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Vlasenko et al.

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[54] **ELECTROLUMINESCENT DEVICE WITH VARIABLE EMISSION**

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[58] **Field of Search** ..... 313/108 A, 108 D, 112; 331/94.5 H

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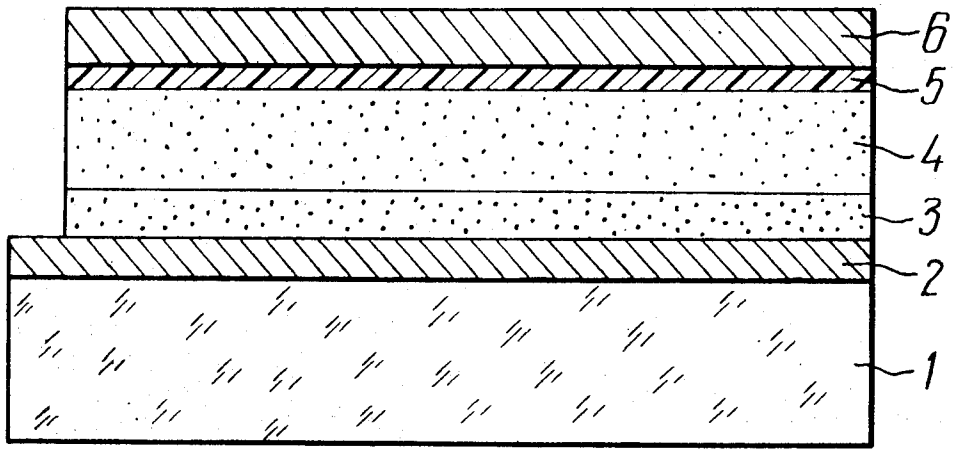
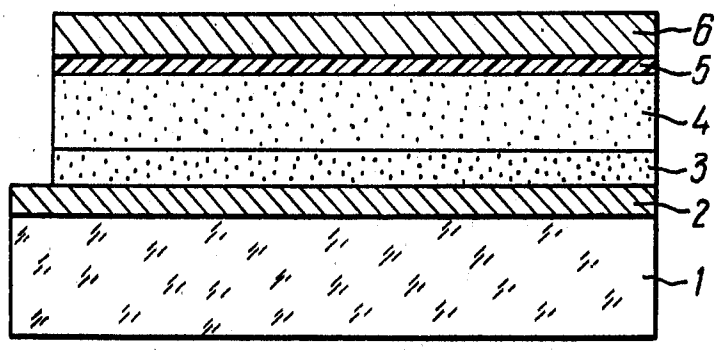
[57] **ABSTRACT**

An electroluminescent device with variable emission colors, comprises at least five layers applied onto a substrate in the following order: a first electrode; a protective layer made from a material transparent for emission, the protective layer having an index of refraction equal or close to that of the electroluminescent substance and being resistant to chemical reaction with the substances of the adjoining layers; a layer of the electroluminescent substance; an insulating layer and a second electrode; one of the electrodes being partially transparent for luminescent emission; both electrodes having a high reflection coefficient and making up a Fabry-Perot cavity tunes in resonance to a prescribed emission wavelength; the thickness of the protective layer, the coefficient of diffusion of its material into the layer of the electroluminescent substance, and the coefficient of diffusion of the material of the first electrode into the protective layer being selected so that during thermal annealing of the electroluminescent layer there is no diffusion into the latter of either the substance of the first electrode or the substance of the protective layer.

2 Claims, 1 Drawing Figure

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ELECTROLUMINESCENT DEVICE WITH VARIABLE EMISSION

BACKGROUND OF THE INVENTION

The invention relates generally to electroluminescent devices and more particularly, it relates to electroluminescent devices having variable emission colors and used, for instance, as light sources, electroluminescent condensers, etc.

Known in the art is an electroluminescent device with variable emission colors wherein a layer of sublimed electroluminescent substance is disposed between two electrodes, one of which is partially transparent and the other is opaque for the electroluminescent emission. The electrodes are made of a highly reflective material and form a Fabry-Perot cavity while the thickness of the electroluminescent layer is multiple to the wavelength of emission with a given color, with the phase jump at the metal-dielectric junction being taken into account.

A disadvantage of the known device is that in the course of thermal annealing of the electroluminescent layer during the manufacture the substance of the partially transparent electrode diffuses into the luminophor layer applied directly onto this electrode.

The result of the diffusion is two-fold: first, it reduces the reflection index of the electrode and hence, spoils the Q-factor of the cavity; second, it lowers the efficiency of the output emission.

SUMMARY OF THE INVENTION

The object of the present invention is to modify the design of an electroluminescent device with variable emission color so as to prevent the substance of the electrode from diffusing into the electroluminescent layer in the course of manufacture. The object is achieved by providing at least five layers applied onto a substrate in the following order: a first electrode; a protective layer made from a material transparent for emission, the protective layer having an index of refraction equal or close to that of the electroluminescent substance and being resistant to chemical reaction with the substances of the adjoining layers; a layer of the electroluminescent substance; an insulating layer and a second electrode; one of the electrodes being partially transparent for luminescent emission; both electrodes having a high reflection coefficient and making up a Fabry-Perot cavity tuned in resonance to a prescribed emission wavelength; the thickness of the protective layer, the coefficient of diffusion of its material into the layer of the electroluminescent substance, and the coefficient of diffusion of the material of the first electrode into the protective layer being selected so that during thermal annealing of the electroluminescent layer there is no diffusion into the latter of either the substance of the first electrode or the substance of the protective layer.

It is also possible to provide an electroluminescent device, wherein the electroluminescent layer is a film of ZnS: Mn applied in vacuum, the partially transparent first electrode is a film of gold, the non-transparent second electrode is a film of aluminum, the protective layer is a film of unalloyed ZnS subjected to crystallization, and the insulating layer is a film of SiO.

The electroluminescent device designed according to the present invention is simple in production, and the thermal annealing of the electroluminescent layer involves no diffusion of the electrode substance into the luminophor layer which makes it possible to obtain high quality devices that exhibit distinctly variable emission colors having their absolute brightness sufficiently high for practical applications.

BRIEF DESCRIPTION OF THE DRAWING

The invention will now be described by way of example with reference to the accompanying drawing which shows a cross section of an electroluminescent device with variable emission colors according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

The device shown in the drawing comprises a dielectric substrate **1** (glass, quartz, etc.).

In case the emission is brought out through a substrate **1**, the latter should be transparent for the emission. Applied onto the substrate **1** by any known procedure (e.g., by vacuum evaporation, cathode spraying or chemical deposition) is an electrode **2** having a high reflection index ($R \geq 65$ percent) made of, say, Au, Ag, Mn. Applied directly onto an electrode **2** is a protective layer **3** made of a substance which is optically transparent for emission and characterized by a refraction index whose value approaches that of the luminophor. The diffusion properties and the thickness of the layer **3** are selected so that no diffusion occurs into the luminophor layer of either the substance of the electrode **2** or the material of the protective layer **3** in the course of thermal treatment. The substance of the layer **3** is resistant to chemical reactions with the materials of the adjacent layers; the coefficient of diffusion of the electrode substance into the layer **3** and the coefficient of diffusion of the layer's components into the electroluminescent layer are low.

Preferably the layer **3** is made as a film of insulating oxides, such as Ta_2O_5, SiO.

It is more preferable that the protective layer **3** be made of a substance used as the basis of the luminophor but without doping impurities, for instance ZnS. The indices of refraction of such substances are equal to that of the luminophor, thus making them optically homogeneous with respect to multi-beam interference.

To reduce the coefficient of diffusion, the substance of the protective layer **3** is subjected to crystallization.

This layer is made as thin as possible so as to reduce the voltage drop across it and to keep the electrical loss in the electroluminescent device to the minimum.

Then, using any of the known procedures, the layer **3** is coated with an electroluminescent layer **4** the optical thickness of which together with that of the protective layer **3** satisfy the interference relationship for the maximum emission at a given wavelength and a given viewing angle with the phase jump at the metal-dielectric junction being taken into account. Placed onto the layer **4** is an insulator layer **5** which is 20–25 nm thick and which protects the device from short-circuits and plays but a minor role in the multi-beam interference process due to its negligible thickness. Applied onto the layer **5** is a second electrode **6** having a high index of reflection ($R \geq 65$ percent). The elec-

trodes 2 and 6 form a Fabry-Perot cavity, one of the electrodes being partially transparent for emission.

The device operates as follows.

A voltage applied to the electrodes 2 and 6 produces an electric field in the layer 4 with an intensity of 10^5 to 10^6 V/dm which makes the layer luminescent. The color of emission is determined by the thickness of the layer 4.

In order to facilitate the understanding of the essence of the present invention, the following examples of its embodiments are given together with a description of the technological procedure employed in the manufacture of the devices given by way of examples.

EXAMPLE 1

The device comprises the following elements arranged in series: a glass substrate 1, an electrode 2 made as an Au-film 50 to 60 nm thick, an undoped ZnS-layer 3 which is from 120 to 180 nm thick, an electroluminescent layer 4 made of a ZnS:Mn-film the thickness of which together with that of the protective layer 3 satisfy the interference relationship, an insulation layer 5 made of SiO 20 to 35 nm thick and an opaque electrode 6 made of an Al-film.

The interference relationship is given by the expression

$$2d\mu\cos\beta = [m + (\phi_1 + \phi_2/2\pi)]\,\lambda,$$

where:

d is the total thickness of two films (the electroluminescent and the protective layers),

μ is the refraction index,

β is the viewing angle of the output emission,

m is the interference order,

λ is the emission wavelength,

ϕ_1, ϕ_2 are the phase jumps occuring when the emission is reflected from the electrodes.

By varying the thickness of the ZnS:Mn electroluminescent films, it is possible to obtain devices having a green glow ($\lambda = 550$ nm), orange ($\lambda = 585$ nm) and red ($\lambda = 640$ nm).

EXAMPLE 2

The device comprises the following elements arranged in series: a glass substrate 1, an electrode 2 made as an Au-film 50 to 60 nm thick, an undoped ZnS layer 3 which is from 120 to 180 nm thick, an electroluminescent layer 4 made of a ZnS:Er-film the thickness of which satisfies the interference relationship, a SiO-insulation layer 5 which is from 20 to 35 nm thick and an opaque electrode 6 made of an Al-film.

EXAMPLE 3

The device comprises the following elements arranged in series: a glass substrate 1, an electrode 2 made of 14 Au-film 50 to 60 nm thick, an undoped ZnSe protection layer 3 which is from 120 to 180 nm thick, an electroluminescent layer 4 made of a Zn Se:Mn-film the thickness of which satisfies the interference relationship, an insulation SiO layer 5 which is from 20–35 nm thick and an opaque electrode 6 made of an Al-film.

The technological procedure involved in the manufacture of these devices is as follows.

A layer of gold 50 to 60 nm thick is evaporated under a vacuum of 1.10^{-5} to 2.10^{-5} torr onto a glass substrate 1 which has been cleaned beforehand. Then a film of undoped ZnS 120 to 180 nm thick is applied onto the gold layer.

After that the samples are annealed in vacuum at 550° to 600°C for 5 to 15 minutes. This results in a crystallization of the undoped ZnS-film. Then a two-step spraying procedure is used to obtain a film of the electroluminescent material of the required thickness.

The two-step procedure is as follows.

The undoped electroluminescent material is sprayed onto a cold substrate by means of evaporation in a vacuum of 1.10^{-5} to 2.10^{-5} torr. Then, an activator, for example, Mn, is introduced into the electroluminescent material by means of vacuum evaporation, the activator material being evaporated in the form of a chemically pure metal of a predetermined weight calculated on the basis of the required activator concentration, for instance, 1 to 5 percent in the case of Mn. Then, another layer of undoped electroluminescent substance (ZnS) is sprayed and the device is subjected to a thermal annealing for example at 650° to 700°C during 5–15 minutes in the case of ZnS:Mn. Under these conditions the electroluminescent film is crystallized and simultaneously the activator diffuses into it, the diffusion being uniform in thickness.

Applied onto the electroluminescent film by means of vacuum evaporation are the SiO insulation layer and the opaque electrode of an Al-film.

What we claim is:

1. An electroluminescent device having variable emission colors, said device comprising:
   - a substrate; and
   - at least five layers comprising, and being disposed onto said substrate in the following order:
     - a. a first electrode;
     - b. a protective layer being formed from a material which is transparent to luminescent emission;
     - c. a layer of electroluminescent substance, said protective layer having an index of refraction which is substantially equal to that of said electroluminescent substance and being resistant to chemical reaction with the substances of the adjoining layers;
     - d. an insulating layer; and
     - e. a second electrode, one of said electrodes being partially transparent for luminescent emission, said first and second electrodes having a high reflection coefficient and forming a Fabry-Perot cavity tuned in resonance to a prescribed emission wavelength; the thickness of said protective layer, the coefficient of diffusion of the material of said protective layer into said layer of said electroluminescent substance and the coefficient of diffusion of the material of said first electrode into said protective layer being selected so that at the temperature of thermal annealing of said layer of said electroluminescent substances there is no diffusion into said layer of said electroluminescent substance from either the material of said first electrode or the material of said protective layer.

2. An electroluminescent device as claimed in claim 1, wherein said layer of said electroluminescent substance comprises a film of ZnS:Mn applied in a vacuum, said first electrode comprises a film of gold, said second electrode comprises a film of aluminum, said protective layer comprises a film of undoped ZnS subjected to crystallization, and said insulating layer comprises a film of SiO.

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