

PATENT SPECIFICATION



DRAWINGS ATTACHED

L178,947

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International Classification:—C 03 c 3/30

COMPLETE SPECIFICATION

Electric Lamp having an Envelope Composed of Photoresistant Soda-Lime Silicate Glass

We, WESTINGHOUSE ELECTRIC CORPORATION, of Three Gateway Center, Pittsburgh 30, Pennsylvania, United States of America, a corporation organized 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 electric lamps and has particular reference to an improved fluorescent, incandescent and mercury-vapor lamp and to envelopes that enhance the performance of such lamps.

Among the factors which determine the light output and maintenance of an electric lamp are the optical and photosensitivity characteristics of the lamp envelope. In the case of a fluorescent lamp, the envelope is made from ordinary soda-lime silicate glass to reduce costs. It has been found that a typical glass of this type that is used for fluorescent glass tubing has an initial absorption coefficient of approximately 0.05 cm^{-1} in the visible region and that it progressively increases to a value of over 0.5 cm^{-1} as the lamp is burned and the envelope is irradiated with ultra-violet-radiations generated by the discharge. This gradual loss of transmissivity is caused by the so-called "solarization" effect of the impinging ultraviolet radiations which produces a discoloring or darkening of the envelope. As far as the optical properties of the lamp envelope are concerned, the two key parameters are, accordingly, the absorption coefficient of the glass both initially and after exposure to intense ultraviolet-radiation during the life of the lamp.

In the case of a fluorescent lamp, discoloration might result from a chemical reaction between ions in the gaseous discharge and the [Price 5s. 0d.]

glass. Chemical properties and stability of the glass envelope are, accordingly, also factors which could affect its transmissivity, and, thus, the light output of the lamp during its life.

The light losses due to absorption are considerable. In a fluorescent lamp, for example, practically all of the light is generated by the phosphor coating which is deposited on the inner surface of the tubular glass envelope. Ordinarily, when light is generated within a transparent cylindrical tube, it is not totally reflected at the outer wall of the tube because, in such a geometry, none of the light can strike the outer surface at an angle of incidence greater than the minimum required for total internal reflection. This angle is approximately 41° for a material having an index of refraction of 1.52. For angles less than 33° , only 4% of the light will be reflected and most of this will pass through the inner wall into the tube, and so, will not be completely lost.

However, since there is a phosphor layer on the inner surface of a fluorescent lamp envelope, many of the phosphor particles will inherently make optical contact with the glass and, thus, light can enter the wall of the tubular envelope at an angle of incidence greater than 41° . A fraction of this light will, accordingly, be trapped in the envelope wall and be lost by absorption. In addition to this loss of trapped totally-reflected light, there is a loss due to the attenuation of the light rays which pass directly through the glass envelope without being trapped. Of course, as the glass solarizes and its absorption coefficient increases, the light losses also increase.

Both of the aforementioned losses can be calculated. Using reasonable values for the amount of optical contact between the phosphor particles and the glass envelope and the aforementioned values for the absorption coefficients, the calculated total loss due to light

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absorption varies from 1.5% for a new lamp to 7% for a lamp near the end of its useful life, that is, after over 10,000 hours of burning. Actual lamp tests utilizing fluorescent lamps having bulbs made with special ultra-violet-transmitting glass (Corning 9821) that has a very low iron content (approximately 0.01%) and a low initial coefficient of absorption for visible light have shown that 2% of the light was absorbed at zero hours and that the absorption gradually increased to 3.5% after only 3000 hours of burning.

Specially formulated soda-lime glasses having low coefficients of absorption for visible light and others which inhibit solarization are known in the art. However, they either require the removal of iron and other impurities from the raw mix materials, and are thus too expensive for use in the lamp industry, or require the use of additives, such as Sb_2O_3 , which are costly and render the widespread use of the glass in lamp envelopes economically impractical.

It is the object of the present invention to provide an electric lamp that generates both visible and ultraviolet-radiations and has an improved lumen maintenance and light output throughout its useful life.

With this object in mind the invention resides in an electric lamp having means that generates both ultraviolet and visible radiations when the lamp is energized, enclosed in a soda-lime silicate glass envelope, wherein the glass contains no more than 0.07% by weight of ferric oxide and an ultraviolet-radiation absorbing material in an amount sufficient to inhibit discoloration of the glass by impinging ultraviolet radiation and maintain the absorption coefficient of the glass in the visible region below approximately 0.4 cm^{-1} during a major portion of the useful life of the lamp, said material comprising from 0.8% to 10% by weight titanium oxide or from 0.5 to 1% by weight molybdenum oxide or mixtures thereof.

The amount of Fe_2O_3 is controlled by using raw materials that will provide the desired concentrations of the various oxides in the finished glass. Since there are sands available having iron contents which meet this requirement, the glass can be prepared from industrial-grade sands which do not have to be processed or cleansed in any way. The glass is thus comparable in cost with conventional soda-lime silicate glasses now being used for fluorescent lamp tubing.

From the cost standpoint, TiO_2 is preferred as the ultraviolet-absorbing material since it is used widely in the paint industry and is thus not as expensive as MoO_3 . The absorption coefficient of the modified glass both prior to and after prolonged exposure to intense ultraviolet irradiation is lower than conventional soda-lime silicate glass and provides a corresponding improvement in the light output of

the fluorescent lamp throughout its useful life. Its ability to resist solarization also makes the glass suitable for use in incandescent lamp bulbs and in the protective outer envelopes of high-pressure mercury vapor lamps.

In order that the invention may be more clearly understood and readily carried into effect, reference will now be made to the accompanying drawings, in which:

Figure 1 is an elevational view of an improved fluorescent lamp having envelope composed of the photo-resistant soda-lime silicate of this invention;

Fig. 2 is a graph illustrating the light-absorption characteristics of various glasses and a TiO_2 -containing glass of the present invention after exposure to ultraviolet radiation;

Fig. 3 is a graph illustrating the marked reduction in the light-absorbing characteristic of a soda-lime silicate glass that has been modified by adding selected amounts of TiO_2 , in accordance with the invention; and,

Figs. 4 and 5 are elevational views of a high-pressure mercury vapor lamp and an incandescent lamp, respectively, having envelopes composed of the improved glass of this invention.

In Figure 1 there is shown a fluorescent lamp 5 having a tubular glass envelope 6 that is sealed at each end by a glass stem 7 and is interiorly coated with a layer 8 of a suitable phosphor that is responsive to ultraviolet (UV) radiations. The sealed ends of the envelope are fitted with base members 9 having the usual pin contacts 19 that are connected to a pair of lead wires 11 and 12 sealed through the respective stems 7. The inner ends of the lead wires are attached to electrodes 13 which emit electrons and sustain the arc discharge when the lamp is energized. The envelope 6 is charged with a predetermined amount of mercury and a suitable starting gas, such as neon or a mixture of neon and argon at a fill pressure of approximately 2 mm., in accordance with standard lamp-making practice.

The envelope 6 in accordance with the present invention is fabricated from soda-lime silicate glass that contains no more than 0.07% by weight Fe_2O_3 and critical amounts of TiO_2 , MoO_3 or mixtures thereof as UV absorbing material. Preferably, the soda-lime silicate glass is of the same basic type as that presently being used for fluorescent lamp tubing but which is modified in accordance with the invention by the selection of the sand and other raw materials and by the addition of the aforementioned UV-absorbing materials, during the melting process, to provide a finished glass that has the desired composition and solarization-inhibiting properties. In addition to the basic constituents (viz, SiO_2 , Na_2O , CaO) of the soda-lime silicate glass, the glass also contains minor amounts of additional usual constituents, such as MgO , K_2O , As_2O_3 and

Al_2O_3 . The composition of such modified glasses and that of conventional soda-lime glass are given below in Table I. The permissible ranges and preferred amounts of the

various oxides in the modified glasses are expressed in percentages by weight as calculated from the batch.

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TABLE I

Constituent	Percent by Weight			
	Range	Preferred		Conventional
SiO_2	60—75	72.5	71.3	72.5
Na_2O	5—18	15.5	15.5	16.5
CaO		5.3	5.3	5.3
	4—13			
MgO		3.7	3.7	3.7
Al_2O_3	0.5—3.4	1.98	1.85	1.7
K_2O	0.1—2	0.23	0.23	0.18
TiO_2	0.8—10	—	2.0	—
or				
MoO_3	0.5—1	0.75	—	—
Fe_2O_3	0.07	0.05	0.05	0.05
As_2O_3	0.01—2	0.07	0.07	0.07

10 Sb_2O_3 can be substituted, if desired, for the As_2O_3 as the firing agent.

The amount of the ultraviolet-absorbing material (or materials) is quite critical, as in-

indicated by the variations in the coefficients of absorption of the series of glasses listed in Table II below and of the series depicted graphically in Figures 2 and 3.

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TABLE II

Absorption Coefficients (cm^{-1}) of Standard Soda-Lime
Silicate Glass and Modified Glasses Before and After
Exposure to Unfiltered Ultraviolet Radiation

Code and Glass Type	Before		After	
	4800 Å	5800 Å	4800 Å	5800 Å
(S) Standard-Contains .05% Fe_2O_3	0.072	0.058	0.808	0.437
(A) Modified " " " and 0.25% TiO_2	0.044	0.047	0.202	0.100
(B) " " " " " 0.5% "	0.042	0.055	0.198	0.125
(C) " " " " " 0.6% "	—	—	0.115	0.063
(D) " " " " " 0.8% "	—	—	0.093	0.048
(E) " " " " " 1.0% "	*	0.026	0.078	0.052
(F) " " " " " 1.5% "	—	—	0.080	0.060
(G) Modified " " " " 0.5% MoO_3	0.147	0.150	0.264	0.166
(H) " " " " " 0.75% "	0.057	0.066	0.185	0.114
(I) " " " " " 1.0% "	0.107	0.115	0.187	0.101
(J) Standard " No Fe_2O_3 , TiO_2 , or MoO_3	0.012	0.019	3.16	1.77
(K) " " " " " " or As_2O_3	0.054	0.029	4.18	2.78

* Too low for measurement.

— No measurement made.

All percentages are percentages by weight.

The glasses were prepared by melting the raw mix constituents (reagent grade) in platinum crucibles at 1500°C for 2 to 3 hours and then pouring the molten glass onto graphite slabs. They were then annealed by slowly cooling them from a temperature of 550°C . The resulting plates of glass were then ground and polished to a thickness of 0.038" (the approximate thickness of a fluorescent lamp bulb) and the visible absorption (4000—7000 Å) was measured with a Model 14 Cary recording spectrophotometer while the samples were immersed in an oil contained in a glass absorption cell which had a path length of 1 centimeter. The oil, having a refractive index close to that of the glass, was used to minimize or eliminate reflection losses. After the initial measurements were taken, the plates were irradiated with intense UV radiations by mounting them side by side 6 inches from a high-pressure mercury vapor arc tube fitted with a reflector. The plates were ex-

posed to the arc tube for 16 hours and the visible absorption measurements were again taken.

As a control, a sample was made of a glass having the same composition as that of conventional fluorescent lamp tubing and contained 0.05% by weight Fe_2O_3 . This control sample is designated glass S in Table II. The other glasses A to K were of the same basic composition except for the changes indicated.

As will be noted from the data in Table II, the series of TiD_2 -modified soda-lime silicate glasses (glasses A through F) have a lower absorption coefficient both before and after UV-irradiation than the unmodified glass S, with the optimum reduction occurring with glasses D to F having from 0.8 to 1.5% by weight TiO_2 . These glasses thus have excellent optical properties and photoresistance.

While the series of glasses containing MoO_3 (glasses G to I) are not quite as good as the TiO_2 -containing glasses, they are superior to

the standard glass S, as shown by the marked reduction of the absorption coefficients after UV irradiation.

5 Even though the MoO_3 -modified glasses tended to increase the initial coefficient of absorption compared to the standard glass S, they did effect a marked reduction in absorption after UV irradiation showing that they experienced less discoloration and thus would
10 be quite suitable as regards inhibiting light losses due to solarization of the lamp envelope.

Surprisingly, it was found that glasses free of Fe_2O_3 were more susceptible to darkening under UV irradiation than glasses which contain controlled amounts of Fe_2O_3 and a selected UV-absorbing material. This is illustrated by glasses J and K in Table II. As will be noted glass J is identical to the standard glass except for the absence of Fe_2O_3 , and while it had a lower initial absorption coefficient its coefficient after UV irradiation was much higher compared to glass S. Glass K, which is also of the same basic composition as the standard glass S but devoid of both Fe_2O_3 and As_2O_3 had an even higher absorption coefficient both before and after UV irradiation indicating that even small amounts of a UV absorber such as As_2O_3 are beneficial and serve to enhance the photoresistance of the glass. From 0.01 to 2% by weight of As_2O_3 is thus preferably included in the formulation as a UV-absorber, in which case the total content of such material is maintained between 0.6% to 12% by weight. The Fe_2O_3 content is also preferably kept as low as possible consistent with the economic necessity of using low cost sand.

The importance of limiting the iron content and maintaining the TiO_2 content within certain limits is also shown by the graphs depicted in Figs. 2 and 3. As indicated by curve 14 of Fig. 2, a conventional soda-lime silicate glass of the type presently used in fluorescent lamp tubing, but devoid of Fe_2O_3 , has an absorption coefficient after UV-irradiation that increases sharply as the wavelength of the light being transmitted decreases (from approximately 6400 Å to 4000 Å). The coefficient of absorption for this particular glass increased from a value of about 1.8 cm^{-1} in the yellow-red region to approximately 4.5 cm^{-1} in the blue-green region of the specter, indicating that it was severely discolored by the UV.

An identical glass containing 0.06% by weight Fe_2O_3 (which is the amount usually present in fluorescent lamp tubing glass) was far superior as regards discoloration, as indicated by curve 15 which shows that the coefficient of absorption was approximately 0.25 cm^{-1} at 6400 Å and gradually increased to a value of about 0.8 cm^{-1} at 4400 Å.

The same glass containing 0.07% by weight Fe_2O_3 was even more resistant to UV-

discoloration, as indicated by curve 16.

However, the same glass with 0.07% by weight Fe_2O_3 and 1% by weight TiO_2 exhibited excellent photoresistance, as indicated by curve 17 which shows that the coefficient of absorption at 6400 Å dropped to less than 0.1 cm^{-1} and then increased very gradually to about 0.15 cm^{-1} at 4000 Å. The addition of 1% by weight TiO_2 thus "desensitized" the glass, so to speak, to the discoloring effect of UV radiation and converted it into a material that retains its light-transmissivity to a very high degree.

The UV light source used to irradiate the glasses discussed above was a 200 watt high-pressure mercury vapor arc tube that produced 1.1 watts of 2537 Å radiation, measured at the wall of the arc tube. On the basis of the physical dimensions of the arc tube and the distance between the latter and the glass plates, the total UV dosage applied to the plates was approximately 0.96 milliwatts per cm^2 of 2537 Å radiation. In a clear four foot, 40 watt fluorescent lamp approximately 15 milliwatts per cm^2 of this same radiation strikes the inside walls of the bulb. However, in a fluorescent lamp coated with phosphor, the latter allows only about 3% of the generated UV to reach the glass envelope. Hence, this reduces the 2537 Å flux reaching the lamp envelope to 3% of 15 milliwatts/ cm^2 , or about 0.45 milliwatts/ cm^2 . Hence, the glasses listed in the Table II and depicted in Fig. 2 received about double the amount of 2537 Å radiation as does the glass in a fluorescent lamp envelope. The comparative tests were, accordingly, an accelerated or forced test as regards the amount of solarization or darkening produced by ultraviolet irradiation.

The amount of TiO_2 than can be added to the modified glass can vary within a rather broad range, as illustrated by the graph shown in Fig. 3. The data on which this graph is based was obtained by adding from 0.1% to 10% by weight of TiO_2 to a conventional soda-lime silicate glass that contained 0.07% by weight Fe_2O_3 and is used for fluorescent lamp tubing. The samples were irradiated for 30 minutes by placing them against a clear UV-transmitting quartz section of a low-pressure mercury vapor discharge lamp which was operated at an arc current and an ambient temperature which simulated these of a standard fluorescent lamp. The glass samples thus received about the same degree of UV-irradiation as does the bulb of a fluorescent lamp which is operated for the same length of time.

As indicated by curve 18 of Fig. 3, the absorption coefficient of these TiO_2 -modified glasses in the 4800 Å region decreased sharply to a value of 0.1 cm^{-1} as the TiO_2 content was increased from 0.1% to 0.8% by weight, reached a minimum of about 0.06 cm^{-1} at 2% TiO_2 , and then increased gradually to 0.1 cm^{-1} when the TiO_2 content

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reached 10% by weight by weight.

- 5 Curve 19 representing the absorption in the 5800 Å was similar but reached a minimum of 0.02 cm.⁻¹ at 3% by weight TiO₂ and increased to 0.04 cm.⁻¹ when 10% by weight TiO₂ was added to the glass.

Surprisingly, the glasses containing such relatively large amounts of TiO₂ did not crystallize and their melt viscosity appeared to be about the same as similar glasses without titania. Their working properties were also very similar, as is shown by Table III below.

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TABLE III

Physical Properties of Conventional
and TiO₂-Modified Soda-Lime
Silicate Glass Tubing

Property	Viscosity	Conventional Tubing	TiO ₂ -Modified Tubing (all percentages by weight)			
			1% TiO ₂	3% TiO ₂	5% TiO ₂	10% TiO ₂
Softening Temp.	log visc = 7.65	693°C	697°C	705°C	708°C	720°C
Annealing Point	log visc = 13.0	515°C	520°C	531°C	540°C	567°C
Strain Point	log visc = 14.5	469°C	475°C	491°C	503°C	532°C

- 15 As will be noted, the TiO₂ additive has little effect on the working properties of the glass, particularly in amounts up to 3% by weight. However, even the higher temperatures required for 5% and 10% by weight TiO₂ contents could be obtained by readjusting the sealing fires. Thus, fluorescent lamps having bulbs made from TiO₂-modified soda-lime silicate glasses of the present invention can be manufactured on the same high-speed manufacturing equipment now in use.
- 20 While the permissible range (R₁ in Fig. 3) for the TiO₂ content extends from 0.8% to not more than 10% by weight, the greatest reduction of the absorption coefficient is achieved with from 0.8% to not more than 3% by weight of TiO₂ and this range (R₂) is preferred. This range is also preferred because it will give the maximum degree of improvement at the least cost. Specific TiO₂ contents of from 1% to 2% by weight are also desirable for these reasons.

- 35 While there are at present no test data on the working properties of glasses containing MoO₃ as an additive in the quantities listed in Table II, it is believed that such properties would also be quite close to those of conventional soda-lime glass. The range in the case of MoO₃ is thus from 0.5% to 1% by weight, and approximately 0.75% by weight appears to be optimum.

- 45 Mixtures of the two additives can also be used if desired. Thus, up to 1% by weight of the TiO₂ can be replaced by MoO₃.

- 50 While the modified soda-lime silicate glasses of the present invention are particularly suited for use in conjunction with fluorescent lamps, they can also be used with advantage

in high-pressure mercury vapor discharge lamps, particularly where cost is a factor and discoloration of the outer envelope during the life of the lamp is a problem. In Fig. 4, there is shown a lamp 20 of this type which has an outer glass envelope 22 that is interiorly coated with a layer 23 of color-correcting UV-responsive phosphor, such as magnesium fluorogermanate for example, which adds red light to the normal blue-green radiation generated by the enclosed arc tube 24. The latter is supported in axially extending position within the outer envelope 22 by a mount 25 which can be formed from a single piece of stiff wire. The arc tube electrodes are electrically connected to a pair of rigid lead wires 26 and 27 and a suitable starting resistor by auxiliary conductors, and the lead wires are sealed through a glass stem 28 and connected to the contacts of a screw-type base 29 in the usual manner.

The improved glass of the present invention can also be used in the envelope of an incandescent lamp since a portion of the power consumed by the filament is expended in generating UV and infrared radiations in addition to visible radiation. The bulb is thus subjected to both UV and visible light and may tend to discolor, especially in high-wattage long-life lamps. Such as incandescent lamp 30 is shown in Fig. 5 and consists of the usual glass envelope 32 that contains a glass stem 34 and a coiled tungsten filament 36 which is held in place by a pair of lead wires 37 and 38 sealed through the stem. The sealed end of the envelope 32 is fitted with a base member 39 in the usual manner.

It will be appreciated from the foregoing

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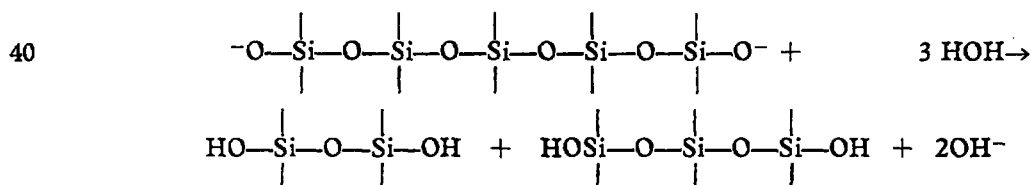
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that the objects of the invention have been achieved in that an electric lamp, and, more specifically a fluorescent lamp, which has a glass envelope that exhibits less UV-discoloration as compared to lamps having bulbs made of conventional soda-lime silicate glass and also may lower the initial value of the absorption coefficient. This improvement is achieved by modifying the basic soda-lime silicate glass composition so that the Fe_2O_3 content does not exceed 0.07% by weight and from 0.8% to 10% by weight of TiO_2 or from 0.5% to 1.0% by weight of MoO_3 is included as a UV-absorbing additive. While the manner in which the controlled iron and ultraviolet-absorbing constituents achieve the improved results is not known, it is believed that it may be due to the elimination or reduction of the color centers formed either by trapping of the electrons in the oxygen-deficient regions of the

glass or by trapping of holes at sites of non bridging oxygen ions. In the case of a phosphor (a calcium halophosphate phosphor that is activated with antimony and manganese for example), such as halophosphate type phosphors, that is adversely affected by sodium or sodium ions, the use of TiO_2 or MoO_3 may also serve to present sodium or sodium ions from diffusing to the inner surface of the bulb and poisoning the phosphor or chemically reacting with mercury or other ions in the discharge and forming a deposit that discolors the inner surface of the envelope. In addition, it is well known that all glasses are more or less subject to attack by water, the most vulnerable point of attack being at oxygen atoms not joining two silicon atoms, that is, at non-bridging oxygen atoms. However, —Si—O—Si— bonds can also be hydrolyzed.



As metal oxides, the cations of which have a charge greater than one, are introduced into the composition, the glass becomes more resistant to attack by water. This is due to the fact that the cation of the added oxide coordinates with oxygens of the glass, thus protecting them from attack by water or its component ions. The greater the positive charge of the added cation, the smaller its size and the larger its coordination number, the more effective it will be in increasing the water resistance of the glass. For a detailed discussion of this phenomenon see "The Constitution of Glass", Vol. II: Part Two (pp. 1103 et seq.) by W. A. Weyl and E. C. Marboe (Interscience Publishers, 1967).

Because of the high charge and small size (high field strength) and large coordination numbers of Ti^{4+} and Mo^{6+} their presence in the improved glass of the present invention makes it less vulnerable to attack by water and, therefore, less likely to contain the elements of water which could be dislodged by ion bombardment of the mercury discharge in the operating lamp and contaminate the lamp. Water in the presence of mercury ion can also produce mercuric oxide which could darken the phosphor and reduce the light output of the lamp.

Whatever the mechanism, comparative 40 watt T12 "cool white" fluorescent lamp tests have shown that after 100 hours burning a gain of 26 lumens has been obtained by using

envelopes containing 0.06% by weight Fe_2O_3 and 1.18% by weight TiO_2 , and that this increased to 31 lumens (1% gain) at 500 hours. Other lamps have exhibited gains as high as 50 lumens after several hundred hours burning.

WHAT WE CLAIM IS:—

1. An electric lamp having means that generates both ultraviolet and visible radiations when the lamp is energized, enclosed in a soda-lime silicate glass envelope wherein the glass contains no more than 0.07% by weight of ferric oxide and an ultraviolet-radiation absorbing material in an amount sufficient to inhibit discoloration of the glass by impinging ultraviolet radiation and maintain the absorption coefficient of the glass in the visible region below approximately 0.4 cm^{-1} during a major portion of the useful life of the lamp, said material comprising from 0.8% to 10% by weight titanium oxide or from 0.5 to 1% by weight molybdenum oxides or mixtures thereof.

2. An electric lamp as claimed in claim 1 wherein said ultra-violet-radiation absorbing material comprises from 0.8% to 3% by weight TiO_2 .

3. An electric lamp as claimed in claim 1 wherein said glass contains 0.05% by weight Fe_2O_3 and 1.5% by weight TiO_2 .

4. An electric lamp as claimed in claim 1 wherein said glass has the following composition:

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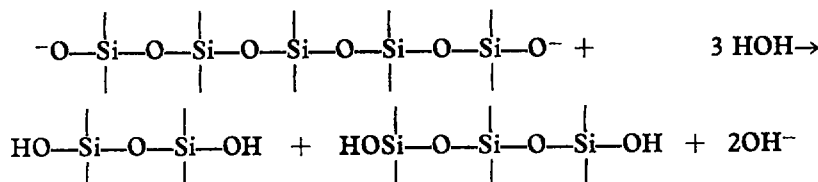
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that the objects of the invention have been achieved in that an electric lamp, and, more specifically a fluorescent lamp, which has a glass envelope that exhibits less UV-discoloration as compared to lamps having bulbs made of conventional soda-lime silicate glass and also may lower the initial value of the absorption coefficient. This improvement is achieved by modifying the basic soda-lime silicate glass composition so that the Fe_2O_3 content does not exceed 0.07% by weight and from 0.8% to 10% by weight of TiO_2 or from 0.5% to 1.0% by weight of MoO_3 is included as a UV-absorbing additive. While the manner in which the controlled iron and ultraviolet-absorbing constituents achieve the improved results is not known, it is believed that it may be due to the elimination or reduction of the color centers formed either by trapping of the electrons in the oxygen-deficient regions of the

glass or by trapping of holes at sites of non bridging oxygen ions. In the case of a phosphor (a calcium halophosphate phosphor that is activated with antimony and manganese for example), such as halophosphate type phosphors, that is adversely affected by sodium or sodium ions, the use of TiO_2 or MoO_3 may also serve to present sodium or sodium ions from diffusing to the inner surface of the bulb and poisoning the phosphor or chemically reacting with mercury or other ions in the discharge and forming a deposit that discolors the inner surface of the envelope. In addition, it is well known that all glasses are more or less subject to attack by water, the most vulnerable point of attack being at oxygen atoms not joining two silicon atoms, that is, at non-bridging oxygen atoms. However, $-\text{Si}-\text{O}-\text{Si}-$ bonds can also be hydrolyzed.

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As metal oxides, the cations of which have a charge greater than one, are introduced into the composition, the glass becomes more resistant to attack by water. This is due to the fact that the cation of the added oxide coordinates with oxygens of the glass, thus protecting them from attack by water or its component ions. The greater the positive charge of the added cation, the smaller its size and the larger its coordination number, the more effective it will be in increasing the water resistance of the glass. For a detailed discussion of this phenomenon see "The Constitution of Glass", Vol. II: Part Two (pp. 1103 et seq.) by W. A. Weyl and E. C. Marboe (Interscience Publishers, 1967).

Because of the high charge and small size (high field strength) and large coordination numbers of Ti^{+4} and Mo^{+6} their presence in the improved glass of the present invention makes it less vulnerable to attack by water and, therefore, less likely to contain the elements of water which could be dislodged by ion bombardment of the mercury discharge in the operating lamp and contaminate the lamp. Water in the presence of mercury ion can also produce mercuric oxide which could darken the phosphor and reduce the light output of the lamp.

Whatever the mechanism, comparative 40 watt T12 "cool white" fluorescent lamp tests have shown that after 100 hours burning a gain of 26 lumens has been obtained by using

envelopes containing 0.06% by weight Fe_2O_3 and 1.18% by weight TiO_2 , and that this increased to 31 lumens (1% gain) at 500 hours. Other lamps have exhibited gains as high as 50 lumens after several hundred hours burning.

WHAT WE CLAIM IS:—

1. An electric lamp having means that generates both ultraviolet and visible radiations when the lamp is energized, enclosed in a soda-lime silicate glass envelope wherein the glass contains no more than 0.07% by weight of ferric oxide and an ultraviolet-radiation absorbing material in an amount sufficient to inhibit discoloration of the glass by impinging ultraviolet radiation and maintain the absorption coefficient of the glass in the visible region below approximately 0.4 cm^{-1} during a major portion of the useful life of the lamp, said material comprising from 0.8% to 10% by weight titanium oxide or from 0.5 to 1% by weight molybdenum oxides or mixtures thereof.

2. An electric lamp as claimed in claim 1 wherein said ultra-violet-radiation absorbing material comprises from 0.8% to 3% by weight TiO_2 .

3. An electric lamp as claimed in claim 1 wherein said glass contains 0.05% by weight Fe_2O_3 and 1.5% by weight TiO_2 .

4. An electric lamp as claimed in claim 1 wherein said glass has the following composition:



Constituent	Percent by Weight
SiO ₂	60—75
Na ₂ O	5—18
CaO	4—13
MgO	
Al ₂ O ₃	0.5—3.4
K ₂ O	0.1—2
TiO ₂	0.8—10
Fe ₂ O ₃	≤0.07
As ₂ O ₃	0.01—2

5. An electric lamp as claimed in claim 1 wherein said glass has the following composition:

Constituent	Percent by Weight
SiO ₂	71.3
Na ₂ O	15.5
CaO	5.3
MgO	3.7
Al ₂ O ₃	1.85
K ₂ O	0.23
TiO ₂	2.0
Fe ₂ O ₃	0.05
As ₂ O ₃	0.07

5 6. An electric lamp as claimed in any one of the preceding claims wherein said lamp is a fluorescent lamp, and said envelope is of tubular form and coated interiorly with a phosphor that is responsive to ultra-violet-radiation.

10 7. An electric lamp as claimed in claim 1, 2 or 3, wherein said lamp is a high-pressure mercury vapor discharge lamp, and said generating means comprises an arc tube that is disposed within said envelope.

15 8. An electric lamp as claimed in claim 1, 2 or 3, wherein said lamp is an incandescent lamp.

9. An electric lamp as claimed in claim 6, wherein said phosphor is of the halophosphate type.

10. An electric lamp as claimed in claim 6, wherein said phosphor is a calcium halophosphate phosphor activated by antimony and manganese.

11. An electric lamp substantially as described with reference to and as illustrated in the accompanying drawings.

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