to eliminate electric field components in the glass envelope may be considered. The electric field is unnecessary during the steady state operation of the lamp and may cause sputtering of the phosphor coating. However, the electric field is necessary for ignition. To allow proper ignition, additional circuitry may be used, or the electric field may be allowed to penetrate the electrostatic or RF-driven shield in a defined area. In less demanding applications, the excitation coil and driving electronics can be optimized for minimum electric field generation while the lamp is in the H-mode, by reducing the number of turns and optimizing the pitch of the coil.

4. RF-Driver Requirements. The RF-driver requires a high efficiency which can be obtained with a Class D or Class E type amplifier, as taught in application Ser. No. 07/887,168, filed May 20, 1992, now U.S. Pat. No. 5,306,986, and application Ser. No. 07/894,020, filed Jun. 5, 1992, respectively, both of which are incorporated herein by reference. The amplifier needs to be capable of driving a high Q circuit (E-mode), where there is no appreciable loading of the excitation coil, and a low Q circuit (H-mode), where the induced plasma current presents a load to the excitation coil. These requirements can be met by the use of an impedance matching and filter network such as is described in application Ser. No. 08/064,779, filed May 19, 1993, incorporated herein by reference.

5. Dimming Capabilities. Dimming of the display can be achieved with two basic concepts: (i) The oscillator that drives the amplifier can be pulse width modulated in the manner taught in application Ser. No. 07/961,763, filed Oct. 14, 1992, incorporated herein by reference. The modulation circuitry should be adapted such that the longest “off” time is shorter than the electron recombination time. (ii) The second method deploys amplitude modulation of the amplifier output square wave. In this case, the minimum amplitude is determined by the minimum number of ampere turns required to sustain the H-mode. By combining both concepts (i) and (ii), a dimmable range of better than 2,000:1 should be achievable.

In sum, advantages of using an electrodeless discharge lamp 400 as a backlight include increased brightness, improved uniformity and a wide dimmability range (2000:1). In addition, lamp 400 provides the flat panel display with a rigid backlight that has a long life expectancy and is also energy efficient.

While several embodiments have been described, these descriptions are not intended to be limiting and other embodiments will be obvious to those skilled in the art based on this disclosure. Thus, while this invention has been described using vessel shapes, coil forms and collimating structures for electrodeless discharge lamps, the principles of this invention apply equally well to preferential direction for any light source.

I claim:

1. An excitation energy source for a rectangular electrodeless discharge lamp to be used as a backlight for a liquid crystal display, the rectangular electrodeless discharge lamp including a discharge vessel containing an ionizable gaseous mixture and having a flat front wall and a flat back wall, the front wall emitting light, the excitation energy source comprising:

a coil for placement adjacent only the back wall of the discharge vessel and for exciting the gaseous mixture, the coil being in the form of a planar quadrilateral spiral.

* * * * *