

## PATENT SPECIFICATION

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## DRAWINGS ATTACHED

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## (54) FLUORESCENT LAMPS

(71) We, WESTINGHOUSE ELECTRIC CORPORATION of Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania, United States of America, a company organised and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to fluorescent lamps and, in particular, to general illumination fluorescent lamps which accentuate the color of green objects, and is an improvement in or modification of the invention of copending Application No. 23214/71 (Serial No. 1293717).

Fluorescent lamps are normally designed to provide a specific color, such as "cool white" for example, while simultaneously providing maximum lumens. The most commonly used phosphors are of the so-called halophosphate type. For some applications, the illumination of green colored objects is not as good as desired, and while it is possible to utilize larger amounts of green-emitting phosphor to improve the color appearance of green objects, the color of the resulting overall lamp emission will then have a greenish cast, which makes the lamp unacceptable. An example of an application where the use of a green accentuating lamp would be desirable, provided the disadvantage of an unnatural color appearance for all other illuminated objects could be overcome, is a vegetable counter in a supermarket.

According to the present invention a fluorescent lamp comprises a sealed radiation-transmitting envelope having electrodes disposed proximate the ends thereof and enclosing a small charge of mercury and inert ionizable gas and a phosphor coating carried on the interior surface of said envelope, said phosphor coating principally comprising a blend

of three different phosphors, a first of said phosphors having an emission peak at between 610 nm and 650 nm and a broad band emission having a bandwidth of more than 100 nm at an emission intensity which is 50% of the maximum emission intensity thereof, a second of said phosphors comprising a blue emitting halophosphate and having an emission peak between 435 nm and 500 nm and a broad band emission having a bandwidth of more than 100 nm at an emission intensity which is 50% of the maximum emission intensity thereof, and the third of said phosphors having an emission peak between 510 nm and 540 nm and a narrow band emission having a bandwidth of less than 50 nm at an emission intensity which is 50% of the maximum emission intensity thereof, and said phosphors being present in predetermined proportions to provide the desired color of composite emission, whereby the narrow band emission of the third phosphor causes the color of green objects illuminated by said lamp to be accentuated with respect to their natural green color while the coupling of said emission with the broad band emissions of the first and second phosphors provides an accurate color rendition for all other objects so illuminated.

In order that the invention can be more clearly understood, convenient embodiments thereof will now be described by way of example, with reference to the accompanying drawings in which:—

Figure 1 is an elevational view, partly broken away, illustrating a fluorescent lamp which incorporates a phosphor blend in accordance with the present invention;

Fig. 2 is a graph of relative energy versus wavelength showing the emission of the blue halophosphate, short wavelength emitting phosphor which comprises a component of the phosphor blend;

Fig. 3 is a graph of relative energy versus wavelength showing the emission of the long

wavelength emitting phosphor which comprises another component of the phosphor blend;

5 Fig. 4 is a graph of relative energy versus wavelength showing the emission of the narrow-band-emitting green phosphor which is used in the composite blend;

10 Fig. 5 is a graph of relative energy versus wavelength illustrating the emission of a short wavelength emitting phosphor which when mixed with the blue halophosphate phosphor constitutes a component of the phosphor blend; and

15 Fig. 6 is a graph of relative energy versus wavelength showing the emission of an alternative narrow-band-emitting green phosphor which can be used as this component of the phosphor blend.

20 Referring to Fig. 1, the numeral 10 indicates a fluorescent lamp comprising a tubular, vitreous, light-transmitting envelope 12 coated internally with a blend of phosphor 14 in accordance with the present invention. Sealed at each end of the envelope 12 are mounts, each comprising an electrode 16, reentrant stem press 18, and lead-in conductors 20. Base caps 22 and base pins 24 are provided at the envelope ends. The envelope contains a small charge of mercury 2 and an inert, ionizable starting gas such as argon at a pressure of 3 torrs for example. Except for the phosphor coating, the construction of the lamp 10 is conventional.

25 Referring to Fig. 2, there is illustrated the spectral energy distribution for a so-called blue halophosphate phosphor. In this figure and in Figures 3 to 6 all relative energies are normalized to a value of "100". This phosphor has an emission peak at about 480 nm, and at an emission intensity which is 50% of the maximum measured emission intensity, the bandwidth of the phosphor is about 127 nm. Such a phosphor can be prepared by mixing the following constituents in the following molar proportions: Calcium pyrophosphate, 1.5 moles; calcium carbonate, 1.275 moles; calcium fluoride, 0.45 moles; cadmium oxide, 0.05 mole; and antimony trioxide 0.015 mole. This mixture is fired in a covered crucible at about 1200° C for about three hours, the fired material is then lightly crushed, washed with a dilute solution of nitric acid, water rinsed and dried.

30 In Fig. 3 is shown the spectral energy emission for strontium-magnesium orthophosphate activated by tin. Such a phosphor has an emission which appears orange and an emission peak at a wavelength of approximately 630 nm. The emission bandwidth is such that at an emission intensity which is 50% of the maximum phosphor emission intensity, the bandwidth is approximately 135 nm. Such a phosphor can be readily prepared by mixing 6.5 moles strontium oxide with 3.5 moles phosphorus pentoxide, 0.3 mole magnesium oxide and 0.2 mole stannous oxide. The mix-

ture is fired in a slightly reducing atmosphere such as nitrogen with 2% hydrogen for about three hours at approximately 1200° C in covered crucibles. In order to be usable in the present blends, such a long wavelength emitting phosphor should have an emission peak of from about 610 nm to 650 nm and a broad band emission having a bandwidth of more than 100 nm as measured at an emission intensity which is 50% of the maximum measured emission intensity of the phosphor.

35 Referring to Fig. 4, there is illustrated the spectral distribution for manganese-activated zinc silicate phosphor. This phosphor has an emission peak at approximately 530 nm and a narrow bandwidth such that at 50% of the maximum measured emission intensity, the bandwidth of the phosphor is approximately 45 nm. Such a phosphor can be prepared by mixing 700 grams zinc oxide with 300 grams silicon dioxide and 30 grams manganous carbonate. For best results there is also included with the phosphor raw mix approximately two grams of plumbous fluoride and a 0.01 gram arsenic trioxide. The resulting raw mix is fired in an air atmosphere for approximately three hours at about 1300° C in covered crucibles. Other phosphors can be substituted for the preferred zinc silicate provided they have an emission which peaks at from about 510 nm to 540 nm and have a narrow band emission with a bandwidth of less than 50 nm as measured at an emission intensity which is 50% of the maximum measured emission intensity for the phosphor.

40 After preparation, the foregoing phosphors are mixed in predetermined proportions which are selected to provide a desired color for the composite emission from the lamp. As an example, the relative weight proportions of the orthophosphate, blue halophosphate and silicate are in the approximate ratio of 63:29:8.

45 The color of the resulting lamp which incorporates the foregoing specific blend approximates that of a so-called "cool white" fluorescent lamp. It has been found that for the specific phosphors as outlined hereinbefore, the orthophosphate desirably is present in amount of from 58% to 68%, preferably 63% by weight of the total phosphor, the blue halophosphate in amount of from 24% to 34%, preferably 29% by weight of the total phosphor, and the silicate in amount of from 6% to 11% preferably 8% by weight of the total phosphor, in order that the color of the resulting lamp will approximate the appearance of the usual fluorescent lamps. In this manner there has been provided a lamp which accentuates the color of green objects while simultaneously providing good color rendition of all other objects illuminated thereby, as well as providing a lighted appearance which closely approximates adja-

cent lamps which are not tailored to accentuate any particular color.

Referring to Fig. 5, there is illustrated the spectral energy distribution for a calcium tungstate phosphor which when mixed with the blue halophosphate phosphor can constitute the short wavelength emitting phosphor component of the blend. The calcium tungstate peaks at about 440 nm and at an emission intensity which is 50% of the maximum measured emission intensity, the bandwidth of the phosphor is about 125 nm. Such a phosphor is known in the art and can be prepared by blending one mole of calcium oxide with 1 mole tungstic oxide ( $\text{WO}_3$ ) and 0.01 mole lead oxide ( $\text{PbO}$ ), with the resulting raw-mix being fired at a temperature of  $1100^\circ\text{C}$  in an air atmosphere for approximately one hour. Thereafter the resulting phosphor is lightly crushed to finely divided form prior to use. For the short wavelength emitting component of the blend, it has been found that the emission peak should be from about 435 nm to 500 nm, and in order to provide the proper broad bandwidth, the emission intensity as measured at 50% of the maximum phosphor emission intensity should have a bandwidth of more than 100 nm.

As another example, manganese-activated zinc magnesium silico-germanate can be substituted for the zinc silicate in the foregoing blend, with the proportions of the silico-germanate in the blend being approximately the same as the zinc silicate which it replaces. As will be seen from Fig. 6, this phosphor has an emission peak at about 535 nm, and at an emission intensity which is 50% of the maximum measured emission intensity, the bandwidth of the phosphor is about 45 nm. Such a phosphor is prepared by mixing the following constituents in the following molar proportions: 1.7 moles zinc oxide, 0.3 mole magnesium fluoride, 0.6 mole germanium dioxide,  $5 \times 10^{-4}$  mole arsenic trioxide, and  $4 \times 10^{-4}$  mole lead oxide ( $\text{PbO}$ ). The raw-mix is fired for two hours in air at  $1200^\circ\text{C}$ , lightly ground and then refired for one hour in a nitrogen atmosphere at  $1100^\circ\text{C}$ .

As another example, strontium-zinc orthophosphate activated by stannous tin, which is a known phosphor, can be substituted for the foregoing strontium-magnesium orthophosphate in the foregoing blend examples.

The foregoing phosphor species which are used to form the blends can also be mixed. As an example, the blue halophosphate can be mixed with the calcium tungstate in equal weight amounts. The resulting preferred blend will then comprise 66% by weight strontium-magnesium orthophosphate, 10% by weight zinc silicate, 12% by weight calcium tungstate, and 12% by weight of blue halophosphate.

While the present phosphor blend principally comprises three major phosphor com-

ponents as described hereinbefore, it should be understood that small amounts of other phosphors may also be included in the blend, such as for special color rendition effects. For example, the blend could also include two percent by weight of any known long wavelength emitting phosphor or a short wavelength emitting phosphor.

#### WHAT WE CLAIM IS:—

1. A fluorescent lamp which comprises a sealed radiation-transmitting envelope having electrodes disposed proximate the ends thereof and enclosing a small charge of mercury and inert ionizable gas and a phosphor coating carried on the interior surface of said envelope, said phosphor coating principally comprising a blend of three different phosphors, a first of said phosphors having an emission peak between 610 nm and 650 nm and a broad band emission having a bandwidth of more than 100 nm at an emission intensity which is 50% of the maximum emission intensity thereof, a second of said phosphors comprising a blue emitting halophosphate and having an emission peak between 435 nm and 500 nm and a broad band emission having a bandwidth of more than 100 nm at an emission intensity which is 50% of the maximum emission intensity thereof, and the third of said phosphors having an emission peak between 510 nm and 540 nm and a narrow band emission having a bandwidth of less than 50 nm at an emission intensity which is 50% of the maximum emission intensity thereof, and said phosphors being present in predetermined proportions to provide the desired color of composite emission, whereby the narrow band emission of the third phosphor causes the color of green objects illuminated by said lamp to be accentuated with respect to their natural green color while the coupling of said emission with the broad band emissions of the first and second phosphors provides an accurate color rendition for all other objects so illuminated.

2. A lamp according to claim 1, wherein the first phosphor is at least one of tin-activated strontium-magnesium orthophosphate and stannous tin-activated strontium-zinc orthophosphate and the third phosphor is at least one of manganese-activated zinc silicate and manganese-activated zinc magnesium silico-germanate.

3. A lamp according to claim 2, wherein the orthophosphate is present in amount of from 58% to 68% by weight of total phosphor, the blue halophosphate is present in amount of from 24% to 34% by weight of total phosphor, and the silicate is present in amount from 6% to 11% by weight of total phosphor.

4. A lamp according to claim 3, wherein the relative weight proportions of the ortho-



cent lamps which are not tailored to accentuate any particular color.

Referring to Fig. 5, there is illustrated the spectral energy distribution for a calcium tungstate phosphor which when mixed with the blue halophosphate phosphor can constitute the short wavelength emitting phosphor component of the blend. The calcium tungstate peaks at about 440 nm and at an emission intensity which is 50% of the maximum measured emission intensity, the bandwidth of the phosphor is about 125 nm. Such a phosphor is known in the art and can be prepared by blending one mole of calcium oxide with 1 mole tungstic oxide ( $\text{WO}_3$ ) and 0.01 mole lead oxide ( $\text{PbO}$ ), with the resulting raw-mix being fired at a temperature of  $1100^\circ\text{C}$  in an air atmosphere for approximately one hour. Thereafter the resulting phosphor is lightly crushed to finely divided form prior to use. For the short wavelength emitting component of the blend, it has been found that the emission peak should be from about 435 nm to 500 nm, and in order to provide the proper broad bandwidth, the emission intensity as measured at 50% of the maximum phosphor emission intensity should have a bandwidth of more than 100 nm.

As another example, manganese-activated zinc magnesium silico-germanate can be substituted for the zinc silicate in the foregoing blend, with the proportions of the silico-germanate in the blend being approximately the same as the zinc silicate which it replaces. As will be seen from Fig. 6, this phosphor has an emission peak at about 535 nm, and at an emission intensity which is 50% of the maximum measured emission intensity, the bandwidth of the phosphor is about 45 nm. Such a phosphor is prepared by mixing the following constituents in the following molar proportions: 1.7 moles zinc oxide, 0.3 mole magnesium fluoride, 0.6 mole germanium dioxide,  $5 \times 10^{-4}$  mole arsenic trioxide, and  $4 \times 10^{-4}$  mole lead oxide ( $\text{PbO}$ ). The raw-mix is fired for two hours in air at  $1200^\circ\text{C}$ , lightly ground and then refired for one hour in a nitrogen atmosphere at  $1100^\circ\text{C}$ .

As another example, strontium-zinc orthophosphate activated by stannous tin, which is a known phosphor, can be substituted for the foregoing strontium-magnesium orthophosphate in the foregoing blend examples.

The foregoing phosphor species which are used to form the blends can also be mixed. As an example, the blue halophosphate can be mixed with the calcium tungstate in equal weight amounts. The resulting preferred blend will then comprise 66% by weight strontium-magnesium orthophosphate, 10% by weight zinc silicate, 12% by weight calcium tungstate, and 12% by weight of blue halophosphate.

While the present phosphor blend principally comprises three major phosphor com-

ponents as described hereinbefore, it should be understood that small amounts of other phosphors may also be included in the blend, such as for special color rendition effects. For example, the blend could also include two percent by weight of any known long wavelength emitting phosphor or a short wavelength emitting phosphor.

#### WHAT WE CLAIM IS:—

1. A fluorescent lamp which comprises a sealed radiation-transmitting envelope having electrodes disposed proximate the ends thereof and enclosing a small charge of mercury and inert ionizable gas and a phosphor coating carried on the interior surface of said envelope, said phosphor coating principally comprising a blend of three different phosphors, a first of said phosphors having an emission peak between 610 nm and 650 nm and a broad band emission having a bandwidth of more than 100 nm at an emission intensity which is 50% of the maximum emission intensity thereof, a second of said phosphors comprising a blue emitting halophosphate and having an emission peak between 435 nm and 500 nm and a broad band emission having a bandwidth of more than 100 nm at an emission intensity which is 50% of the maximum emission intensity thereof, and the third of said phosphors having an emission peak between 510 nm and 540 nm and a narrow band emission having a bandwidth of less than 50 nm at an emission intensity which is 50% of the maximum emission intensity thereof, and said phosphors being present in predetermined proportions to provide the desired color of composite emission, whereby the narrow band emission of the third phosphor causes the color of green objects illuminated by said lamp to be accentuated with respect to their natural green color while the coupling of said emission with the broad band emissions of the first and second phosphors provides an accurate color rendition for all other objects so illuminated.

2. A lamp according to claim 1, wherein the first phosphor is at least one of tin-activated strontium-magnesium orthophosphate and stannous tin-activated strontium-zinc orthophosphate and the third phosphor is at least one of manganese-activated zinc silicate and manganese-activated zinc magnesium silico-germanate.

3. A lamp according to claim 2, wherein the orthophosphate is present in amount of from 58% to 68% by weight of total phosphor, the blue halophosphate is present in amount of from 24% to 34% by weight of total phosphor, and the silicate is present in amount from 6% to 11% by weight of total phosphor.

4. A lamp according to claim 3, wherein the relative weight proportions of the ortho-



phosphate, the blue halophosphate and the silicate are approximately 63:29:8.

5. A lamp according to claim 1 or 2, wherein the second phosphor additionally includes calcium tungstate.

- 5 6. A lamp according to claim 5, wherein the blue halophosphate and calcium tungstate of the second phosphor are present in equal proportions.

7. Fluorescent lamps substantially as described herein with particular reference to the accompanying drawings. 10

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