

[54] CONTROLLED SPECTRUM FLASH LAMP
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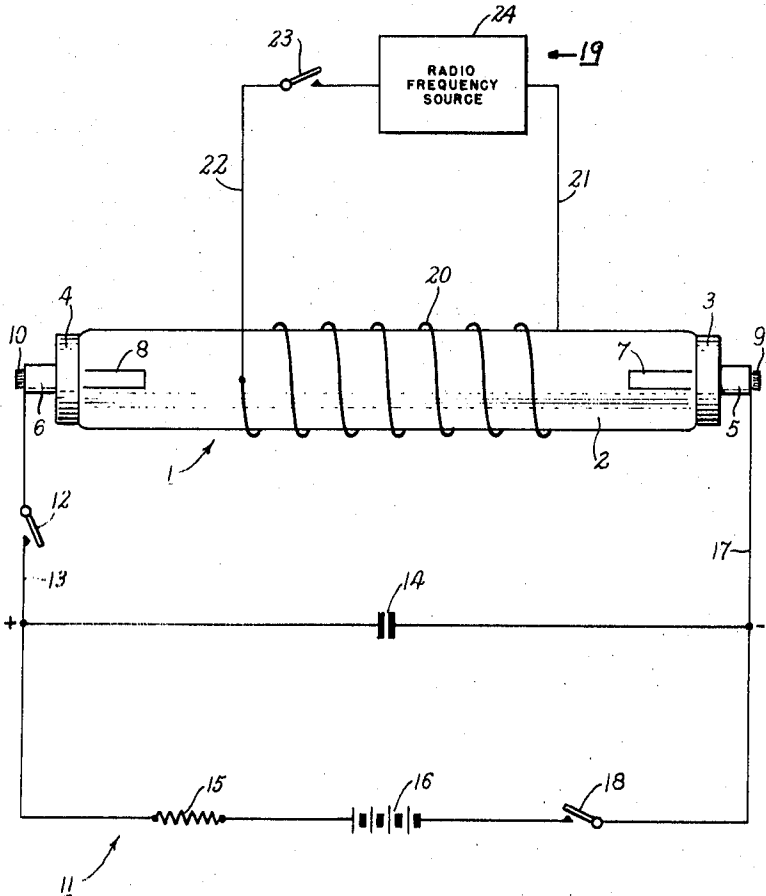
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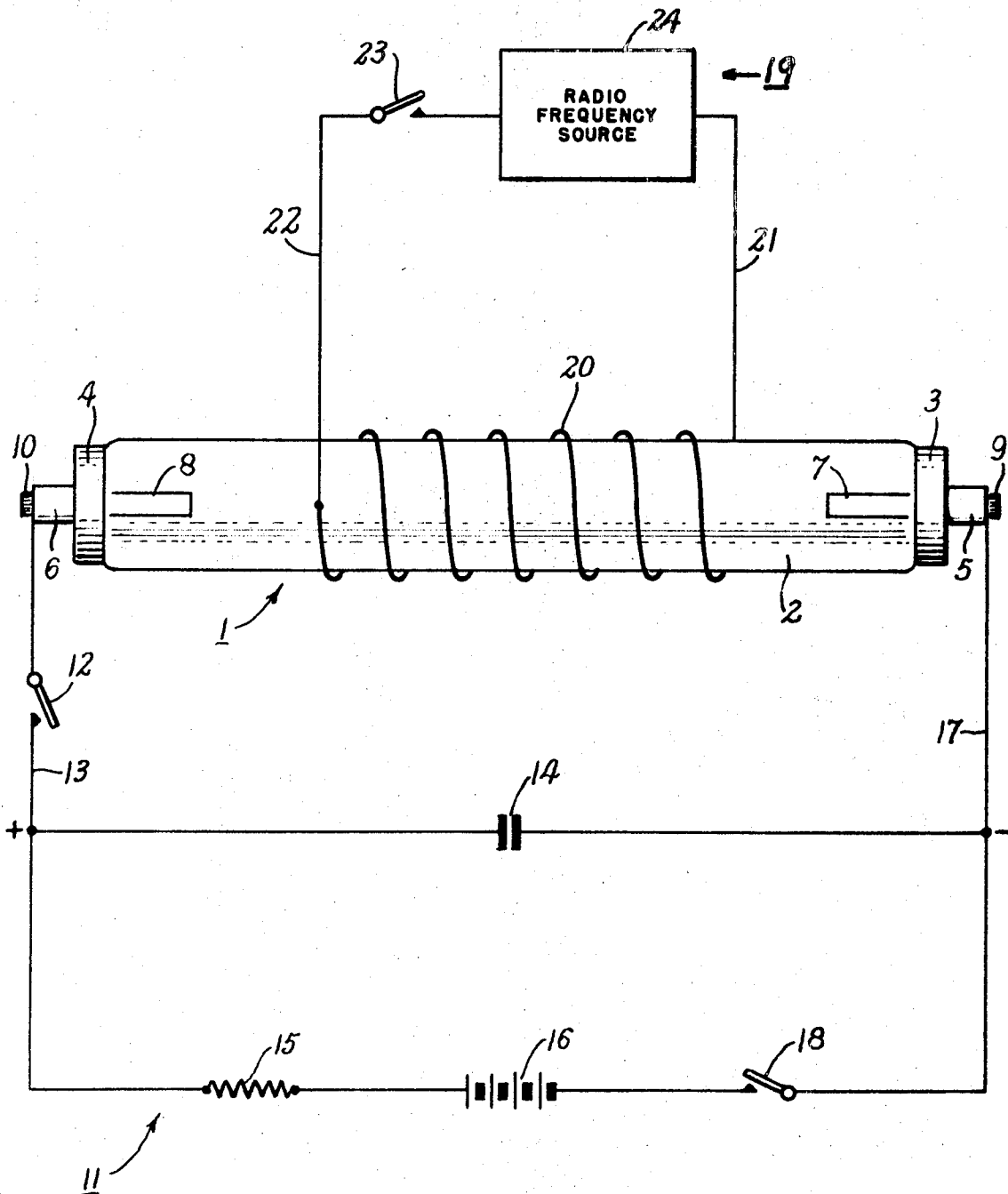
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[57] ABSTRACT

A high intensity inert gas flash lamp adapted to be operated with a predetermined energy input, said lamp comprising a sealed elongated envelope formed of light transmitting material having a high melting point, electrodes operatively disposed within said envelope and adapted to sustain a pulsed arc discharge therebetween, a predetermined amount of a rare gas disposed within said envelope and a predetermined amount of at least one ionizable low vapor pressure metal or metal compound additive disposed on the tube wall, the relationship of the dimensions of said envelope and the amount of metal or metal compound additive in said envelope being such that during operation of said lamp sufficient power is supplied accorss the electrodes to form a shock wave of sufficient amplitude to evaporate substantially all of said ionizable additive material from the tube wall, providing high intensity flash illumination, the emission range of which can be tailored by the addition of several emission modifying additives in combination.

11 Claims, 1 Drawing Figure





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CONTROLLED SPECTRUM FLASH LAMP

This invention relates to high intensity inert gas flash lamps which emit continuous and line radiation upon being energized by a pulsed electrical signal of the proper energy. More particularly, the invention relates to pulsed high intensity inert gas flash lamps which have a rare gas such as xenon as the filler gas and at least one ionizable low vapor pressure metal or metal compound additive in an amount which is predetermined to coat the tube wall and to vaporize under operating conditions for the lamp.

Various types of high pressure inert gas discharge lamps are known. The mercury vapor lamp, which is the most common type, is normally constructed of an arc tube fabricated of quartz, the arc tube containing a starting gas and a measured quantity of mercury which vaporizes when the lamp is operated. The color of the mercury vapor arc is primarily a line spectrum and the resultant light differs considerably from natural light. These lamps are generally quite efficient when they incorporate a color modifying phosphor, the efficiency running as high as about 60 to 70 lumens per watt.

Steady discharge xenon lamps have been suggested as substitutes for the mercury vapor lamps because the color of the discharge is a continuous spectrum which renders objects illuminated by the lamp much more natural in appearance. However, the efficiency of these lamps is about 35 lumens per watt which is considerably below that of mercury discharge lamps.

High intensity inert gas flash lamps emit either continuous radiation or a spark spectrum of the fill gas, depending upon input energy and pressure of the fill gas. It is often desirable to change the spectrum of the radiation emitted by the inert fill gas in order that it fall within a selected spectral region. To this end additives have been introduced into lamps in an effort to produce or enhance radiation in a desired spectral region. These additives fall into two categories. One type consists of those which have vapor pressures high enough to supply a relatively high number density of the additive atoms to the discharge and the other type consists of those whose vapor pressures are low and therefore must be injected into the discharge by other means. To the former group belong the xenon-iodine lamps (described in U. S. Pat. No. 3,453,427) and probably the xenon-mercury discharge lamps. In the case of xenon-iodine lamps, metastable xenon atoms collisionally excite the neutral species of the additive, producing a selective spectral emission whose intensity is enhanced beyond that obtained in a discharge of the pure species alone. In the xenon-mercury lamps, because mercury has lower excitation levels, its spectrum dominates the xenon spectrum.

Prior to the present invention, attempts to employ low vapor pressure additives such as thallium iodide in flash discharge lamps have met with little success. Such attempts have proceeded upon the assumption that to obtain white light with good efficiency it was necessary to achieve a vapor pressure for the additive of at least 100 torr up to 1 atmosphere and more, by maintaining a high temperature, the temperature being as high as could be reasonably sustained within the lamp arc tube to generate a usable vapor pressure for the low vapor pressure additive. This temperature had to be quite high in operating a flash discharge lamp in accordance

with prior concepts so that the coolest portion of the envelope was sufficient to vaporize the low vapor pressure additive. When the envelope is formed of quartz, as is usual, the temperature should not exceed 800° to 900°C. because quartz devitrifies above this range; yet in this range many low vapor pressure additives will not vaporize sufficiently under the conditions employed in the prior art. When a lamp is operated in a manner such that the additives are not fully vaporized, the unvaporized material wets either a part or all of the envelope wall, and if the material is not colorless and transparent, it will block either fully or partially the spectral emission of the lamp.

Thus, in the present state of the art there is no practical way of enhancing the spectral emission of inert gas flash lamps by the use of low vapor pressure additives without resort to bulky and expensive heat conservator means to maintain the lamp envelope at the required high temperature by reducing radiation of heat from said lamp envelope to a minimum. It would be desirable to have a high intensity flash lamp which can operate with low vapor pressure additives without the need for high wall temperatures to serve the function of raising the vapor pressure of such additives. It would also be desirable to have means of operating an inert gas flash discharge lamp in a manner which permits the addition of other metals in combination with low vapor pressure additives such as thallium and low vapor pressure thallium compounds in order to increase total radiation output and extend the desired emission range of the lamp so that the resultant pulsed light source could be tailored to produce a predetermined spectral emission.

Accordingly, it is an object of the present invention to provide a practical way of enhancing the spectral emission of inert gas flash discharge lamps by the use of low vapor pressure additives.

It is a further object of this invention to provide a practical way of enhancing the spectral emission of inert gas flash discharge lamps without resort to bulky and expensive heat conservator means to maintain high temperatures within the lamp envelope.

It is still another object of the present invention to provide a high intensity flash lamp which can operate with low vapor pressure additives without the need for high wall temperatures to serve the function of evaporating such additives.

It is an object of the present invention to provide an inert gas pulsed discharge lamp having a low vapor pressure additive to extend the desired emission range of the lamp so that the resultant light source can be tailored to produce a predetermined spectral emission.

Other objects of this invention will be apparent from the ensuing description thereof.

This invention accomplishes the foregoing objects by the provision of a high intensity inert gas flash lamp adapted to be operated with a predetermined energy input from a pulsed energy source such as a charged capacitor, said lamp comprising a sealed elongated envelope formed of light transmitting material having a high melting point, electrodes operatively disposed within said envelope and adapted to sustain an arc discharge therebetween, a predetermined amount of a rare gas disposed within said envelope and a predetermined amount of a low vapor pressure ionizable additive disposed (coated) on the wall of such tube, the relationship of the dimensions of said envelope, the amount of rare gas, the amount of low vapor pressure ionizable

additive within said envelope, and the level of power input to said electrodes being such that during operation of said lamp sufficient power is supplied across the electrodes to form a shock wave of sufficient amplitude to evaporate substantially all of said ionizable low vapor pressure additive. The shock wave is an acoustical one caused by discharge of energy stored in a capacitor through a relatively low impedance path established by the initial spark of the discharge. The rare gas becomes heated because of the discharge and expands at a greater rate than the velocity of sound thereby creating an acoustical shock wave. In conventional lamps the acoustical energy is dissipated by heating the envelope walls. In this invention, by coating the low vapor pressure additive upon the envelope wall, the energy is instead used to heat and evaporate that material.

A particular use of the high intensity lamps of this invention is a light source in photochemical reactions. Other particular uses are: as a light source for photoconductive reactions and in laser pumping, wherein light of a predetermined energy band is provided to excite the absorption band of the particular reaction.

The invention will be better understood from a consideration of the following detailed description taken in conjunction with the accompanying drawing in which the FIGURE is an illustration of one embodiment of the lamp of this invention.

The lamp shown generally by reference numeral 1 consists of an envelope 2 fabricated of a high melting material such as quartz or glass terminating in caps 3 and 4 respectively at each end of envelope 2. Caps 3 and 4 are hermetically sealed to envelope 2 and to electrodes 5 and 6 respectively. Any conventional means may be used to form the seals between the envelope and the caps and between the electrodes and the caps. The electrodes may be formed of tungsten or any similar refractory conductive material. Electrodes 5 and 6 have ends 7 and 8 respectively disposed within the envelope and terminals 9 and 10 leading from electrodes 5 and 6 respectively to circuit generally designated by reference numeral 11. Circuit 11 may be constructed in any one of a number of specific ways which are known to those skilled in the art to provide the necessary electrical input to electrodes 5 and 6. In one form shown in the illustration, anode electrode 10 is connected through switch 12 and conductor 13 to the positive terminal of capacitor 14 and through resistor 15 to an energy source such as battery 16. Cathode electrode 9 is connected through conductor 17 to the negative terminal of capacitor 14 and through switch 18 to the other terminal of battery 16.

When switch 18 is closed, capacitor 14 is charged by energy source 16 to the voltage required to cause a pulse discharge between electrodes 9 and 10 when switch 12 is subsequently in the closed position. The voltage required to effect a discharge through the gaseous medium contained in envelope 2, is herein called the "breakdown voltage," which, as previously set forth, depends on various factors such as the distance between electrodes, the pressure of rare gas within the envelope and the degree of ionization of the rare gas.

The breakdown voltage can be lowered by employing a trigger circuit such as that generally indicated by reference numeral 19. The trigger circuit includes external windings 20 connected through leads 21 and 22 and switch 23 to radio frequency source 24. When switch 23 is in a closed condition an impulse is transmitted

from radio frequency source 24 to external windings 20 thereby causing the gas within envelope 2 to become partially ionized and thus conductive enough to permit discharge through the gaseous medium at a lower breakdown voltage.

Disposed within envelope 2 is a sufficient quantity of a gas such as xenon, krypton, argon or the like to sustain the discharge across electrodes 5 and 6 when the discharge is first initiated by circuit 11. By proper balancing of gas pressure, ionizable additive content and pulse discharge magnitude the ionizable additive is completely evaporated by the acoustical shock of the discharge thus producing a spectrum of both the rare gas and the additive.

The amount of rare gas which the envelope contains should be sufficient to sustain a discharge across the electrodes, but not so high that the strong continuum will dominate, and possibly obscure the spectrum produced by the ionizable additives. Gas pressures of about 50 to 1,200 torr can suitably be employed.

Operating energies for the lamps of this invention must be sufficiently high to produce the acoustical shock wave which is necessary to cause the evaporation of the ionizable additive. Pulse discharges of at least 5 Joules/cm. are generally required to accomplish this objective in a lamp of 7mm bore. More usually, at least about 45 Joules/cm. should be used to produce a shock wave which is sufficient to evaporate an ionizable thallium additive.

In addition to the starting rare gas, the envelope should be charged with the low vapor pressure ionizable additive, optionally in combination with another heavy gas or vapor to fortify the emission spectrum in desirable regions. The amount of low vapor ionizable additive which can be vaporized under operating conditions depends upon the operating parameters. Generally, sufficient additive should be used to coat the inner walls of the envelope with a coating at least 25 Angstroms in thickness. Thus, a lamp operating in the range of about 5 Joules/cm. to about 100 Joules/cm. and charged with rare gas to a pressure between 50 and 1,200 torr, will generally require less than 1 gram of ionizable additive to form such coating.

The ionizable additive can be incorporated into the lamp by depositing a uniform coating by self evaporation of chips of the pure metallic form or laying the powdered additive down around the inside of the envelope.

The low vapor pressure ionizable additives which can be employed in accordance with this invention are any metals with a vapor pressure below about 10^{-8} torr at 25°C. and inorganic compounds of such metals. Examples of such additives are thallium, thallium iodide, zinc iodide, aluminum, lead, cadmium, and the like, as well as combinations of such materials with each other and with high vapor pressure additives such as mercury.

The lamp of the present invention is quite distinct from standard lamps which depend upon thermal evaporation of additives in a steady or pulsed discharge. In a steady discharge lamp the vapor pressure of the additive depends upon the lowest temperature of the discharge tube. In the present invention, the lamp is not dependent upon thermal evaporation of the additive. In the present invention, the lamp envelope is not heated by external means, the material being evaporated into the discharge by an acoustical shock wave. The vapor pressure of the ionizable additive never remains high as

it redeposits on the tube wall as the discharge quenches. Therefore, little energy is utilized in keeping the vapor pressure high, as in thermal evaporation. There is also less time for the material to migrate to cooler parts of the wall, so that the coating remains uniform over many pulses. Thus, the lamps of this invention, unlike those which depend upon thermal evaporation, do not have to be maintained sufficiently hot to prevent collection of the metallic additive at the cooler parts and thereby sustain the desired vapor pressure of the additive.

Under optimal operating conditions the metallic compound lamps of this invention produce an ultraviolet continuum at energy densities lower than lamps charged with rare gas alone. Theoretically, the additive compound increases the light intensity by increasing the pressure in the lamp thereby causing a higher temperature discharge. It is speculated, that the continuum is due to "free-free" transitions which are possible at lower energy densities because of the comparatively low ionization potential of the additive. Another possible explanation for the efficiency at which the lamp of the present invention can be operated depends upon the high density of plasma near the envelope wall. Thus, a rare gas plasma is quite opaque so that one normally sees only a short distance into the tube. Therefore, most radiation initiated near the tube axis is totally absorbed by the heated gas. By timing the current peak to occur just after the shock front has evaporated material from the tube wall, the plasma density near the tube wall where radiation easily escapes, is greatly increased. This also leads to a higher plasma temperature near the wall than is normally attainable at similar input energy. It is believed that at optimum pulse duration, little material has migrated to the envelope axis and the temperature there remains close to that of the arc temperature of pure xenon. This theoretical explanation is given for purposes of explanation but is not intended to serve as a limitation upon a scope of the present invention.

With a pure metallic wall coating, such as pure thallium, the fact that a line spectrum is obtained with relatively low energy pulses can have a direct application to xerographic copying equipment using flash exposure, especially such equipment which utilizes selenium as the photoconductor. Presently used xenon lamps emit a continuum which is strong in blue radiation and filters must occasionally be used to remove this undesirable component in order to obtain acceptable blue on white copy. The thallium line radiation is strong in 3776 and 5350A emission, both regions of high blue on white contrast. Moreover, since the lamps of this invention can have other metals added in the envelope, in combination with thallium, the desired emission range can be extended, and in fact tailored, to a predetermined spectral emission.

The following examples further define, describe and compare aspects of the lamp devices of the present invention and the manner by which such devices can be effectively utilized. These examples are not intended to limit, but only to illustrate, the present invention.

EXAMPLE 1

Three additive combinations, viz. thallium iodide; thallium iodide and mercury; and pure thallium were used in this example. The materials were inserted into flash tubes and distributed as evenly as possible over

the inside walls. The flash tubes were of 7×9mm diameter Suprasil quartz and used PEK XE-15 electrodes spaced 6 inches apart. A filling pressure of 50 torr xenon was chosen. A 150μf capacitor bank, charged to various voltages was discharged across the tubes and spectra were recorded photographically. The results are described below:

1. The lamp containing thallium iodide plus xenon, at 5 Joules/cm. and 20 Joules/cm., showed the thallium iodide thickly deposited over the entire tube wall and little radiation was able to penetrate therethrough. However, at 45, 61 and 80 Joules/cm., an unexpected and strong continuum, peaking at about 3,500A was emitted upon which was superimposed a broadened thallium absorption spectrum. In this spectral region, the continuum was more intense than that of a 300 torr xenon lamp flashed at the same voltage. A pure xenon lamp at 50 torr emits only a xenon spark spectrum.

2. The lamp containing thallium iodide, mercury and xenon yielded results similar to the lamp having thallium iodide and xenon, except that a strong mercury emission spectrum was superimposed on the continuum. As less thallium iodide was inserted into this tube, a weak spectrum was obtained at 20 Joules/cm. also. This result illustrates the importance of placing the proper amount of additive material into the tube so that the thallium iodide completely evaporates at the chosen firing energy.

3. Thallium and xenon produced strong thallium emission lines which were visible at 5, 20 and 45 Joules/cm. firing energy, with no xenon lines apparent. A weak continuum at 5 Joules/cm. increased in intensity with input until at 80 Joules/cm., thallium was in absorption over a strong continuum. Thus, at low energies almost a pure line spectrum of this additive is obtained. The thallium coated the inner surface of the tube wall rather uniformly showing the suitability of initially disposing the thallium as a uniform coating over the entire inner surface of the tube.

EXAMPLE 2

An additive combination of lead plus cadmium was coated on the wall of a 7×9mm diameter quartz lamp filled with 200 torr xenon by disposing tiny chips of the metals along the length of the tube and flashing several times. These metals were specifically chosen because they have several strong spectral emission lines in the ultraviolet region of the spectrum near 2000A. Emission in this region of the spectrum was desired for a particular photochemical reaction because the absorption band of the particular material peaked near 2100A. At 5, 20 and 45 Joules/cm. strong emission lines appeared: Cadmium lines at 2144, 2195, 2239 and 2265A, and lead lines at 2170 and 2204A were especially prominent and greatly increased the emission in this region of the spectrum as compared with a lamp filled with 300 torr of pure xenon and fired at the same energies.

EXAMPLE 3

A thallium plus europium coating was disposed on the wall of a 200 torr xenon lamp as described in Example 2. Europium has strong emission lines at 4436 and 5257A which appeared along with the thallium spectrum, described in Example 1 (3), when pulsed at 5, 20 and 45 Joules/cm.

EXAMPLE 4

Aluminum chips were dispersed along a lamp of 1,200 torr xenon pressure. Although a lamp of this pressure produces a strong continuum, the aluminum emission lines at 3944 and 3962A were prominent above the continuum when the lamp was pulsed at 22 and 45 Joules/cm.

Although specific devices and conditions were set forth above in the examples, it should be understood that this was only for the purpose of illustrating the present invention. Other modifications of the present invention will occur to those skilled in the art upon a reading of the present disclosure. These are intended to be included within the scope of this invention.

What is claimed is:

1. A high intensity inert gas flash lamp adapted to be operated with a predetermined power input, said lamp comprising a sealed elongated envelope formed of light transmitting material having a high melting point, electrodes operatively disposed within said envelope and adapted to sustain a pulsed arc discharge therebetween, power means for applying said predetermined power input across said electrodes, a predetermined amount of rare gas and a predetermined amount of an ionizable additive disposed within said envelope, the relationship of the dimensions of said envelope and the amount of additive in said envelope being such that during operation of said lamp sufficient pulsed energy is supplied by said power means across the electrodes

to form an acoustical shock wave of sufficient amplitude to evaporate said ionizable additive and produce a spectral emission characteristic of both the rare gas and the ionizable additive.

2. The lamp of claim 1 in which the pressure of rare gas within the lamp is in the range of about 50 to 1,200 torr.

3. The lamp of claim 1 in which the additive is thallium iodide.

4. The lamp of claim 1 in which the additive is thallium.

5. The lamp of claim 4 having a length of at least 7 mm and adapted to be operated at an energy level of at least 45 Joules/cm.

6. The lamp of claim 3 in which mercury is disposed within the envelope along with thallium iodide.

7. The lamp of claim 1 in which the additive is aluminum.

8. The lamp of claim 1 in which the additive is a combination of lead and cadmium.

9. The lamp of claim 1 in which the additive is a combination of thallium and europium.

10. The lamp of claim 1 wherein the rare gas is xenon.

11. The lamp of claim 1 wherein said ionizable additive is coated upon the inner wall of said envelope, and wherein said shock wave evaporates said additive from the envelope wall during operation.

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